Looking back to move forward: Measuring K-12 Computer Science Education Requires an Equity-Explicit Perspective

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***Abstract*—It is critical that we understand the systemic issues that have led to the historic marginalization of students in K-12 computer science education (CSEd) to the degree that we can design equity-centered policy and actions. Investments in CSEd have expanded rapidly through local interventions and state policy, however the data required to understand the impact of this expansion continues to lag or be insufficient. This paper takes a retrospective look at efforts to measure broadening participation in computing (BPC) approaches and identifies equity-explicit strategies moving forward, Over the last two decades, efforts to measure BPC have evolved from ad-hoc grassroots methods to more systematic and sustainable approaches. BPC, often interpreted as access and participation, does not address the inherent inequality embedded in the K-12 American public education system. Current data efforts often focus on the student, obscuring the systems and practices that contribute to inequities in CSEd. This paper concludes with recommendations for prioritizing data utilization and the development of holistic data systems that are woven into strategic plans that lead to systems change and equitable student access, participation and experiences in computing.**

Keywords—Broadening Participation in Computing, Computing Education, Measurement, CS for All

I. Introduction

Broadening participation in computing (BPC) began as a call to significantly increase the number of people receiving post-secondary degrees in computing, and necessarily centers demographic diversity, including students who have been excluded from CS (which the National Science Foundation (NSF) specifies as including women, African Americans, Hispanics, American Indians, Alaska Natives, Native Hawaiians, Native Pacific Islanders, and persons with disabilities) [1]). Local, state, and national BPC efforts, which may include practices, programs and/or policies, have since grown to address the systemic barriers that limit the capacity of schools to equitably reach all students, increasing diversity in the classroom and among degree holders in higher education [2], [3]. Measuring the impact of these efforts is a challenging but critical element of any action taken in service of BPC. CSEd researchers and advocates must continue to push towards measurement strategies and data systems that inform systems change while focusing on the current needs of students. We must look critically at the data that we rely on as we develop policy and strategic plans, appreciate the foundational data efforts, and continue the iterative process of creating a system for data collection and utilization that embraces equity. Understanding the effectiveness of current data in defining disparities will help stakeholders consider if the data and data-informed interventions are serving marginalized students, while also informing future investments in policy, research and practice.

This position paper argues that the efforts to measure BPC must account for an understanding of the systemic and historic marginalization of students broadly, if we are to understand CSEd specifically. Researchers must recognize that current systems of measurement have helped define a new path in education but remain inadequate for framing the whole picture of why CSEd remains exclusionary. Finally, any system for data collection and dissemination needs to be directly tied to sustainable and equity-explicit policy and program design, otherwise we risk perpetuating the marginalization of students by race, class, gender, and ability. Through a historical overview of measurement efforts, and consideration of the lessons learned, we call on researchers to consider new systems for measuring BPC impact that are as unique as the students we are centering in this movement. Our data work constantly leaves more questions and considerations for equity; we are iterating within our own projects, and intend for readers to think critically about the data currently being utilized across CSEd research, policy, and advocacy initiatives.

A. Rise of CS as a core discipline

Fifteen years ago, when the NSF began funding the Broadening Participation in Computing Alliances, efforts to expand CSEd were sparse [4]. Most efforts to increase CSEd, outside of the Alliances, involved individuals taking advantage of opportunities to promote CS, prepare teachers and develop curricular materials as the need arose. Measurement efforts were disconnected and ad-hoc [5]. Over the last five years there have been substantial changes in the CSEd landscape leading to more strategic and large-scale planning. In January 2016, President Obama announced the CS for All initiative to be included in the 2017 federal budget, greatly elevating the prominence of the work being done by many of the professional development (PD) programs funded through the NSF and others involved in CSEd [6]. The development of the K-12 Framework for Computer Science [7] with over 50 writers and advisors and hundreds of reviewers, led to broad support and the adoption or adaptation of the framework for use in many states. Organizations such as the Computer Science Teachers Association (CSTA), the Expanding Computing Education Pathways (ECEP) Alliance, Code.org, and CSforALL have begun working on a national scale supporting teachers, curriculum development, policy reform, and districts. Finally, there has been an increased

presence of industry with organizations such as Infosys, Microsoft, Google and Apple supporting CSEd initiatives which come with individual evaluation and measurement approaches. Understanding the extent to which these BPC efforts are effective has gained increasing importance.

B. BPC movement

Broadening participation alone is not equity; it cannot overcome the practice of student tracking or biased and exclusionary school policy and procedures. However, BPC work can expose these often hidden yet pervasive barriers having the potential to drive action towards equity. Affecting the CSEd landscape with a broadening participation lens requires many approaches from individual teachers practicing culturally relevant student recruitment and pedagogy in their classroom environment to national efforts promoting inclusion of underrepresented populations [8]. BPC has matured as an advocacy movement and gained momentum across the nation. Because of commitments from the NSF, industry, and national CSEd advocacy organizations, BPC is a core tenet of the movement to define K-16 CSEd and ensure that every student has not only access, but is recruited and retained in computing classes [9], [10].

C. Measuring BPC efforts

Measurement is an important tool for setting goals and monitoring progress against those goals [11],[12]. CSEd advocacy and implementation efforts are producing an abundance of data which is often uncoordinated or too superficial to understand the implications of BPC interventions. Measuring the effectiveness of these efforts with an equity lens is critical for understanding what works and for whom [13]. This knowledge helps inform and ultimately, track BPC practices, programs and policies to ensure they are serving students historically marginalized in CSEd [11], [12].

Measuring the impact of BPC efforts is evolving at both a national level and for individual initiatives. In a country where educational decisions are highly localized the policies, definitions and data collection systems vary widely making it difficult to understand the CSEd landscape. Large-scale efforts to get a national sense of participation in CSEd have been challenged by uncoordinated data systems. Some efforts have used self-reported data including trying to understand where CS is offered [14], [15], which is challenged by sampling and understanding what is meant by "computer science." In 2018, the National Survey of Science and Mathematics Education (NSSME+), a representative sample of teachers, added computer science to the disciplines explored to better understand the pedagogy and content instruction as well as the contextual factors that affect student outcomes, however it is correlational, not causal [16]. Each of these efforts have advanced our knowledge of BPC efforts including the challenges of measuring BPC progress. Measuring individual CSEd initiatives can be easier than measuring wide-scale change [17]. These efforts typically include external evaluators who are specifically funded to determine the extent to which projects are meeting their goals. There have been some efforts to support and coordinate these highly-localized efforts including program-wide evaluations in the case of the BPC-Alliances [18] and the development of BPC common measures that emerged out of the BPC-A community [5]. Evaluators themselves have organized to share instruments and best practices through efforts such as the Evaluation Wrecking Crew [19], repositories [20] and CSEdResearch.org, a repository of research articles, a library of instruments and an emerging portal for shared data [21].

It is within this web of rapidly expanding BPC initiatives and evaluation efforts that the authors have engaged in BPC measurement efforts. Most recently, we've been involved with several national CS-measurement initiatives including the ECEP Alliance [22], co-authors of the State of CS report which detailed the policy efforts in each state [23], and the first author has been the PI on a grant convening the CSforAll: Research Practice Partnerships community [24]. From our standpoint the strengths and weaknesses of these measurement efforts should serve as a call to action to develop measurement systems that fully capture the unique story of BPC, while providing data to direct ongoing work. Our work is both exploratory as we try to understand the feasibility of large-scale data collection, and focused on trying to capture outcomes in an effort to understand the impact of BPC efforts at a specific moment in time.

II. Trajectory of Experience and Lessons Learned

A series of localized, state-level CSEd interventions and national work with BPC Alliances, increased the need to define better evaluation frameworks and metrics, ensuring close alignment with equity-focused work in CSEd. Observing projects struggling with the same measurement issues, and rarely hitting the target on a system that captured the richness of BPC work, the authors continue to strive for a common metrics system. While the CAPE framework [3] addresses a portion of this need, it must sit within a more robust process to ensure a full picture of BPC impact. The authors come to this perspective as evaluators and practitioners in the CSEd space respectively giving us the unique ability to observe the rise and expansion of BPC measurement efforts.

1) Understanding the potential in available data: In 2008 SageFox Consulting Group, an evaluation firm, began its first large-scale CS evaluation in support of a state-wide CS network designed to pilot and organize a set of activities in support of broadening participation in institutions of higher education. In addition to intervention-specific assessment activities such as surveys after events or training, we sought to use a range of indicators to track the participation in computing at each of the 15 participating institutions. These indicators included data points such as enrollment and graduation data tracked through the National Center for Education Statistics' Integrated Postsecondary Education Data System.

The evaluation utilized institutional data to disaggregate participation and performance in CS correlating it with other factors such as specific course taking and/or participation in supplemental instruction. For many of the participating partners, this was the first time they thought critically about BPC in their own institution. The data motivated additional inquiry and change. One challenge, however, was it was unclear what data were available, thus a comprehensive request was considered burdensome for the institutional records professionals, particularly at community colleges. If measurement efforts are to be developed and sustained, they cannot be experienced as

burdensome, or they will not be utilized at the risk of losing access to the data necessary to measure BPC.

In the K-12 system, AP data has been one of the most reliable indicators of participation in computing available because it is standardized across states. AP CS-A data was a reliable measure and showed the disparities for who was participating in AP computing [25] which helped mobilize support for the AP Computer Science Principles (AP CSP) exam. However, it was not until the 2016 launch of the AP CSP exam participation in CS-related AP exams increased significantly and diversified who was participating, though it is not necessarily useful for predicting future CS participation [26], [27]. It is also limited to schools that have a computing education program and an AP program, which may not represent diverse and historically marginalized student populations. Often there are also high academic and financial barriers to participating in AP exams. AP data is reliable, but is typically available nearly a year after students participate which makes it difficult to capture the impact of particular BPC efforts. Finally, the AP exam does not capture the infusion of CS across the K-12 pathway generally.

2) The complications of looking at impacts across programs: Beginning in 2008 NSF worked with AAAS to bring together evaluators from each of the 15 Alliances to explore common metrics for measuring the collective impact of the alliances. The group ultimately created a set of parameters for 1) demonstrating increased participation from underrepresented groups 2) tracking the building of organizational capacity for sustaining participation and 3) documenting the impact of the alliances beyond the immediate activities. NSF contracted with Educational Development Center (EDC) and Westat to conduct an evaluation of the BPC-A program using the framework that had been developed by evaluators through the AAAS process. Ultimately, the effort proved too challenging to collect meaningful impact data across Alliances because (among other reasons) 1) Alliances don't operate as a coordinated system, 2) data definitions were not consistent and 3) most Alliances did not examine whether their strategies led to differential outcomes for particular populations across the K–20 academic pipeline [28, p.43]. The process uncovered the need for higher quality impact data, raising the bar for Alliances and projects to capture metrics that demonstrated BPC.

ECEP faced similar data challenges as arose to those identified in the BPC-A evaluation effort. While each state works within a collective impact project with a common goal to increase the number and diversity of students in K-16 computing, a common metrics system across participants has proven difficult to develop. Finding a way to measure overall impact was a complicated activity because each participant's context was too unique. The data structures, the definition of CSEd, the policies and the state capacity to share data all needed to be taken into account. By year 6 of the project we began making progress on a common measurement system (discussed further below) via multiple working groups at national summits, listening sessions with state teams, and early attempts at creating a common system. Complex data work requires communication with a broad-based group of stakeholders to account for the interaction of disparate CSEd programs and the broader social and educational environment.

3) Building Teacher Capacity: Sustainable data collection in an increasingly complex CS education ecosystem: In 2012 NSF began to fund teacher-professional development (PD) programs in an effort to "to have rigorous, academic computing courses taught in 10,000 high schools by 10,000 well-prepared teachers" [29]. In an effort to answer "how many teachers have been trained?" each project was asked to provide a teacher count. Though most projects were able to account for the numbers of teachers who participated in PD, there were diminishing returns when asked to report teacher demographics, the schools in which they taught and the students reached. Ultimately it became clear that this self-report mechanism was a) not sustainable and b) increasingly unreliable as projects evolved, overlapped, or sunset and as additional teacher PD investments were being made through NSF and private funding and c) offered no insight into the quality of PD or subsequent student instruction. Finally, the effort placed the measurement burden on accounting for individual teachers, rather than examining the impact of the program on building systemic capacity for offering CS and the subsequent impact on students. The Evaluator Working Group (EWG) concluded the project with recommendations to create a more sustainable data collection model which we continue to endorse. Specifically, a) establish clear reporting requirements upon the issue of a request for proposals to minimize the confusion, burden, and resistance to participation and b) consider utilizing state-level data as it allows researchers and practitioners to understand the current landscape and track progress over time, and is reliable and sustainable.

4) State data systems are valuable and cumbersome: By 2017 it was clear that the need for systematic, sustainable data collection was a pressing concern for many in the BPC community and across STEM education research. Measurement was also emerging as a key challenge and was the theme of the ECEP annual gathering in early 2018. The EWG partnered with ECEP to explore the feasibility of using statewide data systems to assess BPC progress. We created the Ease and Value survey to assess how easy it would be for states to access data through their departments of education and how valuable that data would be to measure BPC progress. ECEP spent the meeting assessing the measurement potential of a) what is being taught (defining CS) b) who is teaching CS c) who is taking CS and d) how well students do in their CS courses with probes for the ease and value of collecting data at the state, district and school levels with special attention to how well data could be disaggregated. Results showed that states found each of the data domains to be valuable, particularly student related measures at the state level [30]. The data, however, would be difficult to collect, particularly defining what was being taught and who was teaching. Collecting data was more difficult at the school or individual level than at the state or district level.

5) Feasibility of a cross-state measurement system: In 2019, six states participated in the New England Common Metrics Project, led by ECEP and SageFox which included the development of a shared framework for monitoring progress in K-16 CSEd policy and advocacy. This project convened teams from state education agencies, local education agencies, higher education, and nonprofits. Each team was asked to identify leaders who were involved in some level of data gathering, data analysis, data reporting, and data utilization. This project formed with the explicit understanding that the national landscape of CSEd requires examining data that often sits siloed within state systems. Alone, these state-level data are inconsistent in their ability to define CS courses and document participation. Working towards common definitions and structures that can be applied across states and remaining useful in a local context was an important goal. Through a five-phase process, state teams agreed to a "common enough" framework that allowed for agreement on data and definitions, formed working groups to examine the School Courses for the Exchange of Data (SCED) codes and are universally applicable, examined CS pathways, and focused on dissemination and data visualization. The CAPE framework provided an additional overlay to the effort, and states agreed to utilize the same definition of CS[1]. Ultimately uniform reporting from each state validated the opportunity presented by a shared metrics system while also uncovering systems that may remain locally dependent but can be adapted across states.

III. Moving Forward

The recent Priorities for the 117th Congress and 2021-2025 Administration, released in partnership by the American Statistical Association, The American Research Association, the Council of Professional Associations on Federal Statistics, and the Population Association of America, identifies that one of the most highly utilized data sources in education, the National Center for Education Statistics (NECS) is in need of an overhaul. When national, trusted data sources are struggling with issues of resourcing and capacity, it is no wonder that CSEd efforts are also grappling with similar challenges. For BPC data to be meaningful it needs to have a longitudinal perspective so that we can understand the impact of these investments over time. Until we have stronger methods, and data available, CSEd researchers will need to continue to stitch together good enough data, which hardly seems like it will support a mission as large as BPC. Having the ability to match or develop culturally relevant recruitment strategies, pedagogy and curriculum will allow us to strategically invest in CSEd that is impactful. Data must inform policies that benefit all students, while prioritizing historically marginalized students. Understanding the unique aspects of not only individual projects and their measurement needs, but also individual states and their data systems will allow state CS advocates, and CSEd researchers greater access to the best data available. Through our participation in multiple iterations of data collection efforts, it is the "common enough" model we developed in the New England Common Metrics Project, combined with the CAPE Framework that is showing the greatest potential for impact on data efforts across states. Working with state data leaders from departments of education, researchers, and K-12 teachers, 'common enough' as a baseline allowed us to get messy with data. Suddenly, when experts were allowed to explore datasets with fewer assumptions and traditional labels, we surfaced real commonalities. Gaps in data collection that were not observed in prior efforts emerged, allowing state teams to consider modifications to all levels of data reporting. Those of us working with data in the CS for All movement must recognize that data can serve both as an obstacle, as well as a solution for change. Data must be able to help researchers and advocates disrupt systems that are disrupting CSEd pathways for historically marginalized students. Just as the field of CS has been building capacity, so has our collective ability to measure how well we're achieving the BPC goals of CS for All. Most importantly, foundational data efforts have allowed CSEd to shift from expanding access and increasing participation to better understanding how CS considers educational justice and equity in parallel with the capacity that needs to be built within education systems. As we continue to refine our measurement of BPC efforts, we need to recognize how far we have come while continuing to push for greater data transparency, new systems of measurement, while spotlighting systems, not student access, interest, or ability as the obstacle to BPC As the BPC community builds the capacity to measure access and participation to CS at a high level, and capacity and experience of students more locally, we need to tie the measurement of local practices ,programs and policy together. Doing this will allow us to tie the outcomes for students to the specific interventions and direct finite resources (financial and human) to have an impact in proportion to our BPC values.

In theory data allows us to identify marginalized students, laying bare the inequities occurring in CSEd. To some extent the data also allows researchers to see systems-level gaps that create these inequities as well as maintain them. However, the current data seen as the 'gold standard' (e.g. NECS, AP), is still not framing the story of historic marginalization of students in CSEd in totality. We must demand more of our systems, create stronger systems and recognize the current inefficiencies if we are able to fully tell the story of the impact of BPC and define the direction for the next iterations of the work. The education research community needs to collectively ask if what we are doing in regard to data collection and utilization is working. Are we moving the needle closer to CS for All, or supporting status quo efforts?

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[1]The definition used for this project was: Computer science courses involve the study of computers and algorithmic process, including their principles, hardware and software designs, applications, and their impact on society. They often include computer programming or coding as a tool to create things like software, applications, … [etc.] Computer science does not include using a computer to do everyday things, such as word processing, spreadsheets… [etc.]

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