DAY ONE PROJECT

A National Commitment to Post-Graduate Education in Information Technology[1]

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The Day One Project offers a platform for ideas that represent a broad range of perspectives across S&T disciplines. The views and opinions expressed in this proposal are those of the author and do not reflect the views and opinions of the Day One Project or its S&T Leadership Council.

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Summary

Information technology (IT) refers to the full range of computing technologies and the people that work with them. IT itself is among the world's fastest-growing economic sectors, and is an integral part of most other sectors. Rapid growth and demand for IT services have led to critical workforce shortages. Efforts to address these shortages have largely focused on K–12 and college education while ignoring the post-graduate population. This is a critical error. The post-graduate population is a valuable potential source of high-skilled tech talent and diversity. Many individuals with computing-related degrees would benefit from updates to their training, while individuals with expertise in other areas increasingly stand to benefit from adding IT competencies to their existing skills. Expanding post-graduate education and training opportunities would give current employees additional avenues for advancement, while also offering displaced workers ways to reenter the job market with a new set of skills. Such opportunities would also help employers quickly meet workforce needs, enabling the IT sector to become more dynamic, agile, productive, and innovative.

The Biden-Harris Administration should make a substantial investment in post-graduate opportunities that enable college graduates from a range of disciplines to build or upgrade their computational skills. These opportunities could include everything from business-to-business (B2B) short-term classes to update computational skills, to Master of Science (MS) degree programs that don't require prior computer science experience, to research and mentoring experiences that prepare students for Ph.D. studies. When implemented at scale, such opportunities will enable our nation to address pressing IT talent shortages while empowering Americans of all backgrounds to participate in—and benefit from—the IT economy.

Challenge and Opportunity

The U.S. Bureau of Labor Statistics forecasts an 11% overall growth in U.S. computing and IT occupations between 2019 and 2029, adding an estimated 531,200 jobs.[2] Even with the national CSforAll initiative (which is expanding K–12 computer-science (CS) education) and recent growth in undergraduate CS degrees, it will be difficult to fill these new jobs as well as meet turnover in existing jobs. In a recent survey of 3,000 Chief Information Officers (CIOs), 65% reported that hiring challenges were already hurting their industry.[3] Projections of increasing shortfalls of high-skilled tech workers are sobering. The Korn Ferry "Future of Work" series found that by 2030, "in tech alone, the U.S. could lose out on $162 billion worth of revenues annually unless it finds

[2] Bureau of Labor Statistics. (2020). "Computer and Information Technology Occupations." Occupational Outlook Handbook, September 1. https://www.bls.gov/ooh/computer-and-information-technology/home.htm
[3] Gleber, M. (2017). "The tech talent gap is even larger than you thought." Monster, August. https://www.monster.com/career-advice/article/tech-talent-gap-survey-0816

more high-tech workers."[4] We can expect shortages to increase even further because of COVID-19, as the pandemic has prevented many of the international students who make up a large part of U.S. graduate-school attendees (often remaining in the United States post-graduation to join the workforce) from entering the country. These tech workforce shortages threaten to derail our nation's global leadership in IT innovation.

Indeed, shortages exist at every level: from *basic programing and software skills* to code and maintain routine applications; *sophisticated engineering skills* to design and implement complex, secure systems; *fundamental knowledge of CS* to drive research and innovation; and *domain knowledge* to apply the latest developments in cybersecurity, data science, artificial intelligence (AI), and machine learning to real societal problems. Faced with such widespread and unmet demand for tech workers, the market response has been to support "bootcamps" that train individuals to meet minimal short-term, low-level needs. Bootcamps teach programming skills but fail to provide the broader fundamental CS education (including, for example, courses in computer organization and systems, theory, data structures, algorithms, AI, human-computer interaction (HCI), data science, graphics and ethics). Meanwhile, our nation's companies and universities are relying on imported international talent for deep research and innovative applications. Over 60% of CS doctoral degrees awarded by U.S. institutions in recent years went to foreign nationals.[5] For decades, recipients of advanced CS degrees from U.S. institutions stayed in the United States to work after graduation. But they are increasingly being pulled back to attractive jobs in their home countries.

There is a clear need to provide new CS and IT opportunities for people who live in the United States, many of whom have little or no access to high-quality education and training once they graduate from high school or college. With decades ahead of them, today's post-graduate population represents a valuable source of potential tech and computing talent. The diversity of this population, unmatched anywhere else in the world, gives the United States a competitive advantage if tapped. There is now overwhelming evidence that companies that are more diverse are also more profitable, effective, innovative, and resilient.[6,7] Yet employees at leading Silicon Valley tech companies are more than 91% White and Asian, and 70% male.[8] The post-graduate population is considerably more diverse than the CS undergraduate population.[9] Giving this population as a whole access to CS training is a compelling way to address the longstanding lack

[4] Korn Ferry. (2018). *Future of Work: The Global Talent Crunch, https://www.kornferry.com/insights/articles/talent-crunch-future-of-work.*

[5] Zweben, S.; Bizot, B. (2020). "2019 Taulbee Survey." Computing Research Association, May. https://cra.org/wp content/uploads/2020/05/2019-Taulbee-Survey.pdf

[6] Eswaran, V. (2019). "The business case for diversity is now overwhelming." World Economic Forum, April 29. https://www.weforum.org/agenda/2019/04/business-case-for-diversity-in-the-workplace/

[7] Powers, A. (2018). "A study finds that diverse companies produce 19% more revenue." *Forbes*, June 27. https://www.forbes.com/sites/annapowers/2018/06/27/a-study-finds-that-diverse-companies-produce-19-more-revenue/?sh=13c1c333506f

[8] U.S. Equal Employment Opportunity Commission, "Diversity in High Tech," https://www.eeoc.gov/special report/diversity-high-tech

[9] U.S. Department of Education. (2018). "Postsecondary Institutions and Cost of Attendance in 2017-18; Degrees and Other Awards Conferred, 2016-17; and 12-Month Enrollment, 2016-2017". National Center for Education Statistics. Technical Report, June. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2018060REV

of diversity in computing. The diversity problem can also be addressed by encouraging members of underrepresented groups with some CS experience to take their training to the next level. Women comprise 21% of CS bachelor-degree recipients, but only about 3% of CS doctoral-degree recipients. Minorities similarly comprise 12.4% of CS bachelor-degree recipients, but also only about 3% of CS doctoral-degree recipients.[10] The tech sector could be considerably strengthened through intentionally developed—i.e., focused on diversity, equity, and inclusion—programs to reskill those without CS degrees and upskill those with.

Multiple programs or pilot programs exist to support post-grad training in CS and IT (Box 1 as an example). But they are too small and too scattered to solve the national IT talent shortage. The federal government can and should build upon these existing programs with a national initiative to leverage the post-graduate population and build a large, diverse, innovative, and high-powered pool of domestic tech professionals and researchers.

Plan of Action

Building on the national K–12 CSforAll initiative launched by the Obama Administration, the Biden-Harris Administration should invest $115 million over 5 years to support post-graduate education in computing (a CSforPostGrads initiative). $50 million of investment should be dedicated to funding the development of new programs and to scaling. The remaining $65 million should fund scholarships, fellowships, and loan-forgiveness programs needed to increase access to post-grad opportunities in CS and IT for individuals from low-income or other groups traditionally underrepresented in tech. Like CSforAll, CSforPostGrads would benefit from strong partnerships with nonprofits, industry, and institutions of higher learning.

Box 1. Case study—Master of Science in Computer Science (MSCS) degree program.

In 2013, Northeastern University launched its Align Program, which offers a Master of Science in Computer Science (MSCS) degree for students who have an undergraduate degree in something other than computing.[5] Align exemplifies the demand for—and scaling potential of—this type of degree program. Align began with just 11 students on Northeastern's Seattle campus. This academic year, despite the pandemic, 1,187 students were enrolled on six Northeastern campuses. The program has even gained traction beyond Northeastern campuses. 12 other universities—Clemson University, the Colorado School of Mines, Columbia University, DePaul University, George Mason University, the Georgia Institute of Technology, Tufts University, the University of California Riverside, the University of Illinois Urbana-Champaign, the University of Maryland Baltimore County, the University of North Texas, and the University of South Florida—have joined Northeastern in the MSCS Pathways to Computing Consortium, a collaboration that enables members to build on each other's experiences in building the IT work force. Each institution participating in the consortium is in the process of developing or improving a post-grad CS program similar to Align. These programs are considerably more diverse than most CS degree programs. 52% of Align students enrolled in fall 2020 were female, and 15% of domestic students were from other underrepresented groups in computing. All of the institutional members of the MSCS Pathways to Computing Consortium are likewise committed to increasing diversity in tech.

[10] U.S. Department of Education. (2019). *Status and Trends in the Education of Racial and Ethnic Groups, 2019*. National Center for Education Statistics. https://nces.ed.gov/programs/raceindicators/indicator_ree.asp

Programs supported by CSforPostGrads could include:

- Business-to-business (B2B) certificate programs to update IT skills for existing employees, focusing on essential topics such as cybersecurity, machine learning, and AI.
- Bachelor's of Science in CS (BSCS) degree-completion programs for holders of associate degrees in IT-related fields. These programs might function best as joint ventures among community colleges, universities, and local industry.
- Master's of Science in CS (MSCS) programs aimed at those with undergraduate degrees in fields other than computing. Starting with a sequence of courses that "bridge" students into more traditional MS programs, these degrees could well become the tech equivalent of an MBA: degrees open to people from a range of backgrounds that add value across a spectrum of career paths.
- Mentored, short research experiences in academia or industry for MSCS students. These opportunities—typically the length of a quarter or a semester—would be guided by faculty members and industry practitioners, and could encourage students to continue beyond an MSCS to a Ph.D. and/or a career in research. Such programs are particularly important for students from underrepresented groups and from disciplines outside of computing, who often lack access to research experiences.
- Pre-Ph.D. programs that aim to prepare students with computing-related degrees to gain admission to very competitive Ph.D. programs in CS at top departments. More intensive than short-term mentored research experiences, pre-Ph.D. programs allow students to obtain the foundational knowledge, research experiences, professional training, and recommendations needed for competitive admissions. They focus on minority and low-income students who lacked access to these opportunities at the undergraduate level.
- Ph.D. retention and faculty-preparation programs that aim to retain post-grads from underrepresented groups in strong Ph.D. programs that prepare candidates for faculty positions. In addition to their technical innovation and diversity of viewpoints, faculty who can serve as role models for students from underrepresented groups are sorely needed.
- Visiting scientist programs that allow non-CS scientists—such as biologists, chemists, physicists, and others—to collaborate on interdisciplinary research projects, enabling those scientists to contribute to the vast field of computing application research. Given their domain expertise, often in data-intensive disciplines, these individuals bring experience, knowledge, and diverse perspectives to computing research.

The success of CSforPostGrads could be measured by the number of new, effective educational programs created, the extent to which those programs are scaled, and the number,

demographics, and ultimate employment of their graduates.

The CSforPostGrads initiative should be led by the National Science Foundation (NSF). NSF has considerable experience funding research on and development of effective educational science, technology, engineering, and math (STEM) programs for diverse audiences. NSF is also experienced in the logistics of funding individual scholarships and fellowships. Specifically, the CSforPostGrads initiative should be managed by NSF's Computer and Information Science and Engineering Directorate (CISE). CISE has already demonstrated interest in the post-grad space with its recent announcement of CSGrad4US. CSGrad4US is a program for CS graduates who are 2–5 years out from their degree. CSGrad4US fellows will participate in a year-long preparation program that includes mentoring, community building, and assistance in identifying a graduate program, finding a research mentor and applying to CISE-related graduate programs. Once accepted to a graduate program, CSGrad4US fellows will receive up to three years of funding towards a stipend, tuition, and school-related expenses. Demonstrating the potential for partnerships in this space, a professional organization (the Computing Research Association) is providing the first year of mentoring for CSGrad4US fellows.

Of course, the mission and activities of a CSforPostGrads initiative overlap with the purview of many government agencies besides CISE. At NSF, the Education and Human Resources Directorate (EHR) also has the capacity to run similar programs and has worked with the CISE Directorate on CSforAll. Outside of NSF, other agencies that should be engaged in designing and implementing CSforPostGrads include the National Institutes of Health (as related to computational biology, robotics, and machine learning), the Department of Homeland Security (as related to cybersecurity), the Department of Defense (as related to a technically prepared military and for advanced technology), and the Departments of Education and Labor (as related to developing job skills for a modern-day workforce).

Conclusion

By investing in a CSforPostGrads initiative, the Biden-Harris Administration can alleviate the national shortage of tech professionals, grow the numbers of people in non-CS disciplines equipped to use computation in sophisticated and innovative ways, provide pathways for displaced workers reenter the workforce in stable, high-paying positions, and address social disparities by providing equitable access to CS and IT training and economic opportunities. Under the Obama Administration, CSforAll recognized the importance of training K–12 students in the CS skills that have become indispensable in today's world. Under the Biden-Harris Administration, CSforPostGrads can recognize that post-grads represent a valuable and diverse source of tech talent as well. Tapping into this pool through an array of federally sponsored educational and training opportunities, financial support to expand access to such opportunities,

and robust university and industry partnerships that link post-grad opportunities with post-grad employment will ensure that our nation remains at the forefront of tech innovation, and that all Americans can participate in—and benefit from—the tech economy.

Frequently Asked Questions

Where does the $115 million price tag come from?

Over five years, an estimated $50 million is needed to meaningfully develop and scale post-grad CS and IT programs through agencies such as NSF and the Departments of Defense, Education, and Labor. An estimated $65 million is needed to financially support an initial group of 4,000 post-graduate students from low-income and other underrepresented communities to participate in CSforPostGrads opportunities. The cost of requisite financial support per individual will vary depending on the type of opportunity pursed. Low-cost programs include a short sequence of online courses culminating in a CS certificate or industry credential. High-cost programs include two to three years of tuition, stipends, and student-support services during participation in MSCS or pre-Ph.D. programs. Assuming that requisite financial support for low- and high-cost programs averages $5,000 and $35,000 per individual, respectively, and that three times as many students participate in low-cost programs as do in high-cost programs, then supporting 4,000 students would cost approximately $65 million. We caveat that these are very rough estimates. More precise cost projections could be developed as the structure and scale of CSforPostGrads is further developed. We also anticipate that some of the costs of CSforPostGrads will be shared or matched by industry and philanthropies, increasing access to provide even more people.

For comparison, CSforAll was launched at NSF with $200 million over four years to support research and design of K–12 teaching materials and program assessments. Additional funding came from the Department of Education and the Department of Defense. Industry supporters included Amazon, Cisco, Facebook, Google, Infosys, Microsoft, and Uber and much of their money was funneled through the private nonprofit Code.org. Additional private money, foundation grants, and state financing have continued to support the CSforAll effort locally over more than 10 years. CSforAll was aimed at K–12 students in public school, so therefore did not need money for scholarships. That money is critical in the post-grad space because lack of funding is one of the main reasons why many students choose not to continue their education after graduating from high school or from an undergraduate degree program. Scaling back or eliminating financial supports would make it difficult to attract low-income students to post-grad CS and IT opportunities, hurting diversity.

Can the private sector launch CSforPostGrads without government involvement?

The private sector has supported short-term coding "bootcamps," but is doing little to help the post-grad population develop the foundational expertise in computer science needed for American companies to continue to drive tech innovation in a very competitive global market. To remain a global leader in CS and IT, we as a nation must transition from relying heavily on imported international talent to investing in large-scale, long-term educational opportunities

that will cultivate talent from the U.S. post-grad population. This type of investment in our nation's human capital is a public good that the federal government can and should provide. If programs developed under a federally sponsored CSforPostGrads initiative succeed, then industry—including local and regional companies—may well be willing to fund their expansion as well as continued student support.

Isn't training people in CS what colleges and universities do as a routine part of their mission?

Colleges and universities typically focus on bachelor's degrees, and—for students in select disciplines—follow-on MS and Ph.D. degrees. Colleges and universities do not usually provide comprehensive reskilling opportunities that students from non-CS disciplines need to switch into tech or to complement their domain expertise with significant CS capacity. Nor do colleges and universities typically provide the kinds of post-graduate programs that can unlock CS opportunities for students from a broad range of backgrounds. Again, this workforce-development gap is one that the federal government can and should fill.

Where will the educational workforce needed to implement these programs come from?

Many CS departments are already struggling to manage soaring enrollments at a time when there is strong competition for faculty. In the short term, minimizing additional strain that CSforPostGrads programs could impose on faculty resources may involve approaches such as flipped classes, online courses, or reliance on graduate students and part-time faculty "borrowed" from industry for some of CSforPostGrads teaching. In the longer term, we expect that faculty strain will be alleviated as CSforPostGrads itself produces trained alumni who expand the pool of qualified instructors.

About the Authors

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Andrea Danyluk is a Professor of Computer Science at Williams College. Danyluk works in three distinct areas: machine learning research; computing education; diversity, equity, and inclusion. Her machine learning research has been motivated by a variety of applications, from telecommunications to ecology. Her recent curricular work includes co-Chairing the ACM Data Science Task Force. Danyluk is co-Chair of the Computing Research Association's Committee on Widening Participation in Computing Research. Danyluk was Northeastern University's inaugural Global Director of Align, a Master's in Computer Science designed to bring a diversity of thought, background, race, and gender to the field of computing.

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About the Day One Project

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