Three Metrics of Success for High School CSforAll Initiatives: Demographic Patterns from 2003 to 2019 on Advanced Placement Computer Science Exams

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ABSTRACT

There has been an expansion of computer science (CS) in high schools in the USA. In most cases, initiatives seeking to expand high school CS offerings are not focused simply on increasing the number of students enrolled, but are focused on broadening participation in computing (BPC). Ideally we can *evaluate* and *replicate* effective BPC, or CSforAll, initiatives at the high school level. However, analyses of CS expansion frequently focus on the national landscape, despite the decentralized nature of public education in the USA. State-level analyses, when present, often do not take into account the demographics of high school students in the state, which are also changing over time. We propose three metrics for evaluating the impact of state-level initiatives to broaden participation in computing at the high school level. These metrics and our data set can be helpful benchmarks for evaluating high school CSforAll initiatives.

KEYWORDS

Advanced Placement; CS for All; computer science pipeline

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1 INTRODUCTION

Computer science (CS) in the United States of America (USA) has historically seen over-representation of White[1] and Asian[2] males but not of Black[3], Hispanic[4], Native American[5], and Pacific Islander[6] individuals or women [3, 11, 23]. Despite growth within computing departments across the USA [4], the proportion of women and students from underrepresented groups participating in undergraduate institutions does not mirror their proportion within the population of the USA [5].

Increasing diversity in CS helps build a more equitable society and creates more opportunities for traditionally excluded groups, such as underrepresented minorities[7] (URMs) and women. Additionally, diverse teams solve problems more efficiently and creatively [22].

Despite proactive measures to broaden participation in computing at the secondary level (e.g. [9, 17, 18]), it is unclear how much progress has been made. We use the demographics of student examinees participating in a College Board's Advanced Placement (AP) CS exams as a proxy for measuring the demographics of high school CS students within each state. Given that demographics vary between states, we compare participation of each group within AP CS examinees to the group's proportion within high school students in the state with data from the Common Core of Data (CCD) in the Department of Education.

Consistent with previous analyses [15], we found that in 2018 Asian and White students tended to be overrepresented on the AP CS exams in most states across the US. Native American, Hispanic, Black, Pacific Islander, and female students were all underrepresented on the AP CS exams for a majority of states.

The primary contribution of this paper is the following three metrics for evaluating the impact of state-level initiatives to broaden participation in computing at the high school level. These metrics and our data set[8], compiled from the College Board and Department of Education, can provide benchmarks for future work evaluating high school CSforAll initiatives.

1.1 Single-Year Metric: Representation

A group's *representation* on an AP exam is the percent of AP examinees who are from that group, divided by the percentage of high

[1]We refer to individuals who identified as "White" or "Caucasian" on demographic surveys as "White."

[2]We refer to individuals who identified as "Asian," "Chinese," "Vietnamese," "Japanese," "Indian," "Burmese," or any other Asian subgroup as "Asian." Unfortunately, none of our data sources distinguished among Asian subgroups. We recognize that this broad label ignores the different socioeconomic backgrounds, educational attainments, and histories of different Asian subgroups, and ignoring these can serve to reinforce the model minority stereotype [27].

[3]We refer to individuals who identified as "Black/African American" on demographic surveys as "Black."

[4]We refer to individuals who identified as "Hispanic/Latino" on demographic surveys as either "Hispanic" or "Latinx."

[5]We refer to individuals who identified as "American Indian/Alaska Native" on demographic surveys as "Native American."

[6]We refer to individuals who identified as "Native Hawaiian/Pacific Islander" on demographic surveys as "Pacific Islander."

[7]According to the NSF, "underrepresented minorities" includes individuals who identify as Black, Hispanic, Native American, or Pacific Islander [19].

[8]The full data set is available at http://tinyurl.com/LimLewis2020

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school students from that group. For an AP CS representation of 1, the percentage of students of a racial group among the state's AP CS examinees equals the percentage of students of a racial group among the state's high school student population. We refer to a group as underrepresented if their representation was less than 1 and overrepresented if their representation was greater than 1.

1.2 Single-Year Metric: Relative Representation

A group's *relative AP CS representation* is the ratio of their AP CS representation and their representation on all other AP exams. A value of 1 indicates equivalent AP CS and AP representation among students from a demographic group in that state. Cases where a group's AP CS representation is higher than their AP representation may indicate successful initiatives to broaden participation in computing.

1.3 Multi-Year Metric: Representation Trend

A group's AP CS *representation trend* is the average change in their AP CS representation in one year. This is calculated by finding a line of best fit for the group's representation (i.e., percentage of examinees divided by the percentage among high school students) in a state. This line of best fit is weighted based upon the number of test takers in the state in each year. This reduces the influence of large variation in representation resulting from small sample sizes.

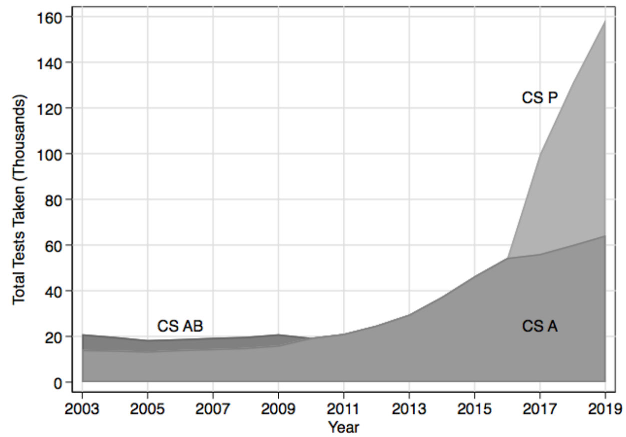
2 PREVIOUS RESEARCH

Previous research using nationwide 2014 AP CS A data revealed that the majority of AP CS A exam-takers were White or Asian [15]. Additionally, the participation of students belonging to underrepresented minorities [19] in AP CS A lagged behind participation of those groups in other exams [15]. In 2014, Black and Hispanic examinees accounted for 4.1% and 7.7% of all AP CS A examinees, respectively [15]. By contrast, 2017 national student demographics showed that the high school student population was 15.33% Black and 25.00% Latinx [16]. Furthermore, only 18.7% of the 2014 AP CS A examinees were women [15]. In 2018, just under a quarter of the AP CS examinees were female [12]. By comparison, 55% of all AP examinees in 2018 were women [2].

Figure 1 shows the explosive growth in AP CS tests taken from 2003 to 2019. This range included three different AP exams: CS A (AP CS A), CS AB (AP CS AB; available before 2010), and AP CS Principles (AP CS P; available starting in 2017). Between 2003 and 2012, there were under 25 thousand AP CS exams taken each year. The next four years (2013-2016) saw an average yearly increase of more than 7 thousand test takers. The last three years (2017-2019), since AP CS P was launched, saw an average yearly increase of nearly 35 thousand test takers.

There are a number of initiatives that aim to change current patterns of underrepresentation. For example, the National Center for Women and Information Technology (NCWIT) has organized the Aspirations in Computing award to recognize and encourage high school women interested in computing [17]. In the USA, the Obama administration created CS for All [9, 18], which aims to expand CS learning opportunities to students in K-12 institutions. Similarly, the Expanding Computing Education Pathways (ECEP) Alliance works with states to increase students' access to CS at the state level

Figure 1: Total CS tests taken in thousands from 2003 to 2019



[1, 13, 21] in addition to highlighting effective teaching practices [14, 24, 26]. This NSF-funded initiative, in conjunction with other advocacy groups such as CSforAll.org and Code.org, has resulted in 34 states that have adopted K-12 CS standards [7, 8]. Given that the education system in the USA is decentralized, national patterns may not show the impact of these state-level initiatives. Ultimately, it is unclear the extent to which these initiatives have been successful broadening participation in computing, beyond their success increasing overall participation in computing.

Our research questions are:

RQ1 How do states vary in their patterns of representation within AP CS exams by gender and race?

RQ2 How do these patterns compare to patterns of representation on other AP exams in the state?

RQ3 How do states vary in the trend of their patterns of AP CS representation for Black, Hispanic, and female students?

3 DATA SOURCES AND METHODS

3.1 AP Data

We used the College Board AP exam's annual gender and race data from 2003 to 2019 for the fifty states and Washington D.C.[9] [2]. To capture the demographics of high school CS students, we combined AP CS A, AP CS AB and AP CS P data. Unfortunately, any student that takes multiple AP exams in one year will be recounted for those exams.

The College Board disaggregates data by race. Individuals self-reported race as "American Indian/Alaska Native," "Asian," "Black," "Hispanic/Latino"[10], "Native Hawaiian/Other Pacific Islander," "White,"

[9]The College Board only provides data from Washington D.C. and the 50 states. Demographics and performance data were not reported for any US Territories such as Puerto Rico.

[10]Prior to 2016, the "Hispanic/Latino" option was not included, but "Mexican American," "Other Hispanic," and "Puerto Rican" were options. For years before 2016, we combine these three options to create a subset of students intended to be comparable to the current option of "Hispanic/Latino."

Table 1: National Summary of 2018 AP CS, 2018 AP, 2017 High School Student Demographics

	2018 AP CS		2018 AP		2017 HS	
	%	N	%	N	%	N
Asian	27.07	34,468	15.05	740,825	5.20	783,990
Black	5.57	7,310	6.27	308,791	15.33	2,312,039
Hispanic	16.33	20,786	22.19	1,092,606	25.00	3,771,476
Multiracial	4.66	5,939	4.53	223,259	2.93	441,916
Native American	0.21	269	0.25	12,459	1.01	152,510
Pacific Islander	0.15	191	0.15	7,340	0.36	54,883
White	45.83	58,355	49.63	2,443,317	50.17	7,569,479
Female	28.04	36,709	55.17	2,716,142	48.86	7,370,840
Male	71.96	94,195	44.83	2,206,930	51.14	7,715,453
Total	100.0	127,318	100.0	4,923,072	100.0	15,086,293

or "Other." Individuals that selected more than one option were categorized as "Two or More Races"[11] and students that did not report their race were categorized as "No Response." Our single-year analyses (see Sections 4.1, 4.2, and 5) focus on 2018 and exclude the racial categories "No Response" (N=3,582) and "Other" (N=4).

The College Board also disaggregate data by gender, but does not have options for non-binary genders[12]. Examinees must select "Male" or "Female." There was no option such as "Decline to State," and examinees were required to respond.

3.2 Student Demographic Data

We used the US National Center for Education Statistics' Common Core of Data (CCD) gender, race, and grade level data for public and private high school[13] students in the fifty states and Washington D.C. [16]. Unlike the AP Data, racial demographics were reported for all students, that is, options of "Other" or "No Response" were not provided. All other racial categories used in the AP data set were also used in the CCD data set. Our single-year analyses of AP CS test taking in 2018 are matched with data from the 2016-2017, which was the most recent data available at the time of analysis. Our multi-year analyses begin before state-level data was available from the CCD, which began with the 2009-2010 school year. This first year of state-level CCD data was duplicated to match with the 2003 through 2009 AP CS data. We generally matched 11th grade students with the AP CS data. However, the CCD has not released 2018-2019 data. 2019 AP CS data was matched with 10th grade students from the 2017-2018 CDC data.

4 RESULTS

Table 1 shows the demographics of 2018 AP CS examinees in the USA. For comparisons, Table 1 also includes demographics for all high school students in the USA (i.e., showing representation) and demographics for all 2018 AP examinees (i.e., showing relative representation).

[11] We refer to individuals who identified as "Two or More Races" on demographic surveys as Multiracial.

[12] Gender refers to the personal identification of the individual. This can include "man," "woman," "genderqueer," or "other," and may differ from sex. Sex refers to physical and/or biological characteristics and genetics.

[13] High school students in the USA are typically 13 to 18 years old.

4.1 2018 AP CS Representation

Figure 2 shows box and whisker plots for state AP CS representations. Due to space constraints, we excluded Asian and Multiracial examinees, who participated in AP CS at higher rates than their percentage of high school students in the state. The vertical, black line denotes representations of 1, our threshold for under- and over-representation. The 25th percentiles of Asian and Multiracial representations were above 1, indicating that both groups were overrepresented in a majority of states. Meanwhile, the median of White representations was near 1, indicating that White examinees were underrepresented and overrepresented in a similar number of states. Conversely, the 75th percentiles of Black, Hispanic, Native American, Pacific Islander and female representations were below 1, indicating that these groups were underrepresented on the AP CS exams in a majority of states. AP CS representation rates in some states are primarily driven by small sample sizes, and Section 5 provides further discussion of these results.

4.2 2018 AP CS Relative Representation

Figure 4 shows states' relative AP CS representation. That is, we plotted state's AP CS representation versus their AP representation for Black, Hispanic and female students. These three groups were chosen because they are traditionally underrepresented and included over 300 examinees nationwide in 2018. We removed state data points where the number of AP CS examinees belonging to that demographic group was less than 50. The diagonal black line indicates where the representation of a group on the AP CS exam is equal to the representation of the same group on all AP exams. States above this line have higher AP CS representation than AP representation, which may be evidence of effective state-level CSforAll initiatives.

In all states, the percentage of female AP CS test takers was less than the percentage of female students among its high school student population. Female examinees were slightly overrepresented on AP exams in general but were underrepresented on AP CS exams specifically, as shown in Figure 4.

As shown in Figure 4, most states showed roughly equal participation of Black and Hispanic students on AP CS exams versus the participation of Black and Hispanic students on AP exams in general. Table 2 shows an alphabetized list of the 16 states in which

Figure 2: Box Plots for 2018 AP CS Representation within States per Demographic Group Other Than Asian and Multiracial Examinees

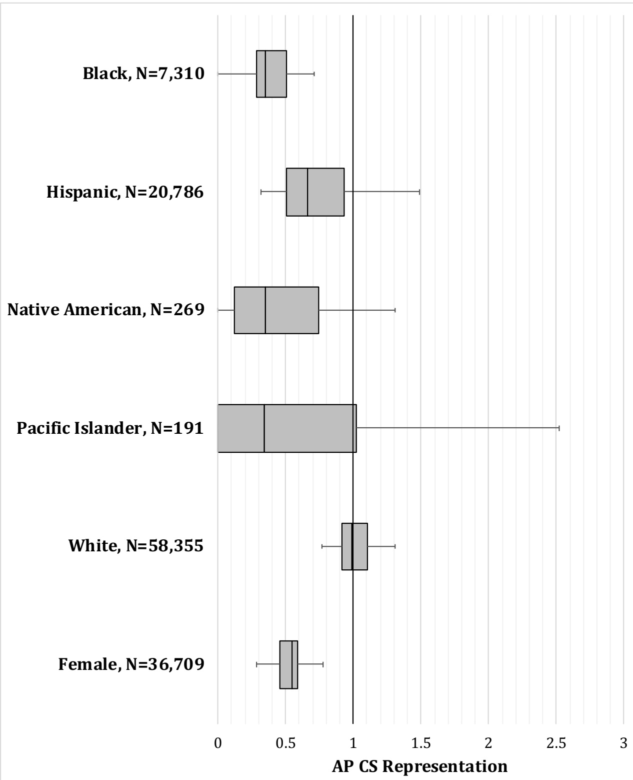
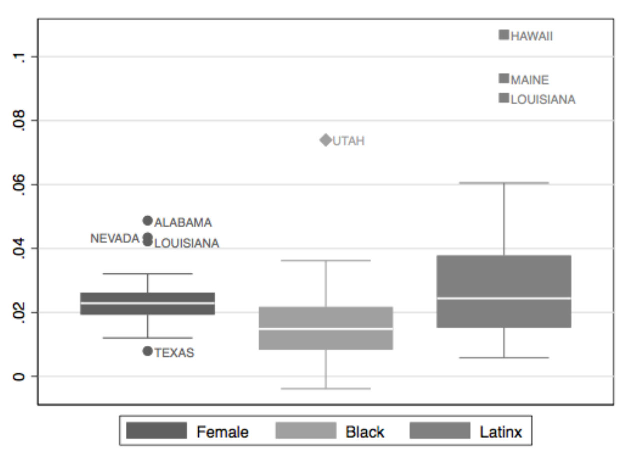


Figure 3: Box Plots for AP CS Representation Trends for states with over 2000 examinees from 2003 to 2019



either the Black or Hispanic student representation among AP CS examinees exceeds their representation among AP examinees.

Twelve states had higher representation of Black students on the AP CS exams than on AP exams overall (see Table 2)[14]. Two of these states, Florida and New York, each had approximately 1000 Black examinees, which may be partially attributed to CS initiatives in each state [10, 25].

In fourteen states, the proportion of Hispanic AP CS examinees was equal to or greater than the proportion of Hispanic students among its high school student population. Eight states had higher representation of Hispanic students on the AP CS exams than on AP exams overall (see Table 2). Hawaii and South Dakota show the greatest positive difference between the representation of Hispanic examinees on the AP CS exams and AP exams overall. However, in both cases, these results are driven by a relatively small number of AP CS test takers: 52 and 3, respectively. The next highest difference occurs in Utah, where the representation of Hispanic examinees on the AP CS exams (16.89%) exceeds Hispanic student representation within AP examinees (10.90%) and high school students in general (16.46%). However, this was driven by 62 Hispanic AP CS examinees. In Florida, the representation of Hispanic examinees on the AP CS exams (32.55%) was less than their representation on all AP exams (34.78%), but was still higher than their representation among high school students in general (31.18%). This maybe be evidence of initiatives within the state (see [6]).

4.3 2003 to 2019 AP CS Representation Trend

From 2003 to 2019, the representation of Black, Hispanic, and female students has increased (for each $p < 0.001$). Recall that the line of best fit is for *representation*, which is the percent of AP CS examinees who are from a group, divided by the percentage of high school students from that group. Therefore, the line of best fit captures the increases in participation among a group above and beyond what changes would be expected based upon changes in the demographics of the state. AP CS Representation of Hispanic students had the steepest slope (0.024), followed by female students (0.021) and Black students (O.013). That is, one year was associated with a 0.013 increase in the AP CS representation among Black students.

Figure 3 shows box and whisker plots for state *AP CS representations trends* for female, Black, and Hispanic students. Figure 3 contains the 38 states and District of Columbia with over 2000 examinees from 2003 to 2019.

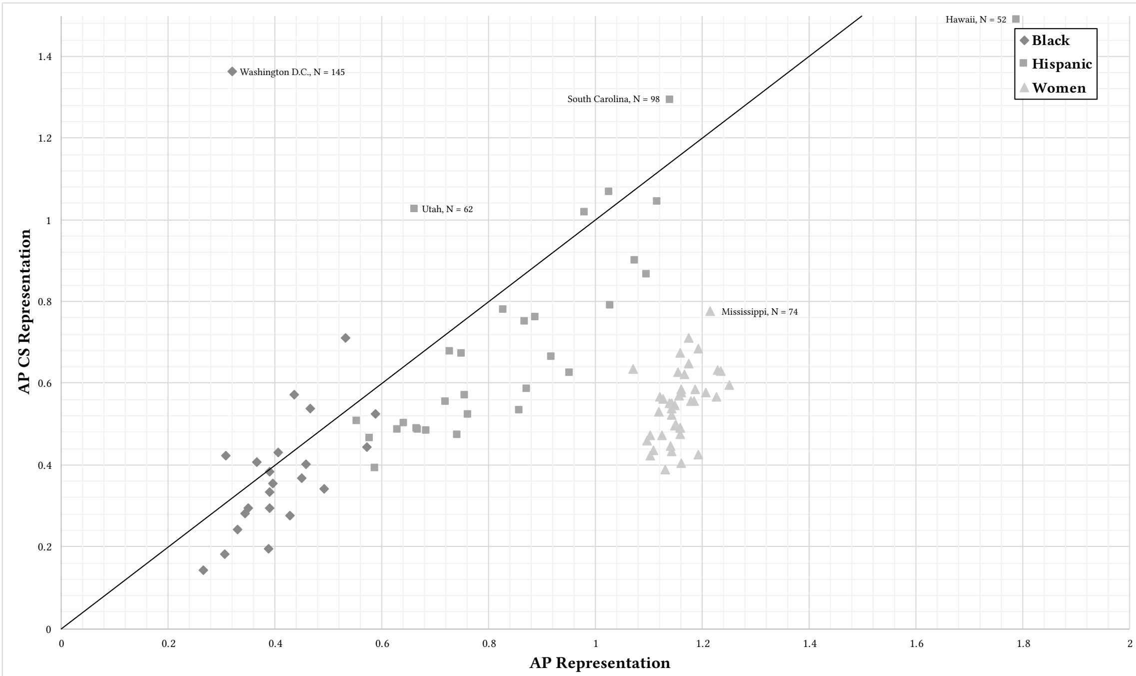
5 DETAILED 2018 PATTERNS

5.1 Asian Student AP CS Participation

Asian examinees participated in both AP and AP CS exams at higher rates than their representation among high school students. Asian students made up just 5.2% of all high school students nationwide in 2017, but accounted for 15.05% of all AP examinees and 27.07% of AP CS examinees in 2018 (see Table 1). Asian students were consistently overrepresented on the 2018 AP CS exams (N = 34,468). The AP CS representations for Asian examinees ranged from 1.03 to 16.63 (mean = 6.18; median = 5.95). In all states, the percentage of Asian AP CS test takers was equal to or greater than the percentage of Asian students among its high school student population.

[14] Only six of those states had over 100 Black AP CS examinees.

Figure 4: Scatter Plot for AP CS Representation versus AP Representation for Black, Hispanic, and Women Students



5.2 Multiracial Student AP CS Participation

Multiracial examinees participated in both AP and AP CS exams at higher rates than their representation among high school students. Multiracial students made up just 2.93% of all high school students nationwide in 2017, but accounted for 4.53% of all AP examinees and 4.66% of AP CS examinees in 2018 (see Table 1). Multiracial students were generally well-represented on the 2018 AP CS exams (N = 5,939). The representations for Multiracial examinees ranged from 0.60 to 8.26 (mean = 2.14, median = 1.63). In two states, the proportion of Multiracial AP CS examinees was less than or equal to the proportion of Multiracial students among its high school student population: Kansas and Ohio. In the remaining forty-eight states and Washington D.C., the percentage of Multiracial AP CS examinees was equal to or greater than the proportion of Multiracial students.

5.3 White Student AP CS Participation

White examinees participated in both AP and AP CS exams at slightly lower rates than their representation among high school students. White students made up 50.17% of all high school students nationwide in 2017 and accounted for 49.63% of all AP examinees and 45.83% of AP CS examinees in 2018 (see Table 1). White students were generally overrepresented on the 2018 AP CS exams (N = 58,355). The representations of White examinees ranged from 0.62 to 9.22 (mean = 1.17; median = 0.99). In twenty-four states, the percentage of White AP CS test takers was equal to or greater than the percentage of White students among its state high school population. In all states, the representation was over 0.75.

5.4 Black Student AP CS Participation

Black examinees participated in both AP and AP CS exams at much lower rates than their representation among high school students. Black students made up 15.33% of all high school students nationwide in 2017, but accounted for just 6.27% of all AP examinees and 5.57% of AP CS examinees in 2018 (see Table 1). Black students were generally underrepresented on the 2018 AP CS exams. The representations for Black examinees ranged from 0 to 2.26 (mean = 0.43; median = 0.34).

5.5 Hispanic Student AP CS Participation

Hispanic examinees participated in both AP and AP CS exams at slightly lower rates than their representation among high school students. Hispanic students made up 25.00% of all high school students nationwide in 2017 and accounted for 22.19% of all AP examinees and 16.33% AP CS examinees in 2018 (see Table 1). Hispanic students were generally underrepresented on the 2018 AP CS exams. The representations for Hispanic examinees ranged from 0.31 to 3.44 (mean = 0.82; median = 0.66).

5.6 Native American Student AP CS Participation

Native American examinees participated in both AP and AP CS exams at much lower rates than their representation among high school students. Native American students made up 1.01% of all high school students nationwide in 2017, but accounted for just 0.25% of all AP examinees and 0.21% of AP CS examinees in 2018 (see Table 1). Native American students were generally underrepresented on the 2018 AP CS exams (N = 269). The representations for Native

Table 2: Summary of AP CS, All AP, and High School Demographics of Black and Hispanic Students for Sixteen States with a Greater Percentage of Black or Hispanic AP CS Examinees Than Percentage of Black or Hispanic High School Students

	Black Examinees						Hispanic Examinees					
	AP CS		All AP		HS		AP CS		All AP		HS	
	%	N	%	N	%	N	%	N	%	N	%	N
Alaska	0.89	1	1.61	89	3.49	1346	12.50	14	9.41	504	6.69	2579
Delaware	7.53	29	10.02	1315	31.40	12720	8.57	33	8.87	1164	14.63	5926
Florida	9.67	1006	9.09	35579	22.39	189833	32.55	3385	34.78	35579	31.18	264372
Hawaii	1.32	6	0.89	140	2.00	1008	11.48	52	0.89	2163	7.70	3869
Louisiana	17.55	92	19.93	6981	43.56	87163	9.35	49	7.94	2780	5.32	10643
Massachusetts	6.52	263	4.86	5888	9.15	27023	8.20	331	10.17	12319	17.60	32447
Nevada	5.53	47	3.47	1341	6.59	14722	32.00	272	33.93	13112	41.00	57284
New Mexico	1.98	4	1.01	174	2.07	2071	40.10	81	55.36	9474	60.30	60209
New York	9.66	969	8.33	25051	17.93	146795	16.45	1649	18.37	314	24.51	200702
North Dakota	2.94	2	2.88	130	4.49	1369	1.47	1	2.95	133	4.01	1240
Ohio	6.59	177	5.90	7498	16.16	84009	4.59	125	4.48	5698	4.57	23775
South Carolina	14.35	148	10.41	5904	33.90	75689	9.51	98	8.38	4753	7.35	16420
South Dakota	0.00	0	2.72	128	2.95	1109	15.79	3	4.71	222	4.59	1725
Tennessee	12.96	162	9.90	6467	22.68	66586	8.40	105	8.09	5286	7.89	23128
Utah	1.63	6	0.73	313	1.49	2809	16.89	62	10.90	4672	16.46	31051
Wyoming	2.7	1	0.76	25	1.20	322	5.41	2	10.65	351	13.32	3587

American examinees ranged from 0 to 5.82 (mean = 0.60; median = 0.35).

5.7 Pacific Islander AP CS Participation

Pacific Islander examinees participated in both AP and AP CS exams at lower rates than their representation among high school students. Pacific Islander students made up 0.36% of all high school students nationwide in 2017, but accounted for just 0.15% of all AP and AP CS examinees in 2018 (see Table 1). Pacific Islander students were generally underrepresented on the 2018 AP CS exam (N = 191). The representations for Pacific Islander examinees ranged from 0 to 11.76 (mean = 0.88; median = 0.34).

5.8 Female Student AP CS Participation

Female examinees participated in AP exams at higher rates than their representation in high schools but participated in AP CS exams at much lower rates than their representation among high school students. Female students made up 48.86% of all high school students nationwide in 2017 and accounted for 55.17% of all AP examinees but only 28.04% of AP CS examinees in 2018 (see Table 1). The representations for female examinees ranged from 0.18 to 0.79 (mean = 0.52; median = 0.55).

6 CONCLUSION

Statistics regarding awarded bachelor's degrees in the USA [28] mirror participation rates in the 2018 AP CS exams. There may be a causal relationship if high school students who take the AP CS exams are more likely to enter college as CS majors [20] and implies that the diversity problem is not unique to the high school level. Increasing participation of underrepresented individuals in AP CS may ultimately lead to greater diversity of CS graduates. The three metrics proposed in this paper for evaluating state-level CSforAll initiatives can help evaluate and ultimately disseminate effective interventions.

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