CRA-WP
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Widening Participation

Fostering a Post-Graduate Tech Boom

A Computing Research Association – Widening Participation Quadrennial Paper

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Computer Science is Central to National Security, Infrastructure, Economy, and Social Equity

In order to maintain its political and economic position in the world, and for that position to benefit its citizens, the United States must build and retain the strongest and most innovative tech talent at all levels – from programmers, software engineers, and project managers to computer science researchers and faculty.

Technology is among the world's fastest growing economic industries. The U.S. Bureau of Labor Statistics *Occupational Outlook Handbook* forecasts 11% overall growth in U.S. computing and IT occupations between 2019 and 2029, and an even more significant 15% growth in positions for computer and information science researchers. Technology is not an industry unto itself, but is integral to every economic sector – e.g., agriculture and other natural resource industries; manufacturing; service industries; education and research; and government. As a result, it affects every individual in tangible ways. And it is of vital importance to national security, energy infrastructure, and public health infrastructure, among others.

Not only is a broad range of technical *competence* in high demand, but there is also a need for technical *innovation*. Evidence suggests that the U.S. is getting less competitive in terms of attracting post-graduate talent, which is sorely needed to keep pace with advances in technology.

There is a need for high-quality employment in the U.S. Many individuals do not have access to the education and training needed to pursue a technology career once they are past typical college age. As life-expectancy is near 80 years, the nation cannot afford for its population to be limited by career choices made before the age of 22. With decades ahead of them, *today's post-graduate population represents a valuable source of potential tech and computing research talent.*

Core Needs for an Expert Computing Research and Technology Workforce

The expertise needed to build the largest and most talented computing research and technology workforce is significant and will require massive investment in post-graduate support.

- **Basic programming and software skills** – Basic programming and software skills are needed to continually keep systems up-to-date. Every enterprise depends on software, but no software system can be designed to accommodate all possible hardware, network, and business processes that arise with time. Many business, industry, and government operations slow down because initially well-designed systems need modification to keep up with even modest unforeseen changes in processes. Capable programmers are needed to make even routine updates quickly to maintain overall organizational performance.
- **Sophisticated software engineering skills to design, implement, and maintain complex software systems** – Many programmers can produce systems with a detailed specification. But many new applications to resolve organizational problems are never developed because of the lack of people to translate problems in real world narrative form into technical specifications for complex processes. Talented and innovative software engineers are needed to design new systems and maintain existing ones.
- **Fundamental computer science skills for research and driving innovation** – Online ordering, recommender, and delivery systems that are fundamental to e-commerce are examples of entirely new types of enterprises being developed as the result of research and innovation. Research and innovation are needed to develop new industries, to eliminate hazardous low paying jobs, and to replace them with higher productivity, higher income jobs. Basic research in computing is critical to advancing computer hardware, ensuring security and privacy of systems, and making strides in allied areas, such as health care informatics, among many others.
- **Domain knowledge (CS+X) to apply the latest developments in Data Science, Artificial Intelligence (AI), and Machine Learning to society's problems** – Well intended efforts from the tech community have attempted to address problems in other domains such as health and law enforcement. However, without broad domain knowledge such systems can do more harm than good. People are needed who have both a deep understanding of application domains and the technical skills to develop, implement, and apply new methods in Data Science, AI, and Machine Learning.
- **Faculty** – With the steady and unrelenting need for computer science capability from basic coding to research skills, the demand for faculty at all levels will continue.

An Opportunity to Address Issues of Social Equity and Inclusion

Though undergraduate programs in computing across the U.S. have more than doubled in size over the last decade [BizZwe 2019], they are insufficient to fill the required talent pipeline. Furthermore, these programs have not substantially increased in diversity: women represent 57% [DOE 2018] and individuals from underrepresented racial and ethnic groups in CS (URG in CS)[1] represent 25% [DOE 2019] of all bachelor's recipients in the U.S., but only 19.5% and 12.6% of CS graduates, respectively.

[1] Underrepresented racial and ethnic groups in CS include all U.S. minorities except Asian Americans who are well represented.

Jobs in the tech space are some of the highest paying jobs, and yet women and URG in CS are missing out on this opportunity. If we can fill this opportunity gap, we will not only satisfy a major national security and economic need, but also address an issue of social equity and inclusion.

Filling the Gap

The current tech talent pipeline falls far short of meeting demand, particularly in computing research. Substantial progress has been made in developing future generations of computing professionals. With the CS4All movement, curriculum has been designed for K-12 classrooms, a number of states have adopted CS standards for K-12 education and/or CS teacher certification, and schools of education are adding CS to their preparation of future teachers. However, *the U.S. cannot simply wait for future generations to fill the current tech gap. Nor can it continue to rely on international talent to fill this need*, as (1) international students are increasingly returning to their home countries to pursue tech opportunities there and (2) the current COVID pandemic has demonstrated the fragility of an economy that depends upon students and employees that may not be able to enter the U.S. during times of crisis.

The U.S. must build domestic computing technology and research talent now. At the same time, many people in the U.S. need employment, or better employment, and do not have access to the resources needed to acquire the requisite education and skills. While the need for computing expertise has been recognized, the market response has primarily been a combination of coding bootcamps for very short term low-level needs, and relying on international talent for depth and innovative research.

A number of institutions have gone beyond these solutions, working to develop programs that re-train professionals in other fields to become computing professionals and researchers. They include the NYU Tandon Bridge program, Northeastern University's Align Master of Science in Computer Science, and Tufts University's Post-Baccalaureate in Computer Science, among others. Bridge programs such as these teach students the core concepts of an undergraduate computing degree. Many of these programs either automatically accept or encourage "bridge" students to apply to their own or other graduate programs, ultimately aiming to increase both the number of tech professionals and the number of computer science researchers. Though the details of the programs vary, they include features such as online courses, so students can learn "where they are"; low-cost tuition or scholarships, so students do not have to take on exorbitant debt; industry and research lab internships, so that students can gain practical experience and develop their professional networks.

Other programs also aim to provide training and further development for post-graduates, those with undergraduate degrees in computing and as well as those with undergraduate degrees in other disciplines.

- B2B certificate programs – around topics such as Cyber Security, Machine Learning, or AI – develop and increase the skill level of existing employees.
- Mentored research internships at the M.S. level increase students' interest in going beyond software development training to pursue a Ph.D. and a career in research. These are particularly important for students from underrepresented groups and from disciplines outside of computing, who may have either shied away from or not had access to research experiences.
- Pre-Ph.D. programs can provide additional research and training to prepare individuals for entry into a top Ph.D. program. Top Ph.D. programs look for students with achievement in advanced courses, previous research experiences, and recommendations from faculty members who know the students well. These credentials are simply not accessible to students at many institutions in the U.S. Programs bridging undergraduate to graduate enrollment can fill this gap.
- Programs such as the FLIP (Diversifying Future Leadership in the Professoriate) Alliance[2] aim to recruit more students from underrepresented groups into strong Ph.D. programs and hopefully then into faculty positions, where their presence as role models (in addition to their technical innovation) is sorely needed.
- Some institutions are developing programs that allow Ph.D. scientists – biologists, chemists, physicists, etc. – to contribute to the vast field of computing research. With a high level of expertise, often in data intensive disciplines, these individuals bring experience, knowledge, and a fresh perspective to computing research.

These pilot programs demonstrate that there is great potential in developing a large, diverse, innovative, and high-power pool of domestic tech professionals and computing researchers from the post-graduate population. The U.S. has the opportunity to support and sustain these programs, as well as to support and sustain the individuals who would make a commitment to re-training in tech.

What is Needed

The U.S. is currently unable to fill its need for tech talent. If it is to remain the leader in the global political and economic space, it needs to fill that gap, and it needs to fill it with individuals who bring to the field a diversity of experience and perspectives in order to fuel innovation. In doing so, it has the opportunity to also overcome problems of social justice and equity.

What is needed is a significant multi-agency initiative to provide post-graduate training and opportunities now. We simply cannot wait a decade or more for today's school-age population to train for tech careers.

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[2] https://cmd-it.org/program/current/flip-alliance/

This effort falls within the mission of many government agencies, including the National Science Foundation, the National Institutes of Health (e.g., as related to computational biology, robotics, and machine learning), the Department of Homeland Security (e.g., as related to cybersecurity), the Department of Defense (for a technically prepared military and for advanced technology), and the Departments of Education and Labor (as related to developing job skills for a 21st century workforce), among others. It will require

- Funding to support the development of university-led post-baccalaureate, Master's, and Ph.D. programs for individuals who did not study computing as undergraduates.
- Fellowships and scholarships. Whether they are recent college graduates or experienced professionals who are leaving their jobs to re-train in tech, the cost of more education is a significant barrier for many individuals.
- Government loan forgiveness or payment programs, so individuals considering such a move do not have to overcome the hurdle of large loan burdens.
- Large-scale infrastructure programs to make broadband internet available in all communities, providing access to online instantiations of such programs.

Because these programs will further increase the enrollment strain on university level Computer Science departments, it will also be necessary to bolster their teaching capacity. Achieving this may include fellowships for Computer Science teaching professors, making these positions more desirable and thus mitigating the departure of faculty from academia to higher-paying industry jobs. Though industry researchers are needed, faculty to teach and mentor future generations are critical as well.

References

[BizZwe 2019] Betsy Bizot and Stu Zweben. 2019. Generation CS, Three Years Later. On the Internet at https://cra.org/generation-cs-three-years-later/ (visited October 2020).

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This quadrennial paper is part of a series of papers compiled every four years by the Computing Research Association and members of the computing research community to inform policymakers, community members and the public on important research opportunities in areas of national priority. The topics chosen represent areas of mutual interest among the members spanning various subdisciplines of the computing research field. The papers attempt to portray a

comprehensive picture of the computing research field detailing potential research directions, challenges, and recommendations.

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