Inclusive Education Strategies for Diversity in Smart Workforce

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ABSTRACT

We review the situation of women in computing professions and note that there is a mismatch between the percentage of women in computing jobs on one hand and their percentage in the population on the other. The absence of women in the computing workforce is to their detriment and the detriment of employers. Companies face difficulties when trying to fill open software positions with qualified applicants. Product teams are missing out on design input from "50% of the population." Women are denied the social mobility that well-paying computing jobs provide. Thus, improving the percentage of women in the computing workforce would be beneficial to the companies in multiple ways, to the women, and to society as whole, making it more equitable. Unfortunately, achieving this goal is a problem that has resisted decades of efforts. Only a multi-pronged approach spanning all levels of education, government and industry can lead to a breakthrough. It is especially urgent to overcome the shortage of qualified and certified middle and high school teachers. We present ongoing activities at one college to bring women into computing and to keep them in the program, and suggestions how governments at the federal and state levels can contribute to overcoming the computing teacher shortage, creating a pipeline to CS programs in colleges.

CCS CONCEPTS

• **Social and professional topics** → **Women**; • **Applied computing** → **Education**.

KEYWORDS

Diversity in workforce, women in computing, workforce development, equity in computing education

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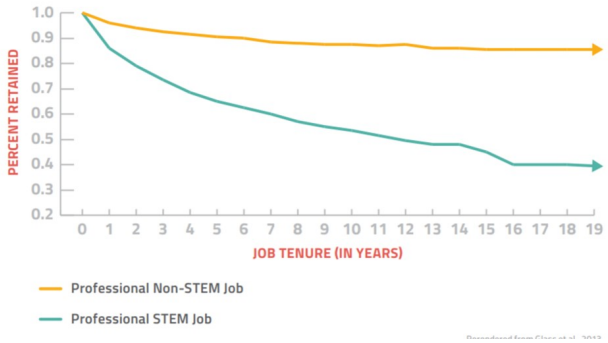

Figure 1: Percentage of women retained in career field over time (Source: NCWIT [34])

1 INTRODUCTION

The five largest US companies, by market capitalization are software companies. Microsoft leads the pack with a market capitalization of $1.359 trillion. Worldwide, only Aramco in Saudi Arabia is bigger. On US places two to five are Apple, Amazon, Alphabet (Google's parent), and Facebook, the latter worth "only" $583 billion. Alibaba and Tencent Holdings, two Chinese technology companies, follow in the world ranking on seventh and eighth place. Only Berkshire Hathaway and Johnson & Johnson are US companies in the top ten that are not software companies [1]. The chip maker Intel is #21, the phone network and media company AT&T is at #26. Cisco Systems, the company that makes the "pipes" for the internet, at position #39, still has a respectable valuation of $179.7 billion. Finding reliable numbers about employment is more difficult, due to the multi-national nature of the largest employers. However, it is estimated that the US employs 12.1 million tech workers [47]. When looking at gender diversity in the technology workforce, the picture that emerges is bleak. Only 26% of computing jobs are staffed by women [35]. With a fine-grained analysis, the workforce is even more biased. According to data collected by NCWIT [34], the numbers of Black/African American and Latina/Hispanic women among computing research scientists are too small to report. Asian women make up 8% and White women 13% of researchers. For software developers, the numbers are 1%, 1%, 7%, and 9% for Black-African/American, Latina/Hispanic, Asian and White women, respectively. Women aren't just employed in smaller numbers in technology jobs, they are also more likely to leave (Figure 1, ibid.).

The absence of women in tech jobs is not just a problem for them, it has negative effects for the whole economy. Extensive research [50] has shown that teams with a high degree of diversity produce better outcomes. Members of the team that have a first-hand knowledge of the concerns of certain subgroups of the population will

be able to bring this knowledge into the requirements engineering phase of software product development. The term "cognitive diversity" has been coined for this effect [8]. The more diversity there is in the team, the more different viewpoints will be considered, and the more users/customers will have advocates of their own needs on the team. Given that women represent over 50% of the population, having a team without a representation of females ignores the needs of half of the population. When it comes to purchasing decisions, women make up a greater percentage of the population still. In fact, 70% to 80% of consumer purchasing decisions are made by women [38]. The United States produce more college graduates than jobs in almost every subject area of higher education. Computer Science is an exception that provides many job opportunities. Projections of the Bureau of Labor Statistics indicate that "Computer and Mathematical Occupations" are expected to grow by 12.1% between 2019 and 2029 [26]. Only Healthcare and Community/Social Services jobs are slated to grow by a higher percentage. It is estimated that 67% of new STEM (Science, Technology, Engineering, and Mathematics) jobs will be in computing, while only 11% of STEM graduates receive Computer Science degrees [29].

From the viewpoint of hiring managers there is a dearth of talent. Widening the pipeline by producing more female computer science Bachelor's graduates could provide badly-needed relief. With the loss of many jobs to automation and outsourcing, there is a bifurcation of the job market, with menial, low-paying jobs at the bottom, and high-education/high-opportunity jobs at the top, with little in between. Income inequality is relentlessly growing in the USA and the Gini index of inequality is highest in the USA among G7 countries [43]. It is an issue of social justice to make the excellent opportunities provided by computing/IT jobs as widely as possible available to a large segment of the population. This requires increasing the opportunities for underrepresented minorities (URMs; especially African American and Latino women and men) and for Caucasian women.

It is possible to claim that coding and programming will be the new literacy [49], although arguments exist on both sides of this hypothesis. With the proliferation of "intelligent" devices and the popularity and simplicity of the Python programming language, "universal coding literacy" in the future is a distinct possibility. In a decade, users might be able to reprogram their home thermostats or the cameras in their refrigerators that will show them what they (don't) need to buy. Coding might become part of universal literacy, together with reading, writing, and basic math. This will be a slow process, but we cannot exclude half of the population from these skills.

One reason for the low representation of women in technology jobs is that they are not getting the requisite education in the first place. College degree programs in computing fields are notoriously undersubscribed by female students, with an estimated participation of 18% [32]. To improve the situation in female job market participation, it is necessary to engage female middle school students early to nurture their interest in technology education and computing jobs [41]. By the time girls reach high school, many of them have already decided that "computing is not for me," and there is also a shortage of Computer Science teachers.

Our goal is to provide a snapshot of existing initiatives for increasing the number of women in computing and to propose steps to be taken at different levels of government to accelerate these processes. We present the educational initiatives and activities for enhancing gender diversity and universal coding skills by US state governments and in OECD countries, by professional organizations and IT industry companies, as well as in academic institutions. We detail a set of activities at NJIT for engaging women in computing fields, from middle and high school outreach to Bachelor's students in CS and technology degree programs. From the review of the current state of the art efforts and a case of an academic institution, we present a set of recommendations for government actions to address the diversity challenge in the highly advanced technology-driven society.

In Section 2, we present ongoing initiatives to address diversity issues in different organizations. Section 3 summarizes several initiatives at the New Jersey Institute of Technology (NJIT) to improve the recruitment and retention of female students in Computer Science. Section 4 provides recommendations how governments at different levels could improve the availability of teachers for the early stages of the pipeline, followed by conclusions and future work.

2 DIVERSITY INITIATIVES IN COMPUTING AND ADVANCED TECHNOLOGY

2.1 US Federal Government Initiatives

Education in the US is the responsibility of individual states, due to the 10th Amendment of the US Constitution. However, the federal government has a footprint in education [11]. The US Department of education is involved at all levels of education through mechanisms such as loans and grants for college students. The ESSA (Every Student Succeeds Act) provides very general guidance. The "Revised State Template for the Consolidated State Plan" of 2017 discusses Math and English [30]. Sciences are mentioned only twice in the 27 page document, and computing does not appear at all. Encouragingly, the issue of Women in Science is raised.

An applicant that proposes to carry out a model science program for secondary students and is concerned that girls may be less likely than boys to enroll in the course, might indicate how it intends to conduct "outreach" efforts to girls, to encourage their enrollment (pg. 25)

Notwithstanding this limited direct influence on education, the federal government has levers to influence it. One organization that is increasingly involved in equitable education is the National Science Foundation (NSF). NSF is the primary federal mechanism for funding non-medical research in universities, and in the past decade officers of NSF have set directions by increasing funding for research into education methods. Computing education is a major area of interest to NSF. The Directorate for Computer Information Science and Engineering (CISE) of NSF has created a pilot program for including BPC (Broadening of Participation in Computing) Statements in any proposal for research grants [12]. NSF

... strongly encourages meaningful actions that address the long-standing underrepresentation of various populations including women,

African Americans, Hispanics, American Indians, Alaska Natives, Native Hawaiians, Native Pacific Islanders, and persons with disabilities in computing and closely related disciplines. All levels within these groups are relevant, from K-12 to workforce.

As of 2021, relevant medium and large project proposals must include meaningful BPC plans at the time of an award of research money to the institution (usually a college or university). For junior faculty in any of the computing sciences, getting one or two NSF grants will be strong contributors to a positive tenure decision (depending on the ranking of the institution itself). Thus the above requirements are de-facto the law of the land for any research-oriented Computer Science department of a college or university. While the above activities of the federal government are encouraging, much more can and should be done, especially at the K-12 level. We will provide ideas for this in Section 4.

2.2 US State Governments and K-12 Computing Literacy

There is a wide variability among the K-12 computing education achievements in the 50 States [2]. The code.org organization has been charting the advancements, and substantial progress has been made in 33 states. Arkansas has a high profile in advancing computing education for K-12 students [19]. It has made Computer Science education a priority. In New Jersey, Governor Murphy has signed legislation in late 2020 to grant $800,000 for training hubs for educators involved with Computer Science education in K-12 schools [13]. The gap in access to computing infrastructure and computing education has been termed the "digital divide," and New Jersey is aggressively attempting to remediate it [14]. This development started already with Governor Murphy's predecessor. NJ State Law A2873/S2487, signed by Governor Christie in January 2018, required all high schools in NJ to offer a CS class by 2018/19 [39]. Unfortunately there is a shortage of qualified and certified teachers. In New York State, the full implementation of "digital fluency" requirements has been pushed back to 2024 [22]. While these educational programs are not targeted specifically at women and minorities, this is a case of "a rising tide lifts all the boats," and the increased availability of computing education opportunities will benefit girls as much as boys.

2.3 OECD and Other Countries

Having looked at the situation in the US, it is instructive to compare it to other rich countries. The Organisation for Economic Co-operation and Development (OECD), commonly referred to as a "club of mostly rich countries" is celebrating its 60th anniversary in 2021. The list of members consists of 37 nations [31], including "expected" countries such as Australia, Canada, France, Germany, Italy, Japan, Korea, Switzerland, the United Kingdom, and the United States, but also smaller and poorer countries such Slovenia and Mexico. The OECD is specifically addressing the "digital divide" [9] in its policies. The OECD data collection includes non-member countries as well. The educational activities of the OECD with world-wide visibility include the PISA tests (Program for International Student Assessment) [25]. Achieving a high ranking in the PISA tests is a national badge of honor. The subjects tested are [17]: Reading literacy, Mathematics literacy, Science literacy, Problem solving, Collaborative problem solving, and Financial literacy.

Computing has not been a test subject, however the topic is "on the radar screen." The OECD refers to lack of access to computing equipment as "first digital divide." The US average in mathematics literacy was lower than the average in 24 other national education systems, higher than in six, and not distinguishable from the remaining six countries, out of 37 members [24]. In the 2018 mathematics world rankings, China leads with 591 points and the US is at position 38, with 478 points. The first non-Asian country is Estonia at rank 8, with 523 points. Given the correlation between mathematical thinking and computational thinking [55], this does not bode well for computing literacy in the US.

According to Vegas and Fowler [54] *…out of 219 countries: 44 (around 20 percent) mandate that schools offer it as an elective or required course; 15 (around 7 percent) offer CS in select schools and some subnational jurisdictions (states, provinces, etc.); and 160 (73 percent) are only piloting CS education programs or had no available evidence of in-school CS education …*

We briefly review a few OECD countries. In German-speaking countries, "Computer Science" is referred to as "Informatik" (Informatics), using the term in a narrower sense than in the United States. Just as in the US, in Germany the teaching of Computer Science is up to the States ("Bundesländer") [16]. Educational standards as of 2019 [6] have been defined, but are still considered recommendations. In Austria, Informatik has been taught, to a limited degree, in schools since 1985. It is a required subject in 9th grade for the higher tiered "AHS" (Allgemein Bildende Höhere Schule) schools. However, stricter local rules of different school districts are allowed. Switzerland has created a harmonized plan in 2017, but the implementation was left to the states ("Kantone"), also giving them the option to make Informatics a part of the mathematics curriculum.

According to a report of the Royal Society from 2017 [3] the computing education in the United Kingdom is "patchy and fragile." A big problem is the availability of educators. Quoting from the report

"…a majority of teachers are teaching an unfamiliar school subject without adequate support. Moreover, they may be the only teacher in their school with this task."

A 2014 publication on CS education in Israel in comparison with the United States [40] focuses on common issues, and comes to the same conclusion for both countries: There is a lack of standards in teacher certification for Computer Science. While the United States have world-leading institutions in computing at the post-secondary level, preparing top scholars for university teaching, research, and work in industry, the situation at the K-12 levels, though rapidly changing, appears to be comparable to the (unsatisfactory) uncoordinated situation in other developed countries.

The Canadian provinces also do not have a single unified approach [45]. Nova Scotia made the interesting choice of mandatory computing classes (as of August 2017) up to Grade 6. Coding is optional in grades 7 to 12. Ontario, the Canadian province with the largest population, was lagging behind. As of fall 2020, computer programming is part of the mathematics curriculum in Ontario, starting in Grade 1 [36].

A fairly recent review paper about Asian education in computational thinking [44] appeared in 2019. It compares attitudes towards teaching this subject among educators, e.g. which sources of educational materials are best for this subject. In Japan coding is mandatory as of 5th Grade since spring 2020. The policy was designed to catch up with other countries and overcome a shortage of IT workers [51]. Korea established a computer science curriculum in 2007, but by 2015 the country experienced a surprising decline in computer education, with fewer students taking relevant classes [37]. Computational thinking is one of four core competencies included in the 2018 high school standards published by the Chinese Ministry of Education. Furthermore, China is attempting to leapfrog over other countries by introducing Artificial Intelligence in K-12 schools [4]. The common assumption in the US has been that students need a certain amount of knowledge about Computer Science before advancing to Artificial Intelligence.

2.4 Professional Organizations

The Association for Computing Machinery (ACM), the largest international organization of computing professionals, including many educators and students as members, has been at the forefront of addressing the problem of insufficient computer education by the essential first step of documenting that there is a problem and creating frameworks for addressing it [18]. The Institute of Electrical and Electronics Engineers (IEEE), in its K-12 Education Position Statement [48], mentions computing in the first sentence: *... and particularly with programs and initiatives that seek to infuse engineering and computer science concepts into K-12 education curriculum (sic!) and learning experiences.* With women lagging far behind in computing education, it is heartening to see that they are increasingly taken their educational fates into their own hands, by founding powerful interest groups. Chief among those in America is the Anita Borg Institute [5]. The Grace Hopper Celebration (GHC) is an annual conference that is attended by a large number of technologically trained or interested women. It has grown to a size of 20,000 attendees. In 2020, due to the COVID pandemic, GHC was held virtually and registration reached 30,000. The attendees are overwhelmingly female (over 90% [23]). GHC promotes the education and career success of women in computing. The extensive programs at GHC conferences span rigorous scientific and technical advancement reports, usually by female leaders in academia, computing businesses or IT companies, mentoring sessions, career guidance, interview preparation, on-site interviews, peer-to-peer programs, and social events.

NCWIT, the annual National Conference on Women and Information Technology [21] runs a plethora of programs and provides large volumes of resources to guide educators and companies on how to create a welcoming environment for women that will lead to more productivity for all. NCWIT provides small grants at all levels of the educational food chain, e.g., Extension Services grants to universities with large undergraduate enrollments. The NCWIT conference is smaller than the GHC Celebration, allowing for a more "intimate" feel of the lectures and workshops. Many activities involve round-table audience participation. A small, but especially attractive, program for encouraging women at the college level to succeed in computing is BRAID (Building, Recruiting and Inclusion for Diversity) which will be discussed in Section 3.1.

2.5 IT Companies

Many Silicon Valley companies have been at the forefront of addressing the issue of a deficient pipeline of women and minority students. For example, Google has organized multi-institutional events for enticing women to join research programs and pursue advanced degrees in computing [10]. Software companies are aware that they are dependent on a high percentage of non-citizen employees. Many of these rise to leadership positions. For example, Google's CEO Sundar Pichai was born in Chennai, India [28]. However, access to immigrant labor has become increasingly more difficult with immigration rules being made ever more restrictive, and changes to these regulations are frequently unpredictable. A substantial increase in female employees could help software companies avoid workforce shortages, while also scoring points for "good corporate behavior," by creating jobs for American citizens.

3 INCREASING FEMALE DIVERSITY IN COMPUTING IN A COLLEGE

NJIT is a public technology university in Newark, NJ. It has a high degree of "first in their family" college students and scores well on educating minorities. Unfortunately, the same cannot be said about the percentage of women in undergraduate programs. About 50% of NJIT students are in the Newark College of Engineering (NCE), and another 25% in the Ying Wu College of Computing (Figure 2). All degree programs in these two colleges are traditionally undersubscribed by women. The remaining quarter of NJIT students are enrolled in programs such as physics, chemistry, mathematics, statistics, and in joint programs with a neighboring institution (the Newark campus of Rutgers University), such as history, biology, and theater. None of these degree programs has as much female participation as, for example, a school of nursing. Unfortunately, NJIT does not have a nursing school. The NJIT Honors College cuts across the five other colleges (see blue box at the bottom of Figure 2 and does not have its own dedicated faculty.

Since 2014, the Computer Science Department at NJIT has been active in improving this gender imbalance by organizing programs and activities specifically for helping and encouraging undergraduate female students in its degree programs and reaching out to middle and high schools for recruitment.

3.1 BRAID

In 2014, at the Snowbird Conference for Computer Science Chairs and Deans, Maria Klawe, a famed educator and the current president of Harvey Mudd College, founded BRAID (Building, Recruiting and Inclusion for Diversity) while presenting her past work for Women in Computing [15]. In an apparently unrehearsed appeal, she invited "the first 10 institutions interested" to join into a special program facilitating the design of women-friendly CS intro courses and taking female students to the Grace Hopper Celebrations. BRAID was given a formal framework and extended from ten to 15 core institutions. The Computer Science Department at NJIT was a co-founding member of this group of 15 universities.

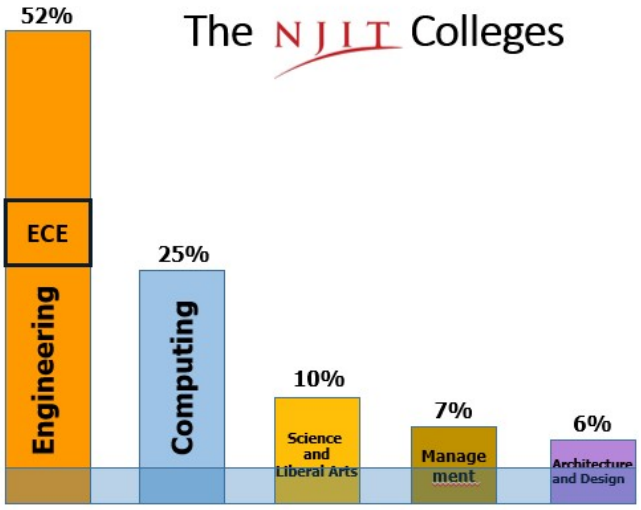

Figure 2: Relative sizes of Colleges at NJIT: 75% of the students are in traditionally male-oriented programs

The 15 department chairs promised to work on three out of four BRAID commitments, quoted below from [7]:

- Modify introductory CS courses to make them more appealing and less intimidating to underrepresented students.
- Lead outreach programs for high school teachers and students to build a diverse pipeline of students.
- Build confidence and community among underrepresented students.
- Develop and/or promote joint majors in areas like CS and biology that are attractive to underrepresented students.

BRAID provided seed funding that was raised from Silicon Valley companies through the Anita Borg Institute. Since 2020, the management of BRAID has been migrated to the Anita Borg Institute itself [7]. BRAID was originally established for a period of three years, but with additional support from companies and NSF, it has been extended until now, into the seventh year. Due to COVID-19, the financial future and prolonged existence of BRAID is not assured. An especially important feature of BRAID is the rigorous scientific evaluation of its activities. The evaluation studies have been performed by the Momentum Team at UCLA [20]. The results of extensive annual scientific analyses of the BRAID impacts at the 15 participating universities show the changing trends [52][53]. Figure 3 shows summary statistics for all 15 universities from the most recent BRAID report [33].

As part of BRAID, NJIT has run several programs targeting improvements for female students in the Computer Science and technology fields. These include, among others: *Student Clubs*: We founded undergraduate and graduate Women in Computing Society (WiCS and G-WiCS) student clubs to provide students with safe spaces and social environments. Outside of NJIT, G-WiCS exists as a chapter of the ACM-W, the Women students' organization of ACM. We currently have 35 female students as members in these clubs.

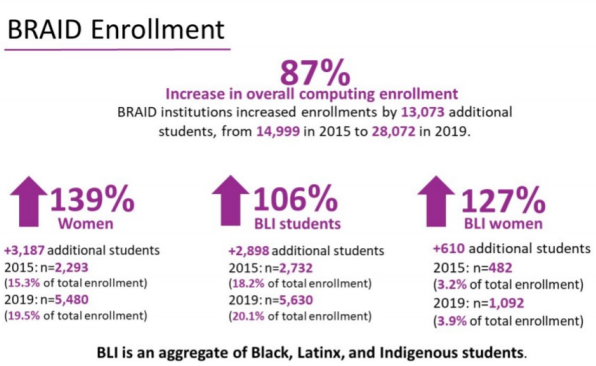

Figure 3: BRAID key numbers [33]

Guest Speakers: We invited guest speakers to allow female students to listen to and ask questions of female role-models with high visibility, including Ruthe Farmer (CS4All), Judith Spitz (Cornell Tech), Jeannette Wing (Director of the Data Science Institute at Columbia University), Leigh Ann DeLyser (CS4All), Joi Troutman (Google), Stephanie Rodriguez, Jaime Payton, Colleen Lewis, etc. Colleen Lewis is a well-known leader in the field who (Zoom-) talked at NJIT about micro-aggression, using breakout rooms and sample situations with a set of "playing cards" of "csteachingtips" that she had developed with NSF support. Jamie Payton presented a talk about "how to give back when advancing in your career." Jamie is well known for many initiatives, especially the 53-college STARS program, which has enrolled over 2500 college students. Stephanie Rodriguez was Vice President at the Anita Borg Institute at the time of her presentation at NJIT, and at the same time BRAID coordinator.

IT Company Visits: WiCS club officers organized visits of groups of female students to IT companies in New York City (especially Facebook and Google), supported by BRAID funding.

Outreach Mentoring: The members of the G-WiCS student club organized an outreach and mentoring program to high schools and middle schools in Newark and the surrounding area. They presented to students, male and female, their views of the IT and CS subjects and the employment prospects. The mentors "demonstrated" the ubiquity of computing in daily lives such as emphasizing the fact that every cell phone, every microwave oven, every train, every car, every airplane and even many humble traffic lights contain high-powered computers. In the study of outreach programs it is commonly said that "if you can't see it, you can't be it." By letting minority and female high school students see successful female Computer Science graduates, the message "you can be it" is given in an effective, yet subtle way.

Conference Participation: To enable female students to participate in and learn from technical and social conferences, we have supported groups of 15 to 20 female students (and some faculty members) each year since 2015 to attend the Grace Hopper Celebration/Conference, with all expenses paid. In 2020, with GHC being virtual (vGHC), BRAID funds enabled the remote attendance of 50 students at no cost to them.

Figure 4: Training of Newark high school students by female MS Student volunteers

Female College Student Mentoring: WiCS officers and members have organized several mentoring programs for other female NJIT students, one of which was entirely executed by a group of female undergraduate students who had been inspired by their trips to GHC.

Training for Coding: WiCS members ran "Girls Who Code" programs for local children in libraries in Newark and West Orange, as well as served as presenters of invited training sessions in local schools (Figure 4), e.g., at the American History High School in Newark, NJ.

3.2 GirlHacks

In Fall 2019 and Fall 2020 the leadership of WiCS ran GirlHacks hackathon events. The hackathons were organized by female undergraduate students for undergraduate students (male and female, but with primary advertising to females), and executed with minimal faculty help. The team members did their own fund raising from local companies and at the 2019 event received so many donated "swag" items, such as tumblers and t-shirts, that unclaimed items were sold to NJIT students after the hackathon. The money was donated to a local women's shelter. We have the intention to continue Girlhacks as an annual event.

3.3 Sisters Helping Sisters

In the past, we have received anecdotal evidence that students are reluctant to search out their professors and even their (student) TAs to get extra help. We speculate that one contributing factor has been that students are afraid to "ask stupid questions." Furthermore, they might believe that the negative impressions made by a bad question could bias the professor when the time comes to give grades. A formal investigation of these assumptions has been left for future work. However, we went ahead and created a Sisters Helping Sisters program for CS 100, the first computing course, which is teaching Python and general Computer Science. The idea of Sisters Helping Sisters is to provide help with Python programming by a graduate student who (1) is in no way involved in the teaching and grading

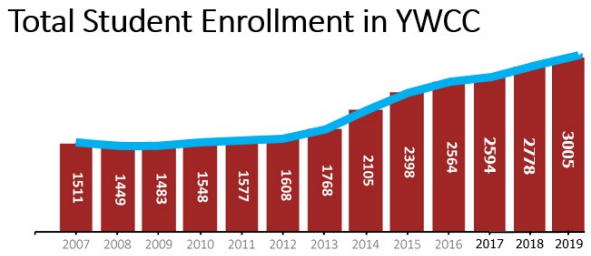

Figure 5: Total enrollment at the Ying Wu College of Computing (YWCC)

of the class the students are taking and (2) who is a female student, creating an additional feeling of comfort and mutual understanding. The program is ongoing and has been extended to the "second Computer Science course," in which principles of Computer Science and the Java programming language are taught. Parenthetically we note that there is no objective basis for the students' fear of affecting their grades by asking "naïve" questions, because the evaluation of their work is highly objective across about 30 sections of CS 100. Students take common exams, and the cohort (Fall 2020) consisted of over 800 students and ten instructors who do not know each other's students.

4 EVALUATIONS AND IMPACTS

The above initiatives in inclusive computing programs have implications for the enrollment of female students, have impacted the university administrators, faculty, and high school training, as well as facilitated obtaining related grants.

4.1 Implications for Enrollment

Efforts of evaluation of our supportive and recruiting programs have been hindered and delayed by COVID and by privacy concerns. For example, we have never collected the names of high school students in our outreach programs, which makes it difficult to determine how many students that participated in these programs decided to join NJIT. Furthermore, the outreach program is specifically designed to convince students to enter any computer science college program. We inform the students that we are from NJIT and that there is a strong Computer Science program available, but this is not a recruitment initiative into NJIT only. Preparations for an evaluation of our mentoring programs with focus group interviews are under way. Observing the success of our recruitment programs by looking at the "raw percentages" of women in computing has been made difficult by the fact that enrollments in computing overall have grown. Female enrollment at NJIT has increased, but the percentage is "drowned out" by the concurrent increase in male students (Figure 5). Thus, absolute numbers of female students have increased, but percentages have fluctuated close to the national average of 18%.

No claim is made that the described programs are unique. Similar activities happen at other colleges and are reported on and supported by organizations such as NCWIT [34]. We do claim, however, that the starting conditions at NJIT are especially challenging, with its heavy enrollment of students in traditionally "male" curricula

(see 2) and that no support programs for women in computing existed at NJIT before the Computer Science Department joined ("cofounded") BRAID. Thus, fairly modest startup funds from BRAID ($30,000 per year, two thirds of which were expended on travel to GHC and NCWIT) made a significant difference and allowed us to initiate many activities that were novel for CS at NJIT. They also helped us increase awareness of the diversity issues among the faculty of the college, as well as engendering further related research grants.

4.2 Impact on University Sponsorship for Diversity Representation

In 2018 and 2019, NJIT sponsored a booth at the Grace Hopper Celebration. This was paid for with university funds and shows a commitment of NJIT concerning the importance of being visible in the world of female computing professionals. In 2019 four NJIT/BRAID alumnae attended Grace Hopper as emissaries from major computing companies (e.g., ADP) to recruit new employees among the attending students.

4.3 Impact on Faculty Awareness Training for Diversity

We have instituted training sessions at the beginning of each semester, taught by a paid outside expert or by a local faculty member, instructing Teaching Assistants of CS 100 about issues in diversity, such as "implicit bias," "growth mindset," and "stereotype threat." Many TAs at NJIT are themselves foreign students. Some of those are from countries that have not yet made female empowerment a goal worthy of pursuing. Thus, these concepts are almost universally unknown to new TAs. Teaching Assistants are also reassured that making their classes friendlier and fairer will benefit male and female students alike.

4.4 Impact on Training of HS Teachers

Since 2016, with support of NJIT's Provost, we have held a special summer session of CS 100, the first Computer Science course, teaching coding in the Python language, every year. This session was open to New Jersey high school teachers, free of tuition, and free of student fees. This program was attended by six or more teachers every summer, and by NJIT freshmen students, listening to the same lectures and taking the same exams as our first year students. High school teachers were trained not only in coding, but also asked to spread the message that "Computing is for everyone" to their high school students, and to encourage them to overcome the misconception that female students are not apt for computing fields. Historically speaking, in the early days of computing, men (engineers) built and operated the computer hardware, and the development of software was relegated as a secondary task to women [46].

4.5 Impact on Related Grants and Activities

NJIT Computer Science is a member of NCWIT, and members of our faculty and staff have attended NCWIT annual meetings. NJIT received an Extension Services grant from the NCWIT/Academic Alliance in 2019.

An NSF grant was awarded to support outreach to middle school students in Newark, with a high percentage of minority students from economically disadvantage families. In this program, students are exposed to simple program development, webpage design and programming of quadcopter drones. This program is run in cooperation with the Urban League of Essex County. While this activity is not exclusively targeted at female students, classes are mixed and it supports the goal of reaching out to female students already at the middle school level.

5 RECOMMENDATIONS FOR US STATE AND FEDERAL GOVERNMENTS

In Section 3, we have reported on a selection of activities that were designed to bring in more female students (outreach to middle and high schools), to keep them engaged (Women in Computing Society, GirlHacks, etc.), to keep them motivated (guest speakers, GHC attendance), and to help them succeed in the difficult first year (Sisters Helping Sisters). However, we cannot convince female students who have decided in middle school that "computing is not for me" to change their minds. Furthermore, because some students enter the CS program without any coding experience, while others have already taken an Advanced Placement test in Computing (AP-CS), the former are often intimidated by the latter in the classroom. To overcome these barriers, it would be helpful to introduce computing courses universally at the middle school level. Unfortunately there is a shortage of qualified and certified Computer Science teachers for middle and high schools.

The biggest concerns that we have encountered when reviewing K-12 computing education frameworks in the US and a few other countries (Section 2.3) is that different states have different curricula for the students and different rules for certifying Computer Science teachers. In addition, these rules are based on old paradigms that have not been designed for a completely new subject "coming out of nowhere" and becoming enormously important to the economy, society, and even national security in a very few decades.

Geographic variations in teacher certification rules inhibit mobility. A teacher from one state cannot cross the boundary to a neighboring state to work there, without getting re-certified. Even if there would be an oversupply of Computer Science high school teachers in one state, the certification rules are a major disincentive to relocate to school districts where the teachers are needed. This issue might affect rural schools disproportionately. Furthermore, even if a teacher from another state could legally teach, she still has to acquaint herself with the curriculum and expectations at the new school district, which might be different from her previous place of employment.

As a solution to this issue, we propose that the Federal Government should endorse a standard for certification of Computer Science middle and high school teachers, and reference curricula for grades 5 to 12. While it cannot force the states to adopt these standards, Washington has levers. To provide an illustrative example, in the early 1970s, Congress withheld federal funding from States that did not enact a maximum speed limit of 55 mph [27]. While this is a heavy-handed approach, which might be tied up in the courts, the Federal Government could make adoption of a standardized certification process and a compliant curriculum the

conditions for federal funding of education programs (Section 2.2) in the states. This would encourage state governments to quickly adopt the new certification rules and reference curricula. Given the leadership of Asian nations in mathematics education, which is highly correlated to computational thinking (Section 2.3), and the low ranking of US students (38), it is in the national interest to implement such programs, which should override traditional concerns about state versus federal powers.

As to the state governments themselves, the best recommendation is to create a fast and flexible process for certifying computing teachers, ideally in coordination with neighboring states. The traditional route of 18 year olds entering the teacher education system and coming out with a CS teaching degree is too slow to deal with the current lack of qualified instructors. One option that is often mentioned in educational circles is to create a shortcut for already certified teachers, especially math and science teachers, to provide them with training in computing (starting with instruction along the lines of our NJIT summer course for high school teachers; Section 3.5) and to grant them the additional CS certification quickly, in a process in which they can continue to work as full time teachers.

We would like to propose an alternative. NJIT and other similar institutions are graduating many foreign MS in CS students who are in the United States on a student visa. As long as the economy is good, those foreign graduates have no problems with finding jobs, including at "blue chip companies" such as Google and Facebook, who are willing to do the costly and time consuming work of sponsoring the new employees for work visas. However, not every CS graduate wants to work in the high pressure environment of a company such as Amazon. When the economy contracts or the visa rules are made more stringent, companies become reluctant to sponsor foreign students. Whether foreign students, even those who are in supportive companies, can stay in the country depends to some degree on the H1B lottery and on federal caps on the numbers of visas issued .

Institutions of higher education are already exempt from federal H1B caps. Institutions which offer higher education beyond secondary level are eligible to be regarded as a cap-exempt employer [42]. It should be relatively easy to extend this legal exemption to K-12 schools, or at least to high schools. Easing the visa rules for teachers would be one way of coaxing MS in CS graduates into high schools to teach computing. The other obstacle for MS in CS graduates (domestic and foreign) is obtaining the teacher certification. We propose a shortcut to certification that let's MS graduates in Computer Science take the required courses in pedagogy, while already teaching at a full starting salary in an apprentice mode, under the close supervision of an experienced (preferably math) teacher. Pedagogy courses would be taken concurrently in distance learning mode or in evening classes. This approach of prioritizing Computer Science proficiency over pedagogical preparation is the reverse of the currently popular idea of educating already certified math and science teachers in computing. With this approach, and with the foreign computing graduates of many universities looking for jobs, the shortage of qualified K-12 Computer Science instructors could be overcome much faster than under the current system.

6 CONCLUSIONS

Unique situations need to be addressed by unique solutions. Never in educational history was a new curricular subject created "out of thin air" like Computer Science was. Never before was there a new educational subject of such immense economic, strategic, military and social importance. The goal of wide-spread computer literacy mirrors the goal of universal literacy. Professional organizations, companies, and universities have made great efforts to increase the number of women who can be professionals in computing jobs, and we are proudly a part of this. However, the feedstock is missing. There are not enough young women interested in signing up for computing degree programs in colleges. All evidence indicates that this is an issue that has to be addressed at latest in middle schools. This is inhibited by a shortage of qualified and certified Computer Science teachers. We recommend to the Federal Government to endorse reference curricula and to use funding mechanisms to encourage states to adopt them. Similarly, teacher certification rules for Computer Science should be unified across the country. This would increase mobility of the teaching workforce, and qualified teachers could easily move to school districts where there is demand for their qualifications.

Creating an easy onramp for foreign MS degree holders that have been educated in the US and are staying in the country on student visas, to entice them into the K-12 teaching profession, would also bear fruit quickly. This would require a fairly benign change to current visa rules, and a well thought-out alternative method of certifying teachers in high demand areas, chief of them Computer Science.

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