16. The Computer Science Challenge

Equitable Broadening Participation, Policy, and the Responsibility of Prestige

FAY COBB PAYTON, MATTHEW HOAGLAND, AND ALEXA BUSCH

Abstract: Motivated by prior research of 2 public schools centrally located near venerable universities and in an area with a high need for computer science (CS) workforce skills, we conjectured what role higher education needed to play in broadening participation, not just within the university system, but at all levels of education. To address this issue, we sought to use a number of data sources related to high school participation along with college public rankings and research funding levels. Inconsistencies in data sources resulted in our inquiry into equity in CS participation. We offer that equitable broadening participation is multidimensional and is informed by educational prestige, resources, and social capital. Equitable broadening participation can shift the current CS education discourse from one of equality and a single measure of success to a framework focused on *inclusion* of underrepresented groups and *policy* shaping primary education through higher education pathways.

Introduction

We examined the computer science (CS) enrollment among high school students in two Wake County, North Carolina, public schools. In earlier works, Abu-El-Haija, Payton, and Hoagland (n. d.) and Abu-El-Haija and Payton (2019) found that underrepresented minority students who met the academic requirements to participate were not participating in CS courses. We sought to find data with the goal of modeling the relationship between the perceptions of prestige of higher education CS departments and broadening participation at the high school level. Inconsistencies in the data-collection process left our team with limited ability to model that relationship using statistical techniques. Table 1 shows the data we initially attempted to use and the associated data integrity issues.

Data Desired	Source
Advanced placement CS exam participation	The 10th Annual AP Report to the Nation, 2014
Rankings of university/college CS programs	U.S. News & World Report (2014), Business Insider, Niche
CS and University federal research funding	National Science Foundation
CS participation at the collegiate level	Integrated Postsecondary Education Data System (IPEDS)

Table 1. Data desired for initial analysis modeling and data source.

As a gauge for participation at the high school level, we used AP CS exam participation (College Board, 2014) and attempted to find relationships within the National Center for Education Statistics' IPEDS data regarding participation. The IPEDS data set, however, showed a lack of reporting and/or missing data in many instances. We used federal funding as a gauge of educational prestige, as well as the U.S. *News and World Report*'s ranking publications. These rankings face criticisms concerning the difficulties in making meaningful comparisons because the methodology is not constant from year to year(Tierney, 2013). Likewise, there is also difficulty comparing academic programs when there is variability with how CS programs are ranked. Reputation and academic quality, often associated with prestige, as "measured" in the rankings also remain questionable.

Given these data inconsistencies, a policy approach to the question becomes even more critical as primary and higher education continues to be challenged by broadening participation (BP) in CS efforts. In this paper, we will do the following: provide a context for broadening participation, examine three important elements to BP, discuss considerations from a case study, and ultimately provide a holistic framework for equitable BP.

Broadening Participation

There is a significant labor shortage in STEM fields, specifically those that call for computing and computational skills (Bayer Corporation, 2014; Xue & Larson, 2015). This shortage indicates the importance of broadening participation in CS, but equitable models are critical if the field will move beyond its capacity-focused approaches to broadening participation while addressing accessibility to a diverse talent pool.

Equitable BP should start in K–12 education as research has shown the number of students taking AP computer science exams is predictive of the number of students intending to major in the subject while in college. In fact, students who take an AP CS course are 4.5 times more likely to major in computer science than those who do not (Kaczmarczyk & Dopplick, 2014). This could partially be attributed to the fact that acquiring CS skills necessary to enter the field are hierarchical in nature and require students to begin preparing in middle school (Frye, Maher, Seehorn, & Morris, 2017; National Academies of Sciences, Engineering, and Medicine, 2019). Therefore, expanding and coordinating access to CS among all levels of education is viewed as imperative to expanding the field while broadening participation (National Academies of Sciences, Engineering, and Medicine, 2019).

Coordination across levels of education needs to be accompanied by the collection of data on equity indicators. This would better enable the field to quantify equity levels in schools and develop policies aimed at BP (National Academies of Sciences, Engineering, and Medicine, 2019). The combination of social capital and resources, two elements of BP discussed later in this article, can create preparatory privilege in the classroom and can limit access to those at the margins (Margolis, Estrella, Goode, Holme, & Nao, 2008). While teacher training can help dampen preparatory privilege (Robinson, Jahanian, & Reich, 2018), measuring equity indicators will allow the field to be more deliberate when implementing policies. The rest of this article will define areas that promote equitable BP and offer deliberations on CS-specific policies.

Defining Important Elements to Broadening Participation

There are three important elements to broadening participation: *educational prestige*, *resources*, and *social capital*. We adopt a multilayered definition of educational prestige, in which there is a "prestige hierarchy" with prestigious universities, prestige-seeking universities, and reputation-seeking universities (Brewer, Gates, & Goldman, 2004; Wong, 2018). Universities that have educational prestige are those that are highly selective, have significant monetary resources (endowment, research grants, etc.), and seek to leverage those resources to maintain that status (Zemsky, 2003. However, we reference resources relative to family support, teacher availability and quality, and access to postsecondary schools. We specifically will discuss equity issues surrounding resources as defined by The National Academies of Sciences, Engineering, and Medicine (2019) and why resources cannot just be provided to a community. Finally, social capital can be defined as "features of a social organization such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefit. Social capital enhances the benefits of investment in physical and human capital" (Putnam, 1993, para. 4).

Educational Prestige

Since U.S. *News & World Report* (USNWR) published its first ranking of U.S. colleges in 1987, many students have relied on national rankings to help them decide where to apply and attend college (Griffith & Rask, 2007; McDonough, Antonio, Walpole, & Perez, 1998). These rankings cultivate perceptions of higher education institutions but have some side effects that negatively influence BP and help consolidate existing prestige perceptions.

When thinking of BP in an equitable way, there is a goal to widen the net to underrepresented minority groups (URMs), and when it comes to educational prestige, these ranking systems are a limiting factor to URMs. Research suggests that in ranking publications, such as USNWR, there is an implicit racial bias. For instance, historically black colleges and universities (HBCUs) are not considered in the main ranking publication, but have a separate report (Richards, Awokoya, Bridges, & Clark, 2018. Moreover, students from higher socioeconomic status backgrounds are most heavily influenced by these rankings, which create a homogenous applicant pool (McDonough et al., 1998).

The ranking institutions, such as USNWR, consider a variety of factors when ranking a university or a specific program: selectivity, university library system, research grants, and research produced (Griffith & Rask, 2007; Morphew & Swanson, 2011. Among the common factors listed, there are few social impact or community variables to advance a university's ranking. In the 2020 USNWR ranking methodology, the *only* social marker is the success of students who are on Pell Grants (Morse, Brooks, & Mason, 2019. With the resources and the accompanying prestige, higher education programs acquire an inherent institutional responsibility to significantly contribute to broadening participation. To this end, computer science is not exempt from this deliberation. Because of the numerous challenges faced by CS, we offer that this institutional responsibility is especially true for highly ranked CS programs.

Resources

Earlier we looked at how university resources can play a role in their rankings and perceptions by students. Here, we consider resources of students, secondary schools, families, and how they influence BP. Measuring disparities in resources is an important element to equity in education (National Academies of Sciences, Engineering, and Medicine, 2019), but the design of resources is imperative to how they influence the student educational experience.

Resources need to be designed for the communities that they intend to help (Reich & Ito, 2017). Open-source technologies are an example of resources that reduce some economic barriers to access. There are disparities in how they benefit certain student groups as open-source technologies disproportionately benefit those privileged (Reich & Ito, 2017). The health-equity model from the Robert Wood Johnson Foundation mirrors the result from Reich and Ito, in which resources can be provided uniformly across groups, addressing equality or everyone with the same resources, but not equity or the ability to have the same outcome, as seen in Figure 1 ("Visualizing Health Equity: One Size Does Not Fit All" infographic, 2017).

Thus, we pose the following question: How should the resources and ingenuity of higher education institutions serve in broadening participation, and what factors are salient to equitable BP? We note that resources are not limited to monetary resources, but include the institutional expertise.

Figure 1. Visualizing health equity: One size does not fit all. Infographic © 2017 Robert Wood Johnson Foundation. May be reproduced with attribution.

Social Capital

Economic development, financial capital, and social activities are positively linked to social capital (Engbers & Rubin, 2018; Putnam, 1993. Networks, norms, and trust are built from the development of social capital in a community. Social capital can be directly linked to building trust and confidence in the classroom, and it translates directly to student success (Allan & Persson, 2018). Education and its attainment can be positively influenced by the development of social capital, thus requiring a change in education to go beyond curricula, and to the promotion of social capital and networks, which we provide an example of later in this paper (Paarlberg, Hoyman, & McCall, 2017).

An Example From North Carolina

In a prior study, we analyzed data from two Wake County, North Carolina, public magnet high schools with the goal of following students through the CS pipeline. The data set contained student course enrollment for academic years 2009–2010 to 2015–2016. The data were structured to allow for post hoc evaluation of students in the CS pipeline. With the new structure the data were used to find participation rates for each demographic group (Asian, Black, White, and Hispanic male and female students). Asian male students in School A participated in CS at the highest rate across all levels. Figure 2 shows projected CS enrollment based on our statistical model, the actual number of students who participated in CS courses, and the difference between these two. There are several groups that did not participate up to potential baselines—namely, White female, Asian female, and Hispanic female students in the college preparatory magnet school (School A). This leads to the question of equitable broadening participation, in which we have groups of students who are capable of CS and who, based on the enrollment data, academically qualify but choose not to or were faced with some barrier(s). This projection was not done for School B, as the offering of CS courses was inconsistent and the participation was minimal in some years.

Demographic	Introductory CS			Higher CS			AP CS		
	Projected	Actual	Difference	Projected	Actual	Difference	Projected	Actual	Difference
White Female	21.15	3	-18.15	15.29	2	-13.29	19.67	2	-17.67
White Male	23.4	36.71	13.31	16.85	22.99	6.14	21.76	24.13	2.38
Black Female	2.7	2.8	0.1	1.94	0	-1.94	2.51	0	-2.52
Black Male	2.25	5.88	3.63	1.62	0.74	-0.88	2.09	0	-2.09
Asian Female	30.6	19.5	-11.1	21.6	7.8	-13.8	27.9	9.76	-18.14
Asian Male	39.6	41.13	1.53	28.8	29.79	0.99	37.2	39	1.8
Hispanic Female	5.85	4.35	-1.5	4.21	0	-4.21	5.44	0	-5.44
Hispanic Male	5.4	14.85	9.45	3.89	2.97	-0.92	5.02	0	-5.02

Figure 2. Projected students in CS versus actual from School A.

Equity Discussion

Equitable solutions to BP in CS should be about more than capacity in the field. Along these lines CS is not exempt from larger ecosystems impacting education attainment and equity, that is, implicit bias and stereotypes may affect the likelihood of academic success (Carnevale, Fasules, Quinn, & Campbell, 2019). Math has been shown to be a predictor of student readiness, serves as a gateway into computer science, and needs to be included when discussing equity in CS (Abu-El-Haija et al., n.d.). Policies that promote math to all students are an obvious area to focus on when considering equitable BP, but we can extend beyond math. Students who have shown interest in the arts/STEAM (STEM + ARTS) have also shown interest in CS, but those students often confront the dichotomy of pathway selection rather than content integration (Abu-El-Haija & Payton, 2019; Sax et al., 2017). To speak to the magnitude of mathematics in the educational equity discourse and per the Georgetown University Center on Education and Workforce, Carnevale et al. (2019) recently concluded: "Across racial and ethnic groups, top-half math scores increase the odds that a low-SES tenth grader will become a high-SES young adult" (p. 35).

There are also considerations surrounding educational prestige, resources, and social capital. As we have shown, the *education prestige* consists of the college/university ranking, its social impact, and current resources, such as grant funding and endowments. The *resources* are salient to the individual student and capture socioeconomic status and how an intervention (or program) serves and impacts the community. Last, *social capital* depicts trust and conference, role of community, and economic development as enabling to the student and educational outcomes. Equitable BP solutions require multidimensional approaches (Figure 3) that must consider these elements. The intersection of these three factors can better foster equity in the broadening participation discourse and implementation. This is not a single-lens approach. Rather, holistic thinking and approaches are warranted in an effort of inclusive participation to assess impact.

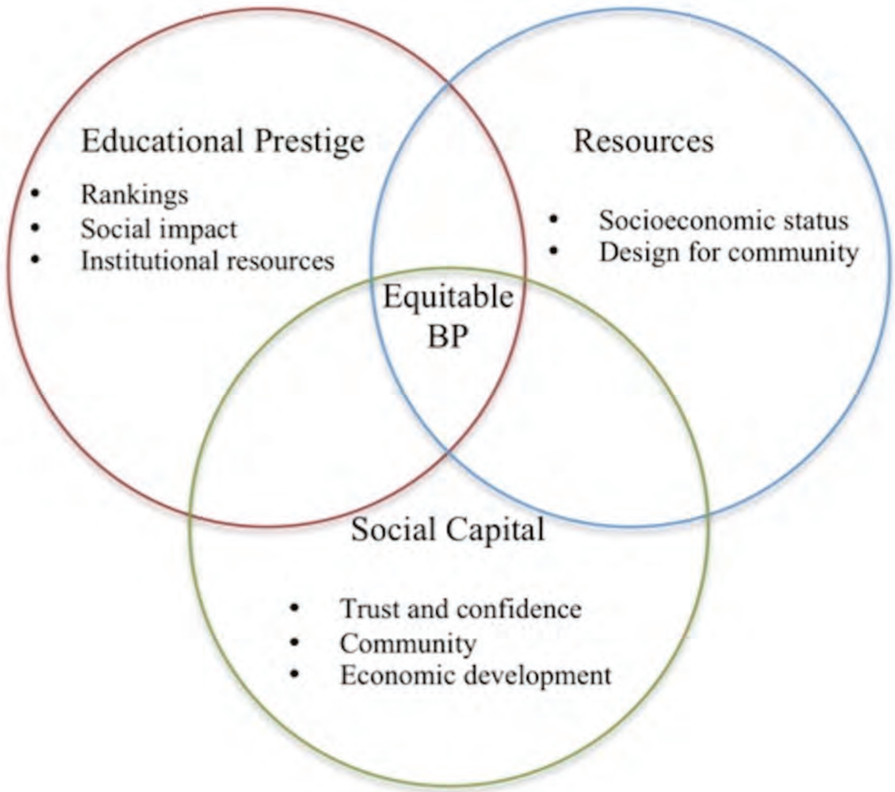

Figure 3. Multidimensionality of broadening participation.

The elements that promote BP can also have adverse side effects that also need to be considered when approaching policies, such as preparatory privilege, which is when a student enters the classroom having previous experience with the concepts (Robinson et al., 2018). Preparatory privilege can be found at the intersection of resources and social capital and limit access to the CS field (Margolis et al., 2008). Resources are also protective in education to White students compared to Black students (Carnevale et al., 2019). Similar findings are likely for others underrepresented in CS participation in K–12, namely Latinx, Native Americans, persons with disabilities, rural students, females, and others.

It is critical to understand the three elements of equitable broadening participation beyond the intersectional identities noted above. We contend that any equity solution or approach will have a clear focus on the systems of oppression that cause the inequities to begin with. This ultimately provides direction to data analyses interpretation and can illuminate reasons for disparate student outcomes.

Conclusion

There is a need for expansion in STEM fields where there is a labor shortage (Bayer Corporation, 2014; Xue & Larson, 2015). Expansion can take several directions, one of which is recruiting more students into these fields and/or a systematic approach to reaching groups that are not currently represented in the field. It has been shown in an analysis of North Carolina public high schools that in secondary education CS misses out on a significant amount of talent. CS skills are largely hierarchical, and by missing students in primary education pathways, the diversity of the field is further limited in higher education matriculation. Thus, equitable broadening participation is needed to grow the discipline with parity. While social capital promotion and trust building in the classrooms and community are also needed, highly resourced higher education institutions can better use what some consider as prestige to leverage their influence and take more collective action in their BP strategies.

References

Abu-El-Haija, L., & Payton, F. C. (2019, February). *Computer science enrollment in magnet high schools: Issues of curricula, equity, and pathways.* Paper presented at RESPECT conference, Minneapolis, MN.

Abu-El-Haija, L., Payton, F. C., & Hoagland, M. (n.d.). *Pathways, participation and policy: Considerations for high school computer science enrollment.* Manuscript submitted for publication.

Allan, J., & Persson, E. (2018). Social capital and trust for inclusion in school and society. *Education Citizenship and Social Justice*, 1–11. https://doi.org/10.1177/1746197918801001

Bayer Corporation. (2014). The Bayer facts of science education XVI: US STEM workforce shortage—myth or reality? Fortune 1000 talent recruiters on the debate. *Journal of Science Education and Technology*, 23(5), 617–623.

Brewer, D. J., Gates, S. M., & Goldman, C. A. (2004). In pursuit of prestige: Strategy and competition in U.S. higher education. Santa Monica, CA: RAND.

Carnevale, A. P., Fasules, M. L., Quinn, M. C., & Campbell, K. P. (2019). *Born to win, schooled to lose: Why equally talented students don't get equal chances to be all they can be.* Washington, DC: Georgetown University Center on Education and the Workforce, McCourt School of Public Policy.

College Board. (2014). *The 10th annual AP report to the nation.* Retrieved from https://research.collegeboard.org/programs/ap/data/nation/2014

Engbers, T. A., & Rubin, B. M. (2018). Theory to practice: Policy recommendations for fostering economic development through social capital. *Public Administration Review*, 78(4), 567–578.

Frye, D., Maher, M., Seehorn, D., & Morris, S. (2017). CS4NC Summit 2017: Lessons learned in developing a coordinated statewide CS for All initiative. In *SIGCSE '18 Proceedings of the 49th ACM Technical Symposium on Computer Science Education* (pp. 1041–1042). Baltimore, MD: ACM.

Griffith, A., & Rask, K. (2007). The Influence of the US News and World Report collegiate rankings on the matriculation decision of high-ability students: 1995–2004. *Economics of Education Review*, *26*(2), 244–255.

Kaczmarczyk, L., & Dopplick, R. (2014). ACM report: Preparing students for computing workforce needs in the U.S. SIGCSE *Bulletin*, 46, 8.

Margolis, J., Estrella, R., Goode, J., Holme, J. J., & Nao, K. (2008). *Stuck in the shallow end: Education, race, and computing.* Cambridge, MA: The MIT Press.

McDonough, P. M., Antonio, L. A., Walpole, M., & Perez, L. X. (1998, October). College rankings: Democratized college knowledge for whom? *Research in Higher Education*, 39(5), 513–537.

Morphew, C. C., & Swanson, C. (2011). On the efficacy of raising your university's rankings. In J. C. Shin, R. K. Toutkoushian, & U. Teichler (Eds.), *University rankings. The changing academy–The changing academic profession in international comparative perspective* (Vol. 3, pp. 185–199). Seoul, South Korea: Springer, Dordrecht.

Morse, R., Brooks, E., & Mason, M. (2019, September 8). How U.S. News calculated the 2020 best colleges rankings. Retrieved from https://www.usnews.com/education/best-colleges/articles/how-us-news-calculated-the-rankings

National Academies of Sciences, Engineering, and Medicine. (2019). *Monitoring educational equity.* Washington, DC: The National Academies Press.

National Center for Education Statistics. *Integrated postsecondary education data system.* https://nces.ed.gov/ipeds/

National Science Foundation. https://www.nsf.gov/

Paarlberg, L. E., Hoyman, M., & McCall, J. (2017, August 28). Heterogeneity, income inequality, and social capital: A new perspective. *Social Science Quarterly*, 99(2), 699–710.

Putnam, R. (1993). The prosperous community: Social capital and public life. *The American Prospect*, 13. Retrieved from https://prospect.org/article/prosperous-community-social-capital-and-public-life

Reich, J., & Ito, M. (2017). *From good intentions to real outcomes: Equity by design in learning technologies.* Irvine, CA: Digital Media and Learning Research Hub.

Richards, D. A., Awokoya, J. T., Bridges, B. K., & Clark, C. (2018). One size does not fit all: A critical race theory perspective on college rankings. *The Review of Higher Education*, 42(1), 269–312.

Robert Wood Johnson Foundation. (2017). Visualizing health equity: One size does not fit all [Infographic]. Princeton, NJ.

Robinson, K., Jahanian, K., & Reich, J. (2018). Using online practice spaces to investigate challenges in enacting principles of equitable computer science teaching. In *SIGCSE '18 Proceedings of the 49th ACM Technical Symposium on Computer Science Education* (pp. 882–887). Baltimore, MD: ACM.

Sax, L., Kathleen, L., Jacobs, J., Kanny, M., Lim, G., Monje-Paulson, L., & Zimmerman, H. (2017). Anatomy of an enduring gender gap: The evolution of women's participation in computer science. *The Journal of Higher Education*, 88(2) 258–293.

Tierney, J. (2013, September 10). Your annual reminder to ignore the *U.S. News & World Report* college rankings: The list's real purpose is to "exacerbate the status anxiety" of prospective students and parents. *The Atlantic.* Retrieved from https://www.theatlantic.com/education/archive/2013/09/your-annual-reminder-to-ignore-the-em-us-news-world-report-em-college-rankings/279103/

U.S. News & World Report. (2014). Best colleges 2014: Top 10 national universities. Retrieved from https://www.usnews.com/education/best-colleges/slideshows/best-colleges-2014-top-10-national-universities/6

Wong, A. (2018, September 11). At private colleges, student pay for prestige. *The Atlantic.* Retrieved from https://www.theatlantic.com/education/archive/2018/09/america-private-college-tuition/569812/

Xue, Y., & Larson, R. (2015, May). *Monthly labor review.* Bureau of Labor Statistics. Retrieved from https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm

Zemsky, R. (2003). In pursuit of prestige: Strategy and competition in U.S. higher education. *The Journal of Higher Education*, 74(4), 474–476.

Acknowledgments

This research is funded by NSF Grant number CNS 1740141.