America's STEM Crisis Threatens Our National Security

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On October 4, 1957, a steel sphere the size of a beach ball and bristling with four radio antennae circled the Earth in eight minutes. Dubbed "Satellite-1," or "PS-1" (*Prosteyshiy Sputnik*-1) by its Soviet fabricators, it was the first artificial Earth satellite. The Soviets had launched it into an elliptical low Earth orbit, where it stayed for three weeks before its batteries died. Then it continued silently in a decaying orbit for another two months before burning up in the atmosphere. Its radio signal pulses were easily detectable by ham radio operators, as well as by every national security listening post in the United States and around the world.

The world had a new word—Sputnik—and the United States a new mission: to close the gap in the race for space with the Soviet Union. That urgent sense of mission triggered a revolution in American education. This revolution was spurred not only by the desire to win the space race, but also to get a generation of young Americans excited about and educated in science, technology, engineering, and mathematics—what would be abbreviated as STEM. At stake was victory in the Cold War, and with it the future of freedom and democracy in the struggle against Communism.

The effects of that post-Sputnik revolution helped to put Americans on the moon a little more than a decade later. It continued to reverberate through the computer and dot-com revolutions of the 1980s and 1990s, as well as in the Strategic Defense Initiative and the Pentagon's technological transformation during the same period, sometimes known as the Second Offset Strategy.

Since then, STEM has been a perennial concern for American education experts and politicians. Beginning in the 1980s, there have been new and growing worries that STEM proficiency is declining in America, and with it the future of America's economic and scientific leadership.

Multiple official reports have pointed out the problem—including the most recent one released by the Trump administration this past December. Yet this perennial hand-wringing and all the spending and grants by agencies like the National Science Foundation have had little effect. This failure is reflected not only in a long history of declining test scores relative to other industrialized countries, but also in a decreasing proportion of American students willing to devote themselves to STEM subjects. By 2009, for example, the total number of students in college had grown by more than 50 percent since 1985. But in mathematics and statistics, there were only 15,496 graduates in 2009, not many more than the 15,009 graduates in 1985. More students were studying the visual and performing arts than were studying computer science, math, and chemical engineering combined.[1]

Meanwhile, a new competitor for STEM leadership is looming on the horizon, just as the Soviet Union did in 1950s—namely China. And STEM leadership remains just as vital to our national security—perhaps even more so now than when Sputnik was launched.

Today's Defense Department and other leading experts all agree that the future of America's defense will rely on advanced technologies such as AI, cyber, quantum, robotics, directed energy and hypersonic weapons, and even 3-D printing. The Obama Pentagon began pointing out this reality in 2014, in a series of landmark speeches unveiling what it dubbed the Third Offset Strategy.[2] All of the above technologies will be critical if the United States is to maintain its military superiority over its rivals, including China. They will also require new levels of scientific and engineering aptitude and understanding, not just from their designers but from producers and users, including the next generation of warfighters.

This is particularly, even acutely, true of quantum computing and quantum technology. Both rest on an entirely different basis than classical computing, namely quantum physics rather than mathematics. As I've written in an earlier *American Affairs* article, quantum's disruptive possibilities far exceed that of any technology since nuclear weapons.[3] Without a trained quantum workforce, and without a strong cadre of researchers and teachers who are capable of expanding our knowledge of quantum information science, we will face a shortfall in this critical twenty-first-century technology. Such a shortfall would materially affect our ability to win wars in the coming decades.

The same is true in other areas of the struggle for high-tech supremacy. Where will those trained cadres come from? If current trends continue, they will increasingly, and inevitably, come from outside the United States. The long-term trend of having to rely on foreign nationals to fill America's STEM gap, which began in the late 1990s and early 2000s, is now here to stay.

Immigrants accounted for well over 50 percent of the growth in employment in STEM-related fields between 2003 and 2008.[4] In addition, foreign students make up the majority of majors and graduate students in many STEM fields in American universities—including students from our leading geopolitical competitor, mainland China.

Overall, the data shows that enrollment of international students in U.S. science and engineering university programs has been steadily rising since 2008, while the number of U.S. citizens and permanent residents enrolled in those programs has steadily declined. We are witnessing a gradual withering away of American college student engagement in the very same STEM disciplines that will determine who dominates, and who is dominated, in the twenty-first century.

The Trump administration's recently released report "Charting a Course for Success: America's Strategy for STEM Education" stated: "Now more than ever the innovation capacity of the United States—and its prosperity and security—depends on an effective and inclusive STEM education ecosystem. . . . Simply to function as an informed consumer and citizen in a world of increasingly sophisticated technology requires the ability to use digital devices and STEM skills such as evidence-based reasoning."[5]

In fact, the administration's report understates the case. We now face a crisis, and one that will not wait for free market forces to solve.

The Current State of U.S. STEM Education

What is the current state of STEM education in America? One of the most important benchmarks for measuring STEM proficiency in the United States and around the world is the Programme for International Student Assessment (PISA). Every three years it measures reading ability, math and science literacy, and other key skills among fifteen-year-olds in a large number of developed and developing countries.

The most recent PISA results date from 2015. The United States ranked thirty-eighth out of seventy-one countries in math and twenty-fourth in science. Among the thirty-five members of the Organisation for Economic Co-operation and Development (the PISA's principal sponsor), the United States comes in fifth from the bottom in math and nineteenth in science.[6]

Dismal scores like these in the early 2000s were enough to trigger a National Academies of Sciences report, "Rising Above the Gathering Storm," which argued that strengthening science and math education was essential if the United States was going to remain prosperous in the twenty-first century. The poor performance was also enough to force Congress to pass the America competes Act, authorizing funding for a variety of new programs to improve K–12 science and math education.[7]

Despite the funding and the national hoopla, however, signs of improvement are hard to find. Another measurement of America's STEM status is the National Assessment of Educational Progress (NAEP) run by the Department of Education. In 2015, eight years after the America competes Act, average math scores for fourth- and eighth-graders fell for the first time since 1990. On a scale of 0 to 500, the average fourth-grade NAEP math score was 240—the same level as in 2009. The average eighth-grade score was 282 in 2015, the lowest since 2007. That year, NAEP revealed that only 38 percent of fourth-graders, 34 percent of eighth-graders, and 22 percent of twelfth-graders could be considered proficient or better in science. At the same time, 24 percent of fourth-graders, 32 percent of eighth-graders, and 40 percent of twelfth-graders were rated “below basic” for their grade levels.[8]

A third measurement is the Trends in International Mathematics and Science Study or timss, which has tested international students in grades four and eight every four years since 1995. Again, in the most recent test from 2015, ten countries (out of forty-eight total) had higher average fourth-grade math scores than the United States, while seven countries had higher average science scores. In the eighth-grade tests, seven out of thirty-seven countries had statistically higher average math scores than the United States, and seven had higher science scores. In the fourth-grade math category, Japan, South Korea, Taiwan, England, and Norway all scored higher—as did China and Russia.[9]

These mediocre results won’t surprise most Americans. A 2015 Pew Research Center report found that only 29 percent of Americans rated their country’s K–12 education in STEM as above average or the best in the world. Scientists were even more critical. A companion survey of members of the American Association for the Advancement of Science found that just 16 percent called U.S. K–12 STEM education the best or above average; 46 percent, by contrast, said K–12 STEM education in the United States was below average.[10]

In summing up the state of STEM in America, the Trump administration's "Charting a Course for Success" report puts the best spin it can on the STEM issue. It asserts that "Americans' basic STEM skills have modestly improved over the past two decades" but also admits that we "continue to lag behind many other countries" and that "recent data from a test commonly taken by college-bound high school students found that only 20% are ready for courses typically required for a STEM major."[11] On the other hand, the report said, "in the past 15 years, India and China have outpaced the United States in the number of science and engineering (S&E) bachelor's degrees conferred." Indeed, "these two countries have produced almost half of the total degrees, with India at 25% and China at 22% of the global total." Meanwhile, "American S&E bachelor's degrees comprised only 10% of the global total."[12]

Which brings us to a double paradox. While Americans perform well below average in STEM disciplines, their colleges and universities continue to have some of the best STEM programs in the world. And while Americans tend to stand aloof from the centers of STEM excellence in our colleges and universities, foreign students emphatically do not.

Foreign Students and America's STEM Future

Today, the United States remains the country of choice for the largest number of international students, hosting about 1.1 million of the 4.6 million enrolled worldwide in 2017. As of March 2018, roughly 1.2 million F-1 (visa for full-time students at an academic institution) and M-1 (visa for full-time students at a vocational or other nonacademic institution) students were enrolled and registered at more than 8,700 certified schools across the United States.[13]

In the 2016–17 school year, China was the top origin country for international students (351,000), representing 33 percent of the total, followed by India (17 percent); South Korea and Saudi Arabia (5 percent each) and Canada (3 percent) rounded out the top five. Engineering, business management, and math and computer science were the top three fields of study for international students in 2016–17, accounting for more than half of all international enrollment at U.S. higher education institutions.

Overall, the data shows that the enrollment of international students in U.S. science and engineering college and university programs has been steadily rising since 2008, while the number of U.S. citizens and permanent residents enrolled in such programs has steadily declined. In 2017, the number of international visa holders increased in computer sciences and mathematics (by 11 and 5 percent, respectively) but declined in engineering (5 percent), social sciences (3 percent), and non-S&E fields (4 percent). At the same time, 48 percent of international students were in STEM fields and were eligible for extended 12- to 36-month Optional Practice Training (OPT) visas upon graduation.[14]

There is an even larger proportion of international graduate students than undergraduates enrolled in science and engineering programs. (More than six in ten international graduate students in the United States in fall 2017 were enrolled in these fields, compared with about four in ten international undergraduates.) In 2017, 62 percent of all international students in graduate programs at U.S. institutions were enrolled in S&E fields—69 percent of those came from China and India.

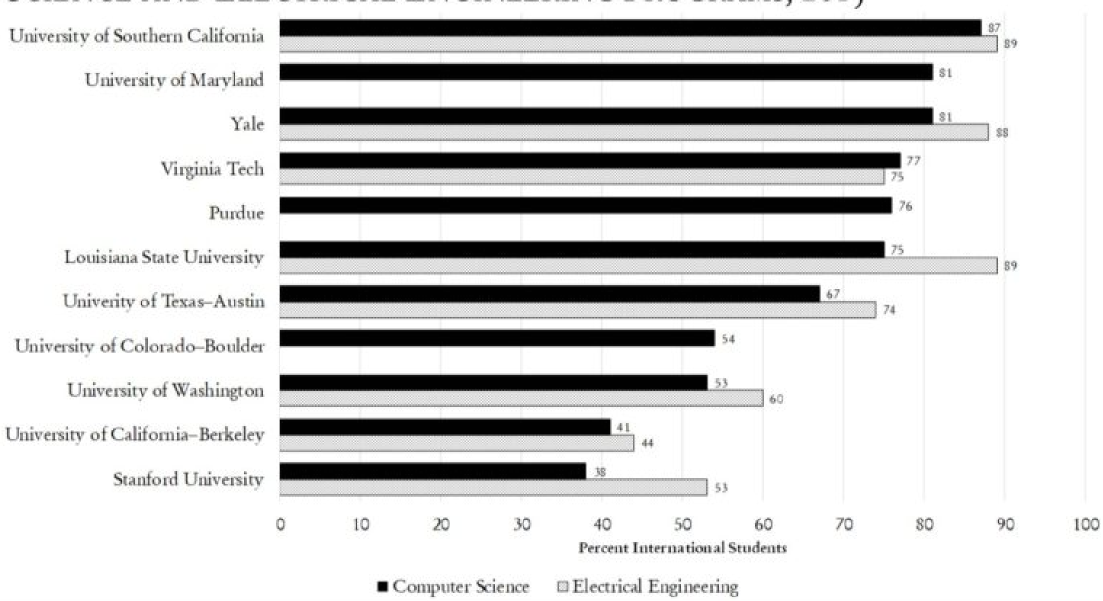
In fact, according to the National Foundation for American Policy, both undergraduate majors and graduate programs at many U.S. universities could not be maintained without international students. Foreign nationals account for 81 percent of the full-time graduate students in electrical engineering, 79 percent in computer science, 75 percent in industrial engineering, 69 percent in statistics, 63 percent in mechanical engineering, 59 percent in civil engineering, and 57 percent in chemical engineering. Without international students, the number of full-time students pursuing graduate degrees in the fields of computer science, electrical engineering, and other fields would be shockingly small for an economy as large as America's.[15]

Furthermore, students on temporary visas continue to earn high proportions of U.S. S&E doctorates, as well as large shares of the master's degrees in these fields. In 2015, international students earned more than half of the doctoral degrees awarded in engineering, economics, computer sciences, mathematics, and statistics; their overall share of S&E degrees was 34 percent. Once again, Chinese students composed a large share: 28.8 percent of the S&E doctorates issued to international students on temporary visas between 1995 and 2015 went to Chinese nationals.[16]

When we look at individual colleges and universities, especially those highly ranked in science and engineering, the numbers look even more alarming. At Harvard University's Computer Sciences Department, for example, more than half (53 percent) of students are foreign students. At MIT, there are slightly fewer (43 percent) in computer sciences, but 55 percent in electrical engineering.

At Princeton and Yale, the picture of American STEM appears even more dismal. In Princeton's computer sciences department, 60 percent of students are international; the number is 70 percent in electrical engineering. Yale's American participation is no more than 19 percent in computer sciences and 12 percent in electrical engineering. At the University of Maryland, computer sciences students are 81 percent foreign nationals; Virginia Tech enrolls 77 percent, and Purdue University computer sciences 76 percent. The graph below tells the rest of the story.

PERCENTAGE OF INTERNATIONAL STUDENTS IN SELECT U.S. COMPUTER SCIENCE AND ELECTRICAL ENGINEERING PROGRAMS, 2015



Source: National Science Board, see note 16.

Overall, the proportion of international PhD-level students on temporary visas to study STEM subjects in the United States has doubled over the past thirty years. A July 2016 report by the Ewing Marion Kauffman Foundation argued that if current trends continue, international students will comprise half of U.S. STEM PhD graduates by 2020.[17]

How serious a national security threat is this trend? On the one hand, the presence of large numbers of foreign students studying in the United States, even Chinese students, should not be a cause for alarm by itself—nothing argues for a xenophobic approach to this growing phenomenon. At the same time, many companies in Silicon Valley will argue that without foreign nationals, they can't fill the gaps in their ranks. Nor, obviously, would similar programs at major universities around the country be able to sustain themselves.

On the other hand, when the Pentagon and other national security agencies start looking for STEM graduates and STEM-trained engineers who can pass the necessary security clearances, they will find themselves facing a severe shortfall of American nationals who can pass muster. In short, an alarming trend is developing: America's ability to produce, sustain, and protect research in key technological and knowledge areas vital to our defense and national security looks vulnerable because the talent pool of American citizens working in this area is shrinking. And while U.S. leadership in STEM is slipping away, other countries, including China, continue to surge ahead.

China: The Threat at Home and Abroad

On June 19, 2017, *NextWeb* ran an article entitled "While U.S. STEM Education Market Declines, China Invests Heavily." The gist of the article by Rick Ye was that, although the United States is the world' s biggest producer of STEM goods and services, and U.S. edtech companies were able to generate an estimated $1.3 billion in venture capital deals in 2016, "the world is questioning the fate of STEM education in US school systems." The growing shortfall in U.S. STEM education and its supporting edtech industry has led major U.S. companies like Microsoft to search for talent—and support education in—other countries, since the United States can't meet their needs.

On the other hand, the article pointed out that China's "STEM learning industry is projected to hit $15 billion by 2020."[18] In addition, the per capita expenditure of Chinese households on education has tripled over the past decade, rising from 670 yuan in 2000 to 2,381 yuan in 2015. China clearly sees investment in STEM as a priority for its future as a superpower, and where the government isn't doing the investing, average Chinese families are.

Today China is the world leader in number of STEM graduates. The World Economic Forum reported that China had 4.7 million recent STEM graduates in 2016, and India had 2.6 million new STEM graduates, while the United States had only 568,000. China's president Xi Jinping has repeatedly declared that his aim is to transform the country into a "science and technology superpower." This is an essential part of his "Made in China 2025" program announced late last year, and China's larger agenda of displacing the United States as the world's dominant superpower. Fortunately for Xi's dream, China has the educational tools to achieve that aim.

Not surprisingly, given its population, the Chinese state-run education system is the largest in the world. The Compulsory Education Law of China mandates nine years of government-funded, compulsory school attendance, which includes six years of primary school and three years of junior high school. After graduating from junior high school, students have to choose between senior high school and vocational school. Senior high school students also have to choose between a social-science and a natural-science orientation. This in turn affects the test categories students later take during the National Higher Education Entrance Examination, an academic examination not unlike the SAT in the United States. The National Higher Education Entrance Examination, or Gaokao, is considered the single most important exam in a student's entire life, since it determines whether he or she is allowed to enter a university.

For those fortunate enough to pass the Gaokao, the choice of places to go for study has dramatically increased recently. The number of universities in China grew by 768 between 2005 and 2015. Among the top twenty universities in Asia in 2017, ten were from the Greater China area.[19] The focus there has been not only on quantity but quality of higher education. Established in 1998, the 985 Project is the Chinese government's program for raising the research standards of China's best universities. At the top of the pyramid is the so-called C9 League, the nation's top nine universities which are guaranteed 10 percent of China's entire national research budget.

One of those is Tsinghua University, which many call China's MIT, and which boasts two Nobel Prize winners on its science faculty. Another is Peking University, which has extensive student exchange programs with Western universities. There is also the University of Science and Technology of China (USTC) in Hefei, adjoining the new $11 billion quantum research center that the government is building to secure "quantum supremacy" for China.

The staffs of these leading schools aren't limited to Chinese scholars. Thanks to China's "Thousand Talents" program launched in 2008, Beijing maintains a coordinated effort to recruit the best and brightest in key STEM areas among foreign scholars as well. Money is no object when it comes to salaries and research support, and a visiting professor at Tsinghua or USTC can count on a coterie of willing and able research assistants. He or she may not even mind that many of those assistants will go on to work for the People's Liberation Army (PLA) and develop the future weapons systems that could threaten the United States and its allies in the future.

It's an impressive, even formidable array of educational resources. But problems and vulnerabilities remain. One is the sharp disparity between the number of universities, and the quality of education, between more urbanized eastern China (e.g., Shanghai, Canton, and Beijing) and more backward western provinces.

Another, according to Hu Weiping, professor and director of the Modern Teaching Technology Lab at Shaanxi Normal University, is that while an increasing number of Chinese companies and schools have been investing in STEM, the focus has tended to be on getting product results instead of laying the groundwork for the future through fostering young talent.

Hu has been quoted as saying that even though the National Natural Science Foundation of China has been heavily funding education projects since 2017, projects related to technology or science education haven't really benefited. "Without funding there won't be input from scientists or anyone else," Hu said. "That's why I have called on the foundation to start working on this issue, so that more experts will be encouraged to do more research on curriculum reform to stimulate technological innovation."

China's STEM education also suffers from a major shortage of both professional science teachers and proper science training for teachers. About 80.5 percent of teachers involved in STEM subjects received no serious science education, and many were at a middle or high school education level, according to Hu.[20]

A recent study by Richard P. Appelbaum and Xueying Han pulled together data from 731 surveys completed by STEM faculty at China's top twenty-five universities. They found "that the Chinese educational system stifles creativity and the critical thinking necessary to achieve innovative breakthroughs, too often hamstrings researchers with bureaucratic requirements, and rewards quantity over quality." "China's emphasis on rote learning and memorization reinforces this," said Appelbaum, "as does a strong cultural emphasis on respect for authority."

In the end, according to Dr. Han, "The challenges that are facing China's research environment are not things that can be easily fixed by money. They're cultural challenges, and that's going to require a major shift in thinking."[21]

One way that the Chinese government has dealt with these deficiencies is by accelerating the migration of its students to foreign universities, especially

U.S. universities. According to Han, “Foreign degree holders get many advantages—higher salaries, easier access to promotions, bigger lab space—compared to their domestic counterparts. . . . We discovered that Chinese domestic degree holders also thought that a foreign degree would give you better recognition from colleagues . . . and this recognition could open doors that might not be available to domestic degree holders.”[22]

A STEM degree from an American university has particular cachet in Chinese scientific circles. So it’s not surprising that hundreds of thousands of Chinese STEM students have applied for and been granted admittance to top U.S. universities, and given top-notch educations in their chosen fields. Meanwhile, those same universities like Chinese students because they pay their exorbitant tuition fees without scholarships or complaint.

How large are the numbers? Every other year, ICE issues a report on the enrollment of foreign students in the United States. According to its latest report, “Sevis by the Numbers: Biannual Report on International Student Trends,” issued in April 2018, Chinese foreign students (377,070) by far outnumbered their closest competitor India (211,700). While the report did not disclose how many Chinese students are enrolled in STEM courses of study, in past years more than half of all Chinese students enrolled in STEM programs.[23]

At the same time, Chinese engineering students take advantage of the expanding opportunities to work in U.S. companies that are of strategic interest to the Chinese government, where they are able to get training and learn about technologies that they can bring back to China. This supports not only Chinese industry but the People’s Liberation Army. As one critic of the open-door policy toward China has put it, "When China rattles its sabers at the United States and other countries around the world, frequently those sabers were designed by those engineers who received their education in the United States."[24]

American universities aren't the only targets. According to the Australian Strategic Policy Institute, some 2,500 Chinese military scientists have been steadily doing research at universities abroad since 2007, often without disclosing their connections to the PLA.[25] By any economic or national security measure, this Chinese penetration of American university STEM programs has become a severe problem. It is in effect a reverse brain drain. Chinese students are able to acquire a first-rate education from programs that are in many cases funded by the U.S. government as well as major private corporations and foundations. They can then take that knowledge back to China to build similar programs aimed at undermining our national security—not to mention engage in "extracurricular" activities such as spying and intellectual property theft from their professors.

The Australian Strategic Policy Institute calls this "picking flowers to make honey in China." American intelligence agencies have a cruder name for it: "Chinese Takeout." It's no wonder there's a growing debate about whether and how to restrict the number of Chinese nationals studying in the United States, and which subjects they can study.

But a much larger lens is required to see the real problem, which is not the large number of foreign students studying STEM in American universities, but the declining number of American students doing the same thing. This is going to demand a much bigger and more comprehensive approach to reform than just putting restrictions on F-1 or M-1 visas. It demands an approach much more akin to the one Sputnik triggered more than sixty years ago, an approach that not only transformed U.S. technology and science, but also the relationship between government and education.

Sputnik was launched on October 4, 1957. On December 30, the American Association for the Advancement of Science (AAAS) published a resolution calling for specialized training for teachers of science. On January 28, 1958, President Eisenhower addressed Congress on how the National Science Foundation was going to answer the need for more scientists and science education. Less than one year later, Congress approved a $1 billion funding bid for the National Defense Education Act (1958), which involved the first complete overhaul of the American education system from schools to universities at the federal level.

In very short order, President Eisenhower established the position of Presidential Science Advisor, and the House and Senate reorganized their committee structures to focus on science policy. Congress also created the National Aeronautics and Space Administration (NASA), in order to create a civilian space program, and tripled funding for the National Science Foundation to improve science education.

What set off this remarkable explosion of federal effort, in effect an "all-of-government" approach to improving America's position as a leader in science and science education? First, of course, was the fear that Sputnik signaled that the United States was losing the space race to the U.S.S.R. It was even feared that the U.S.S.R. would use satellites like Sputnik to spy on America or to fire nuclear weapons from space. Second, there was embarrassment that the United States, which had proved so successful at forging the Arsenal of Democracy in World War II, and winning the nuclear weapons race, and whose industrial might was unparalleled in history, was somehow falling behind in the next important race for the strategic future.[26]

Above all, Sputnik fed a suspicion that America's problem stemmed from an education system that was sadly out of step with the new technological times. In the words of historian Paul Dickson, "Science and mathematics education became, in the public's eye, the solution to winning the science and technology race with the Soviet Union and to regaining global dominance."[27] As the *Hartford Courant* noted, "one of the direct results of the sputniks has been that U.S. people have been taking a long look at their educational system and the program this country has for producing scientists and engineers."[28]

Besides the fear of the Soviets, however, there were other reasons behind this worry about the state of America's science and mathematics educational base. The introduction of the digital computer in the 1950s and '60s created a large demand for mathematicians, programmers, and computer scientists in both the public and private sectors. Since private companies, including defense companies, were drawing their needed talent directly from universities, educational institutions across the country were suffering from a dearth of STEM professors and teachers, even as the GI Bill was rapidly expanding university attendance and the postwar baby boom was about to add to the numbers of children attending school.

America was also losing the generation of engineers, mathematicians, and computer scientists from Europe who had dominated the American scientific landscape during the 1930s and '40s: figures like Albert Einstein, Leo Szilard, and John von Neumann. That loss meant that the country would need new domestic sources for the very highest and most innovative scientific talent—sources that would have to compete with the Soviets' ability to summon the talent it needed virtually on command.

This need for an educational reset was necessary at the top of the intellectual pyramid, in our universities, but also throughout the entire K–12 spectrum. In a speech to the National Education Association, Vice President Nixon argued that America's military and economic strength was entirely dependent on the strength of our educational system. If we lost leadership in the latter, our primacy in the former was bound to suffer.[29]

These worries and the search for a solution culminated in the passage of the National Defense Education Act (NDEA) of 1958. Its goal was "to strengthen the national defense and to encourage and assist in the expansion and improvement of educational programs to meet critical national needs."

The act set aside more than a billion dollars over four years for eight program titles, including student loans and scholarships (Title ii); money for strengthening science, math, and foreign language programs (Title iii); funding for graduate fellowships in certain critical areas of study (Title iv); funding for programs to identify talented and gifted students (Title v); money for research on more effective educational technologies (Title vii) as well as vocational and workforce training (Title viii). The act also established the Science Information Institute and Science Information Council to disseminate scientific information and advise the government on various technical issues (Title ix).

What is striking is how the NDEA viewed STEM in a broader context and sought to address the need for federal support of education as a whole, including language training and "area studies" such as Latin American studies (part of Title vi). Many colleges and universities used these NDEA funds to create specialized language laboratories. Specialized language classes also created a space for other specialized classes, where gifted students could take advanced math and science classes. Different streams of classes for different levels of students were created at the high school and even elementary levels of schooling.[30]

What was the overall impact of the post-Sputnik reforms? Sixty years later, it's hard to say, and harder to measure. To my knowledge, there is still no good quantitative study of the impact of NDEA and other programs coming out of the post-Sputnik reforms. Of course there was a large increase in the numbers of students enrolling in STEM courses and majoring in STEM subjects in the 1960s and '70s, but it is not clear whether this was due to the post-Sputnik education strategy or simply followed from the overall growth in the numbers of students enrolling in colleges and universities, including in STEM subjects. In 1940, about half a million young people, barely 15 percent of college-age Americans, were attending a higher education institution. By 1960 that number had jumped to 3.6 million; by 1970 it had more than doubled again, with 7.5 million Americans, or 40 percent of college-age youth, attending a college or university.[31] Virtually every academic department was bound to see big increases in numbers of students under that kind of demographic pressure, as well as increases in numbers of teachers and instructors.

What we can say is that the post-Sputnik shakeup of American education certainly had its downside. The growth of the bureaucracies that federal funding generated, both at the government and the academic level, soon diluted the NDEA mandates and the STEM offensive by pushing money and attention into relatively minor or even worthless fields. The word "science" soon proliferated in a number of unrelated subjects in order to give them sufficient panache to get students and funding. Programs like "business science" and "communications science" came to be treated as if they were real STEM disciplines, instead of soft and squishy versions of the real things.

Another egregious byproduct was the launching of New Math, made popular by the Cambridge Conference on School Mathematics, which aimed to achieve a radical acceleration of the elementary math curriculum so that calculus could be introduced as a regular high school subject. New Math was supposed to speed up the calculating proficiency of American school children, but in most cases it had the opposite effect. The bewildering flurry of concepts and abstractions borrowed from mathematical logic—for example, Venn diagrams instead of old-fashioned multiplication tables and exercises in long division—certainly killed my interest in mathematics early in my fourth-grade career. From anecdotal evidence, my experience was not unique. The backlash against New Math even had its comical aspects, including Harvard math professor Tom Lehrer's spoof of a lecture on New Math principles that declared, "the important thing is to understand what you're doing rather than to get the right answer," and a 1965 Peanuts cartoon showing a youngster stumbling through her new math assignment: "Sets . . . one to one matching . . . equivalent sets . . . sets of one . . . sets of two . . . renaming two. . . .” Finally, she throws back her head and bursts into tears: “All I want to know is, how much is two and two?”

Underneath the comedy, however, was a genuine frustration with an educational fad gone wrong, like the fate of so many educational fads—especially when they have federal funding to encourage their spread. By the mid-1960s, more than half of American high schools were confusing their students with a New Math curriculum; a decade later it had spread to 85 percent of K–12 education.[32] The fact that, a decade after that, U.S. math test scores seemed to be in free fall may not have been entirely coincidental.

Other critics would complain that the post-Sputnik agenda overstressed and overfunded STEM education at the expense of the humanities and liberal subjects such as history and literature (although one can easily argue that far more damage to those subjects resulted from the 1968 radicalism which still reverberates around schools and universities today). And if declining STEM test scores and enrollments since the 1980s are any indication, no one can claim that the impact of the post-Sputnik push and NDEA on American STEM leadership was particularly lasting.

All the same, one can equally claim that without the post-Sputnik reforms, the computer revolution of the 1970s and ’80s, and the dot-com revolution of the 1990s, would probably not have been possible. Substantial credit for America’s IT leadership in the coming decades has to go to the conscious effort to make science and technology cool and exciting for young people, with an assist from new educational technologies for the classroom like lab kits, overhead projectors, films, and TV learning (the ancestor of today’s online learning).

It is also unlikely that the United States would have gained the clear leadership in defense-related technologies that formed the basis of the Pentagon's Second Offset Strategy in the 1980s. Elements of this strategy—including stealth technology, GPS, and networked warfare, along with the broad, innovative technical and scientific industrial base that the federal government organized and funded after 1958—won the Cold War. Indeed, with Ronald Reagan's Strategic Defense Initiative speech in March 1983, we can hear distant echoes of the excitement and optimism about the possibilities of American science and technology that the post-Sputnik era launched a quarter century earlier.

On the other hand, one obstacle that American education reformers *didn't* face in 1958 was large numbers of Soviet students studying STEM subjects in American universities and going home to help to arm the Red Army, let alone steal research and intellectual property from their professors and colleagues. Nor did we have visa programs that promoted Soviet enrollment in American universities, nor were those same institutions eager to welcome Soviet students into their physics labs and engineering programs with open arms.

Yet that is precisely the situation we face today in our STEM competition with China. In this respect, we are facing an American STEM crisis that is substantially more complex than the one we faced sixty years ago, and one which demands solutions even more radical and disruptive than those Sputnik inspired. Because when a headline-grabbing event like Sputnik occurs this time—e.g., a Chinese quantum computer that can penetrate our most vulnerable public encryption systems—it will almost certainly be too late to do anything about it.

On September 10, 2018, on the eve of the seventeenth anniversary of the attack on 9/11, I wrote a *Forbes* column entitled, "America's High-Tech STEM Crisis." In that column, I wrote of America's declining STEM leadership:

> We are fast approaching another Sputnik moment, we can't afford to ignore. Our national security, as well as economic security, depend on addressing it. We need major high-tech companies like Google and Microsoft; leading universities and colleges; the White House, the Department of Education and the Department of Defense; to come together to craft a high-tech STEM education strategy that can lead us forward to the future.[33]

Three months later, the White House released its plans for a five-year STEM strategy.[34] The report is an important document, with large sections devoted to summarizing a strategy to increase U.S. leadership in science and engineering, and creating more economic opportunities for Americans with a STEM education, especially for women and minorities.

Unfortunately, what's missing is a commitment to specifically address the outstanding national security issues America's STEM crisis entails, especially those relating to topics such as computer engineering and cybersecurity, AI, quantum, and robotics. Hence there is still room for a broader strategy that incorporates more input from our Defense Department and intelligence community, as well as those academic communities whose work in these areas will have a direct impact on our ability to defend ourselves in the future, and cooperation with allies such as Japan, Israel, NATO, and the

Five Eyes (Australia, Canada, New Zealand, the United Kingdom, and United States) on the high-tech frontier.

It is also important to realize that this crisis is not one that's going to wait for the marketplace to solve. Markets are notoriously bad at allocating resources in a crisis, but particularly educational resources because of the time lag involved and other factors. For example, there was a rush of people going into petroleum engineering at precisely the moment oil markets crashed in 2014–15. And when MBAs from Harvard and other prestigious schools flood a business zone, that's usually a good sign that a bubble is about to burst.

In addition, some have argued that much of the current dependence on foreign students and H-1B visa employees happened by design, so that American companies could avoid having to pay full U.S. market prices for this kind of high-tech, highly skilled labor.[35] Be that as it may, it seems obvious that strong and insightful government action on this front is imperative. The question is, what kind?

The issue that has generated the most attention and concrete action to date is the growing number of Chinese nationals, including postdoctoral students and professors, studying and working in the United States—a complex situation given the extent to which American universities have come to rely upon these students. In June 2018, the Trump administration announced plans to limit the time Chinese graduate students will be allowed to study in certain critical areas of high-tech research, including robotics, aeronautics, and high-tech manufacturing, from five years to one.[36] On December 2, 2018, *Voice of America* reported: "US Considers New Restrictions on

Chinese Students."[37] The gist of the story was that American officials have growing worries about spying by Chinese students who are studying in the United States, and about the loss of new technologies important for national security to China through their efforts. In addition to the new visa restrictions, officials are considering whether to carry out additional investigations of Chinese students attending U.S. schools. Reuters reported that officials want to examine student phone calls. They are also considering looking at students' personal accounts on Chinese and U.S. social media sites.[38]

But again, the issue of Chinese students needs to be seen in a larger lens. The greater focus should be on how we get more Americans, especially young Americans, to study and get excited about STEM subjects, especially the high-tech STEM disciplines that have crucial national security implications.

One approach would be to designate certain STEM subjects, such as AI or additive manufacturing, as a "critical knowledge base" as described under the NDEA, and offer government scholarships and funding (including Department of Defense funding) that can be directed to those students and researchers working on that knowledge base. This could be supplemented by encouraging universities and colleges to offer tuition waivers for those same students—a powerful incentive at a time when virtually every college grad leaves school with an enormous loan millstone around his or her neck.

Another approach involves more direct coordination with the high-tech corporate sector. The White House report says very little about more effective coordination between the government and private sector, both to improve education and career opportunities in the United States as well as to advance critical research. The work done at America's corporate labs was an important part of the response to Sputnik sixty years ago. Many of those labs do not exist today, but responding to the present STEM crisis will involve mobilizing resources across society. It cannot remain limited to a few government agencies.

Finally, there needs to be a K–12 teaching offensive, aimed specifically at those "critical knowledge bases." It should incorporate new thinking about how to teach math and science as well as old—old, that is, in terms of best-practice models, including those of countries that consistently outperform us in the international rankings. Trying to import wholesale the pedagogical techniques from Japanese or Taiwanese classrooms may not work from a cultural point of view (although certain American "tiger moms" might disagree). But some applicable lessons might nevertheless be learned by studying these techniques. The United States might also borrow more from Norway or Estonia, which consistently score very well on international tests like PISA, and which could provide constructive models for STEM education in American schools.

The bottom line is that STEM education has become too important to be left to the educators any longer, or to the educational bureaucrats. It's high time the Department of Defense and national security agencies weigh in, as they did post-Sputnik, so that America's future doesn't pass into the hands of foreign nationals, no matter how talented or willing, by default.

Sixty years ago, America's effort to seize global STEM leadership helped to put astronauts on the moon. Today, who can say where retaking STEM leadership can lead us in the twenty-first century? And who can say what the costs might be if we fail?

This article originally appeared in American Affairs *Volume III, Number 1 (Spring 2019): 127–48.*

Notes

The author thanks Brent Cronce, Thomas Keelan, and Kate Rouleau at the Hudson Institute for their assistance with this article.

[1] William J. Bennett and David Wilezol, *Is College Worth It?* (Nashville, Tenn.: Thomas Nelson, 2013), 93.

[2] Arthur Herman, "The Pentagon's 'Smart' Revolution," *Commentary*, June 2016.

[3] Arthur Herman, "Winning the Race in Quantum Computing," *American Affairs* 2, no. 2 (Summer 2018): 96–113.

[4] Bennett and Wilezol, 94.

[5] Committee on STEM Education, "Charting a Course for Success: America's Strategy for STEM Education," National Science and Technology Council, December 2018.

[6] Programme for International Student Assessment, PISA 2015 *Results*, vol. 1, *Excellence and Equity in Education* (Paris: OECD Publishing, 2016).

[7] Committee on Science, Engineering, and Public Policy, “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,” National Academy of Sciences, 2007.

[8] National Center for Education Statistics, “Digest of Education Statistics: 2015,” National Assessment of Educational Progress, December 2016.

[9] National Center for Education Statistics, “Highlights from timss and timss Advanced 2015,” U.S. Department of Education, November 2016.

[10] “Public and Scientists’ Views on Science and Society,” Pew Research Center, January 29, 2015.

[11] “*The Condition of College and Career Readiness: National 2018*,” ACT, 2018.

[12] Committee on STEM Education.

[13] Jeanne Batalova and Jie Zong, “International Students in the United States,” Migration Policy Institute, May 9, 2018.

[14] Batalova and Zong.

[15] “The Importance of International Students to American Science and Engineering: Executive Summary,” National Foundation for American Policy, October 2017.

[16] "Science & Engineering Indicators 2018," National Science Board, January 2018.

[17] Richard P. Appelbaum and Xueying Han, "Will They Stay or Will They Go?," Ewing Marion Kauffman Foundation, July 2016.

[18] Rick Ye, "While US STEM Education Market Declines, China Invests Heavily," *Next Web*, June 19, 2017.

[19] "Asia University Rankings 2018," *Times Higher Education*, accessed January 25, 2019.

[20] Yangfei Zhang, "Experts Call for Emphasis on STEM Education in China," *China Daily*, September 20, 2018.

[21] Appelbaum and Han.

[22] "China's STEM Research Environment in Higher Education," *Science Daily*, April 6, 2018.

[24] Michael Cutler, "Trump Administration Restricts Chinese Students," *Frontpage*, December 25, 2018.

[25] Echo Huang and Isabella Steger, "Foreign Universities are Unwittingly Collaborating with Chinese Military Scientists," *Quartz*, October 29, 2018.

[26] Paul Dickson, *Sputnik: The Shock of the Century* (New York: Walker, 2001).

[27] Dickson.

[28] Keith Schonrock, "Russian Gains Make Americans Take Long Look at Education," *Hartford Courant*, December 15, 1957.

[29] *Proceedings of the National Education Association* 95, (1957).

[30] Barbara Barksdale Clowse, "Brainpower for the Cold War: The Sputnik Crisis and National Defense Education Act of 1958 (Contributions to the Study of Education)," 1981.

[31] National Center for Education Statistics, "120 Years of American Education: A Statistical Portrait," U.S. Department of Education, January 1993.

[32] Jeffrey W. Miller, "Whatever Happened to New Math?," *American Heritage* 41, no. 8 (December 1990).

[33] Arthur Herman, "America's High-Tech STEM Crisis," Forbes, September 10, 2018.

[34] Committee on STEM Education.

[35] Eric R. Weinstein, "How & Why Government, Universities, & Industry Create Domestic Labor Shortages of Scientists & High-Tech Workers," Institute for New Economic Thinking, March 28, 2017.

[37] Mario Ritter Jr., "US Considers New Restrictions on Chinese Students," VOA Learning English, December 2, 2018.

[38] Matt Spetalnick and Patricia Zengerle, "Exclusive: Fearing Espionage, U.S. Weighs Tighter Rules on Chinese Students," Reuters, November 29, 2018.