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Practitioner Perspectives of the Impact of COVID-19 on CS Education in High Schools Serving Historically Marginalized Students (Fundamental)

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Abstract

Practitioners delivering computer science (CS) education during the COVID-19 pandemic have faced numerous challenges, including the move to online learning. Understanding the impact on students, particularly students from historically marginalized groups within the United States, requires deeper exploration. Our research question for this study was: *In what ways has the high school computer science educational ecosystem for students been impacted by COVID-19, particularly when comparing schools that have student populations with a majority of historically underrepresented students to those that do not?*

To answer this question, we used the CAPE theoretical framework to measure schools' Capacity to offer CS, student Access to CS education, student Participation in CS, and Experiences of students taking CS [1]. We developed a quantitative instrument based on the results of a qualitative inquiry, then used the instrument to collect data from CS high school practitioners located in the United States (n=185) and performed a comparative analysis of the results.

We found that the numbers of students participating in AP CS A courses, CS related as well as non-CS related extracurricular activities, and multiple extracurricular activities increased. However, schools primarily serving historically underrepresented students had significantly fewer students taking additional CS courses and fewer students participating in CS related extracurricular activities. Student learning in CS courses decreased significantly; however, engagement did not suffer. Other noncognitive factors, like students' understanding of the relevance of technology and confidence using technology, improved overall; however, student interested in taking additional CS courses was significantly lower in schools primarily serving historically underrepresented students. Last, the numbers of students taking the AP CS A and AP CS Principles exams declined overall.

1 Introduction

Despite learning disruptions being new to many, across the world more local events have significantly disrupted education (e.g., hurricanes, earthquakes, war) [2], [3]. Research into educational disruption has focused on how to rebuild the capacity to reinstate education for students, including finding resources to ensure that education can continue in some form [4]. Primary and secondary education (K-12) practitioners have been significantly impacted by the COVID-19 pandemic. Practitioners have recognized the numerous challenges to student academic achievement and growth, including the move to online learning which was novel to most of the student population in the United States.

Emerging literature has highlighted the pandemic's impact on students, particularly students from historically marginalized groups and the magnification of inequities in K-12 classrooms [5], [6], [7], [8], [9], [10], [11]. This includes impacts on schools' capacity to offer adequate professional development and other resources needed to move instruction online as well as student access to stable, supportive learning environments. This has resulted in a decrease in students' participation in the learning process and, ultimately, declining engagement and academic performance. One study [6] indicated that K-12 students could have potentially lost up to three to four months of instructional time in general, a loss that is likely exacerbated for underserved student populations [12, 10]. Early evidence [12, 13, 14, 15] also suggests that students studying STEM subject-areas may experience the greatest losses, which could be related to findings from Onyema et al. and Adnan and Anwar, who found that online learning was negatively impacted by poor access to technology and weak digital skills [17, 16].

In the U.S., the Institute of Education Sciences (IES) conducted a monthly national survey in 2021 to quantitatively understand learning opportunities offered by schools during the pandemic [18]. Early results offer enrollment trends across different groups for fourth and eighth grade student cohorts, including that Black and Hispanic students were enrolled in fully remote learning models at rates that were higher than the national average (55-60% versus the average 42-45%) and at much higher rates than their White peers (24-27%). Both fourth and eighth grade students in the Western U.S. enrolled in fully remote learning models more so than those in the Northeast, South and Midwest. With respect to school location, fourth and eighth grade students in Urban/Suburban locations were more likely to receive fully remote education, while students in Town/Rural locations were more likely to be learning in person. The findings indicate that these differences are greater for Black students, Hispanic students, and economically disadvantaged students learning English.

With respect to CS education, fewer than 20% of teachers reported suspending CS education during the pandemic, though teachers at schools serving low-income, rural and Black, Latinx, and Indigenous students were more likely to suspend these classes [19]. Simultaneously, however, virtual learning was observed as a major challenge to instruction, and teachers at schools serving rural, low-income, and Black, Latinx, and Indigenous students were more likely to face these challenges. Higher education faculty also reported that it took more of their time to teach online and student learning was hampered by students' family obligations, poor internet access, and mental health issues [20]. Unsurprising, there is evidence that those who work within the CS discipline were significantly more prepared and confident to teach online [21].

Our research question for this study was: *In what ways has the high school computer science (CS)*

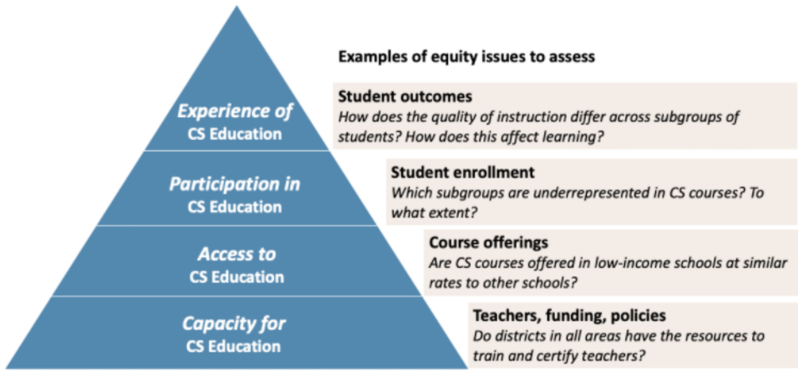

Figure 1: The CAPE framework defines relationships between and the importance of the component of the framework (capacity, access, participation and experience) [1].

educational ecosystem for students been impacted by COVID-19, particularly when comparing schools that have student populations with a majority of historically underrepresented students to those that do not?

Our study is important to stakeholders and funding bodies that are interested in increasing the capacity of equitable CS high school education and want to understand how the pandemic impacted students learning CS as well as efforts to build capacity for CS education in the U.S. Those in other countries may also find our research and findings helpful in understanding the potential impact of the pandemic on similarly marginalized students within their countries.

2 Methodology

To explore this question, we adapted the CAPE theoretical framework, a systems-level framework that disaggregates the education process across four key components [1]. This equity-focused framework can be used to evaluate equity in CS education at multiple levels of educational systems [1]. The systems-level approach (seen in Figure 1) requires those using it to focus on student learning experiences and outcomes and how they are situated within a larger initiative and policy level environment. This illustrates how the framework components are interrelated and rely upon previous components.

The four key components of CAPE and their definitions include:

- Capacity: A district's or school's ability to offer equity-focused policies, resources, and funding - essentially, the extent to which school leadership, staff, and teachers are effectively prepared to implement equity-focused CS courses, advising, and extracurricular activities.
- Access: Students' equitable access to CS courses, advising, and extracurricular activities - essentially, whether or not students are offered equitably to student subgroups across and within schools.
- Participation: Students' awareness of and enrollment in CS courses, extracurricular activities, and AP computer science exams–essentially, the extent to which all students are equally aware of the courses, extracurricular activities, and AP exams offered by their school, and the extent to which they enroll in them in equal proportions.

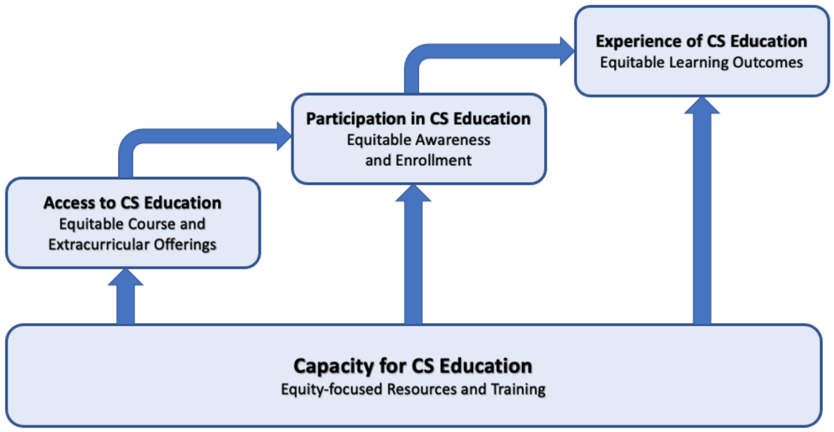

Figure 2: The CAPE framework reframed to highlight the importance of the component within the foundational capacity component.

- Experience: Equitable student outcomes in CS courses and engagement in CS-focused college and career options (e.g., the extent to which the course is equally and positively impacting cognitive and noncognitive outcomes, including interest in attending college and awareness of career options, across student subgroups.)

2.1 Instrumentation

The quantitative survey we created for this study is based on an an open-ended survey we previously used in a qualitative study to understand specific impacts on students based on educator perceptions [ANON, ANON]. Our previous work explains this process in more detail [ANON], so we will note here that we coded and themed the perceived impacts from the qualitative survey and examined these for completeness, uniqueness, and overlap. To identify gaps, we combined these results with impacts from our previous research using CAPE. We also condensed items that were similar or seemed too narrow to reduce the time it would take to complete the survey. The resulting survey had the subcategories shown in Table 1.

We set the scale responses to be Increased, Stayed the same, Decreased, Unsure, and Not Applicable. To limit the length of the survey, we utilized skip logic so that participants randomly received either questions related to Capacity and Access or to Participation and Experience. Since participants with roles of administrator, counselor, etc., would have more familiarity with items related to Capacity and Access, those participants received items from those two components. We anticipated that there would be more participants who identified as teachers; they would have a 50-50 chance of either receiving the Capacity and Access items or the Participation and Experience items. By doing so, we planned to have thorough coverage, while keeping the length of the survey brief (10-15 minutes). After completing the survey, participants could take a second survey for a drawing for one of two $75 gift cards. We used reCaptcha and set up a randomly-generated, simple addition question to prevent bot-created data from entering our dataset.

2.2 Participants

Participants in this study were high school practitioners in the United States who were involved in CS education, either as a teacher, administrator, counselor, curriculum designer, or similar role.

Table 1: *CAPE components segregated by categories with reliability measures. Three scales indicate only Increased, Stayed the Same, and Decreased scales were used (Unsure and Not applicable were removed) and rows with blank data were removed. One additional item is grouped into Access in the analysis, with one dependent on whether or not fees are charged. Due to this disparity, we removed the Student Fees question from the group of items. We note that the low alpha for the 5-item scale is occurring due to the high amount of Unsure and Not Applicable for the "conflicting classes" item.*

Component	**Categories**	**# of Items**	**Cronbach's Alpha (5-scales)**	**Cronbach's Alpha (3-scales)**
Capacity	Funding, Policy, & Curriculum	9	0.88	0.89
	Physical Resources	5	0.79	0.86
	Human Resources	10	0.74	0.79
Access	(Access)	4	0.26	0.58
Participation	(Participation)	10	0.57	0.83
Experience	Learning	6	0.37	0.65
	Engagement	7	0.77	0.91
	Other noncognitive factors	5	0.62	0.76
	CS AP Exams	2	n/a	n/a

We determined the sample size needed for a representative sample of this population based on the following information. In 2019, there were 1,050,800 public and private high school teacher positions. Although there are several subject areas that high schools can offer, we examined this with the assumption that 1% of teachers, or 10,508, taught CS. It is also estimated that 47% of U.S. high schools offer CS in some form, and there are 26,727 high schools as of 2018 leaving 12,561 schools offering CS. Assuming one CS teacher per high school and averaging the difference of the two, we get 11,534. Using this as a basis and an online sample size calculator, to reach a 95% confidence level with a 5% margin of error, we determined that we needed a sample size of 384 for each component or a total of 742 participants.

We recruited participants involved with CS teachers or CS education initiatives (e.g., Computer Science Teachers Association (CSTA), the RPPforCS community, the ECEP Alliance, the ACM SIGCSE listserv) and asked researchers involved in similar CS education studies to share the survey. We did not attempt to query participants from schools that do not already deliver CS education nor from schools where CS practitioners are not connected with existing CS networks (like CSTA). To ascertain the extent of this limitation, we asked a question on the survey about networks of the CS practitioners.

2.3 Data Collection and Cleaning

We received 252 responses to our survey, which opened in February 2021 and closed three weeks later. We removed one response that did not answer a single-digit math question correctly as part of our check to see if the participant was human and not a bot and 66 responses that were incomplete. Of the remaining 185 responses, 98 responses were to questions about Capacity and Access components and 87 responses were to questions about Participation and Experience. Although this number falls short of the sample size needed for a 5% confidence interval we wanted to achieve, it achieves instead a 10% confidence interval.

2.4 Data Analysis

To get a sense of the overall impact of COVID-19 on CS Education, we calculated the percentage of *Increased (1), Stayed the Same (2), and Decreased (3)* responses among all schools. To provide context to the numbers, we ran a one sample t-test against the value ”2”, which represented the Stayed the Same response.

To determine whether statistically significant differences existed based on school racial/ethnic composition, we reverse-coded the response items and conducted a one-way ANOVA or Kruskal-Wallis test (dependent on the skewness and kurtosis of the individual items) using the Decreased (1), Stayed the same (2), and Increased (3) values in the analysis. We used ANOVA (using Bonferroni analysis) as the default analysis unless the skewness/standard error for skewness or the kurtosis/standard error or kurtosis fell outside the [-1.96, 1.96] range, at which point we performed a Kruskal-Wallis test (using a Mann-Whitney U test). We specify which analysis we used for each of the items we tested (Kruskal-Wallis or ANOVA) in the results section.

2.5 Evidence of Reliability and Validity

For this instrument, one of the researchers conducted internal face validity among the four members of the team. The researcher modified the survey items based on the feedback and sent the instrument for a second review and feedback cycle. For reliability, we conducted a Cronbach's alpha test for the groupings presented in Table 1 on all five scales and with only the three scales of Increased, Stayed the Same, and Decreased. The majority of items are close to or above .70, indicating strong reliability between the items in these groups. In our results, we present items individually.

3 Results

In this section, we provide details about the participant demographics followed by the results across each CAPE component. For the comparative analyses in this section, we removed responses of *Unsure* and *Not Applicable*.

3.1 Demographic Data

Most participants were teachers, women, and White (see Table 2). The largest percentage of participants had reportedly been in their positions 1-5 years (see Table 2. Most participants were reportedly affiliated with the CS Teachers Association (CSTA), (n^{total}=123 (54%); $n^{C\&A}$=58 (48%); $n^{P\&E}$=65 (62%)).

Schools reported that 76% of girls comprised 41-60% of the student population, compared to 83% of boys. Additionally, about 2% of participants were practitioners at all-girls or all-boys schools. The highest percentage of participants reported that less than 5% of their students were from rural areas, while one-third indicated that 61% or greater of their students resided in this location. Last, most participants reported that their schools were offering a hybrid model (in-person and online) this semester (n^{total}=96 (52%); $n^{C\&A}$=32 (34%); $n^{P\&E}$=26 (33%)).

To determine whether schools served majority Black, Indigenous, People of Color (BIPOC) or majority non-BIPOC students, we asked participants to identify the composition of their schools. Racial/ethnic groups included Asian, Black, Hispanic, Indigenous, Other (BIPOC), and White

Table 2: Participant Demographics

Category	Subcategory	All	C&A	P&E
Role	Assistant Principal	1 (1%)	1 (1%)	0 (0%)
	District Administrator	3 (2%)	3 (3%)	0 (0%)
	Guidance Counselor	2 (1%)	2 (2%)	0 (0%)
	Principal	2 (1%)	2 (2%)	0 (0%)
	Teacher who teaches CS	161 (88%)	75 (77%)	86 (100%)
	Other	12 (7%)	12 (13%)	0 (0%)
	Prefer not to say	1 (1%)	1 (1%)	0 (0%)
Race/Ethnicity	American Indian or Alaskan Native	4 (%)	3 (3%)	1 (1%)
	Asian	4 (2%)	2 (2%)	2 (2%)
	Black or African America	7 (4%)	6 (6%)	1 (1%)
	Hispanic or Latina/Latino	11 (6%)	6 (6%)	4 (5%)
	Native Hawaiian/Pacific Islander	0 (0%)	0 (0%)	0 (0%)
	White	156 (84%)	81 (83%)	75 (86%)
	Prefer Not to Say	3 (2%)	1 (1%)	2 (2%)
Gender	Men	74 (40%)	37 (38%)	37 (43%)
	Women	99 (53%)	57 (59%)	42 (48%)
	Unspecified	12 (6%)	4 (.04%)	8 (9%)
Time in position	1-5 years	73 (40%)	41 (42%)	32 (37%)
	6-10 years	43 (23%)	17 (17%)	26 (30%)
	11-15 years	20 (11%)	13 (13%)	7 (8%)
	16-20 years	10 (5%)	5 (5%)	5 (6%)
	20+ years	28 (15%)	18 (18%)	10 (12%)
	Prefer not to say	10 (4%)	4 (4%)	6 (7%)

(non-BIPOC). Response options were: 0-5% (0), 6-20% (1), 21-40% (2), 41-60% (3), 61-80% (4), 81-95% (5), and 96-100% (6).

If participants reported that White students comprised 61% or more (4, 5, or 6) of the population, we categorized the school as majority non-BIPOC. Likewise, if participants reported that Asian, Black, Hispanic, Indigenous, Other students comprised 61% or more of the population, we categorized the school as majority BIPOC. When participants identified a racial/ethnic group as comprising 41-60% (3) of the population, we could not determine whether these students comprised a majority (51% or more) or not. Therefore, when participants identified White students as comprising 41-60% (3) of the population, we determined that these schools were likely majority BIPOC when participants also reported any or the following: 1) one of the BIPOC racial/ethnic groups comprised 41-60% (3) **and** another BIPOC group comprised one of the other response categories (21-40% (2) and/or 6-20% (1)), 2) one of the BIPOC racial/ethnic groups comprised 21-40% (2) and **two** others comprised this or another response category (21-40% (2) and/or 6-20% (1))), or 3) **three** of the BIPOC racial/ethnic groups comprised 6-20% (1). This resulted in 42.7% (79) majority BIPOC schools and 57.3% (106) majority non-BIPOC schools.

Table 3: Capacity measured by participants' perceptions of Funding, Policy, & Curriculum.

	Inc.	Same	Decr.	t-test	CI	p
Funding for CS Education	10%	77%	14%	t(80)=0.69	-0.07, 0.14	0.49
State, district, or school initiatives related to CS education	26%	54%	20%	t(84)=-0.80	-0.21, 0.09	0.42
Plans to add additional CS courses	34%	51%	15%	t(90)=-2.61	-0.33, -0.04	0.01
Strategies to make CS curriculum more equitable	33%	58%	9%	t(85)=-3.55	-0.36,- 0.10	0.00
Strategies to improve CS curriculum	41%	48%	11%	t(90)=-4.30	-0.43, -0.16	0.00
Strategies to recruit more diverse students into CS	31%	56%	14%	t(87)=-2.47	-0.31, -0.03	0.02
Strategies to integrate CS into other disciplines	19%	60%	21%	t(84)=0.34	-0.11, 0.16	0.73
Strategies to add CS A or CS Principles courses	29%	59%	13%	t(79)=-2.32	-0.30, -0.02	0.02
CS graduation requirements	9%	85%	6%	H(1)=0.26		0.61

3.2 Capacity

We measured participants' perceptions of the pandemic's impact on schools' capacity to delivery equitable education by exploring three components: Funding, Policy & Curriculum, Physical Resources, and Human Resources. We review all three categories below.

3.2.1 Funding, Policy & Curriculum.

As described in the Data Analysis section, we used a one-sample t-test to determine the presence of statistically significant increases or decreases for any of the items that comprise this component of capacity. Table 3 presents the percentage of responses for each item as well as the results of the t-test. Participants reported statistically significant increases in the following: *Plans to add additional CS courses, Strategies to make CS curriculum more equitable, Strategies to improve CS curriculum, Strategies to recruit more diverse students into CS,* and *Strategies to add CS A or CS Principles courses*.

Next, to determine whether significant differences on any of the items existed between schools serving majority BIPOC and those serving majority non-BIPOC students, we conducted a Kruskal Wallis test on *CS graduation requirements* and an ANOVA on all other items. There were no statistically significant differences for any items based on school racial/ethnic composition.

3.2.2 Physical Resources.

Table 4 presents the results of the one sample t—test on items related to physical resources. Overall, participants reported statistically significant decreases in the following items: *Stable environment for learning, Reliable internet with appropriate bandwidth suitable for learning CS for students who need it,* and *Physical tools used to teach CS*.

The results of the ANOVA revealed that statistically significant differences in the *Physical tools used to teach CS* existed between schools serving majority BIPOC and those serving majority non-BIPOC students. The decrease in physical tools to teach CS was more significant among

Table 4: Capacity measured by participants' perceptions of Physical Resources.

	Inc.	Same	Decr.	t-test	CI	p
Stable environments for learning	11%	33%	56%	t(97)=6.44	0.31, 0.59	0.00
Reliable internet with appropriate bandwidth suitable for learning CS for students who need it	26%	26%	48%	t(95)=2.56	0.05, 0.39	0.01
Devices that meet hardware and software requirements for CS instruction to students who need them	25%	38%	38%	t(95)=1.56	0.03, 0.29	0.12
Physical tools used to teach CS	13%	55%	32%	t(90)=2.75	0.05, 0.32	0.01
Digital tools used to teach CS	25%	53%	22%	t(95)=-0.45	-0.17, 0.11	0.66

schools serving majority BIPOC students (M=1.64) than those serving majority non-BIPOC students (M=1.94), F(1,89)=5.03, p=0.027.

3.2.3 Human Resources (HR).

The results of the one sample t-test show that overall, there were statistically significant decreases in seven of the HR items: *Teacher availability to offer extra instructional help to students, Teacher/staff availability to offer CS-related extracurricular activities, Teacher/staff availability to encourage CS participation, Teacher/staff availability to attend CS professional development, Teacher/staff availability to discuss taking CS courses with parents/guardians, Teacher/staff availability to train parents of CS students,* and *Specialized training to teachers on equity*. See Table 5 for details.

To determine whether differences existed between schools serving majority BIPOC and majority non-BIPOC students, we conducted a Kruskal Wallis test on *Teachers qualified to teach CS* and an ANOVA on all other items. There were no statistically significant differences in any of the items based on BIPOC status.

3.3 Access

We measured educator perceptions of changes to student access using five items. We used a one-sample t-test to determine the presence of statistically significant increases or decreases in access across schools overall. The results presented in Table 6 reveal statistically significant increases in three items (*Number of CS courses offered*, *Fees required to take CS courses in 2019 or 2020*, and *Number of classes conflicting with CS classes*) and statistically significant decreases in two others (*Number of CS related extracurricular activities offered* and *Number of non-CS related extracurricular activities offered*). CS-related and non-CS-related activities were explored, as there was previous speculation from teachers that activities that required physical presence may have differed between CS and non-CS related activities.

We conducted a Kruskal Wallis test on *Fees required to take CS courses in 2019 or 2020* and an ANOVA on all other items to determine whether differences existed between schools based on BIPOC status. We found statistically significant differences in the *Number of CS related extracurricular activities offered* (F(1,85)=5.56, p=0.021), with schools serving majority BIPOC students (M=1.38) reporting greater decreases than those serving majority non-BIPOC students

Table 5: Capacity measured by participants' perceptions of Human Resources.

	Inc.	Same	Decr.	t-test	CI	p
Teacher ability to offer high-quality CS instruction	15%	64%	21%	t(88)=1.06	-0.06, 0.19	0.30
Teacher availability to offer extra instructional help to students	16%	43%	41%	t(90)=3.20	0.09, 0.39	0.00
Teacher/staff availability to offer CS-related ec activities	9%	40%	51%	t(87)=6.01	0.28, 0.56	0.00
Teacher/staff availability to encourage CS participation	20%	45%	34%	t(87)=1.75	-0.02, 0.29	0.08
Number of students who received information about CS courses/CTE pathways	31%	46%	24%	t(67)=-0.82	-0.25, 0.11	0.42
Teacher/staff availability to attend CS PD	20%	43%	37%	t(91)=2.27	0.02, 0.33	0.03
Teacher/staff availability to discuss taking CS courses w/ guardians	6%	47%	47%	t(84)=6.29	0.28, 0.54	0.00
Teacher/staff availability to train parents of CS student	6%	44%	51%	t(70)=6.28	0.31, 0.59	0.00
Specialized training to teachers on equity	18%	48%	33%	t(86)=1.97	0.00, 0.30	0.05
Teachers qualified to teach CS	12%	81%	7%	H(1)=0.74		0.39

(M=1.68).

3.4 Participation

We measured educator perceptions of the impact of the pandemic on student participation in CS using six items. We used a one sample t-test to determine the presence of statistically significant increases or decreases in participation across schools overall. Table 7 shows statistically significant increases in the following participation items: *Number of students enrolled in CS A courses, Number of students participating in CS related extracurricular activities, Number of students participating in non-CS related extracurricular activities,* and *Number of students participating in multiple extracurricular activities*.

To determine whether differences existed between schools serving majority BIPOC and majority non-BIPOC students, we conducted an ANOVA on all items. Schools serving majority non-BIPOC students (M=2.25) reported significantly greater increases in the *Number of students taking additional CS courses* than those serving majority BIPOC (M=1.84; F(1,66)=4.99, p=0.029). Additionally, schools serving majority non-BIPOC sudents (M=1.53) reported significantly greater increases in the number of students participating in *CS related extracurricular activities* than did schools serving majority BIPOC students (M=1.43; F(1,85)=5.56, p=0.021).

3.5 Experience

We measured participants' perceptions of the pandemic's impact on students CS experiences by exploring four components: Learning, Engagement, Other Non-Cognitive Factors, and Taking AP

Table 6: Access measured by participants' perceptions.

	Inc.	Same	Decr.	t-test	CI	p
Number of CS courses offered	26%	65%	9%	t(90)=3.01	-0.29, -0.06	0.00
Number of CS related extracurricular activities offered	6%	44%	51%	t(86)=6.91	0.32, 0.58	0.00
Number of non-CS related extracurricular activities offered	2%	36%	61%	t(84)=10.02	0.47, 0.70	0.00
Number of classes conflicting w/ CS classes	39%	59%	2%	t(58)=5.49	-0.51-0.24	0.00
Fees to take CS courses over the last 12 months	89%	11%	0%	H(1)=1.04		0.31

Exams.

3.5.1 Learning.

As shown in Table 8, the results of the t-test reveal that, overall, there were statistically significant decreases in four learning items: *Content knowledge students gained in CS classes, Grades given in CS classes, Completion of CS homework assignments,* and *Number of instructional hours in CS students received*.

To determine whether statistically significant differences existed between schools serving majority BIPOC and majority non-BIPOC students, we conducted an ANOVA on all items and found no statistically significant differences.

3.5.2 Engagement.

Table 9 reveals statistically significant decreases in all areas of engagement.

The ANOVA found no statistically significant differences based on school BIPOC status.

3.5.3 Other Non-Cognitive Factors.

Table 10 shows the results of the one sample t-test on other non-cognitive factors in schools overall. There were statistically significant increases in *Understanding of the relevance of technology* and *Confidence using technology*.

An ANOVA was conducted on all items and found significantly greater increases in the *Number of students interested in taking additional CS courses* in schools serving majority non-BIPOC students (M=2.30) than in those serving majority BIPOC students (M=1.88; F(1,60)=6.40, p=0.014).

3.5.4 Taking AP Exams.

As shown in Table 11, the results on the one sample t-test reveal that there were statistically significant decreases in both items.

The ANOVA found no statistically significant differences in these items between schools serving majority BIPOC and those serving majority non-BIPOC students.

Table 7: Student Participation measured by participants' perceptions.

	Inc.	Same	Decr.	t-test	CI	p
Number of students enrolled in CS courses	32%	44%	24%	t(81)=-0.88	-0.24, 0.09	0.38
Number of students enrolled in CS A courses	17%	45%	38%	t(49)=1.94	-0.01, 0.41	0.06
Number of students enrolled in CS Principles courses	28%	44%	28%	t(61)=0.00	-0.20, 0.20	1.00
Number of students taking add'l CS courses	34%	44%	22%	t(67)=-0.63	-0.25, 0.13	0.53
Number of girls enrolled in CS classes	25%	48%	27%	t(84)=0.31	-0.13, 0.18	0.76
Number of BIPOC students enrolled in CS classes	20%	68%	12%	t(80)=-0.56	-0.17, 0.09	0.57
Number of students participating in CS related ec activities	9%	34%	57%	t(69)=6.58	0.36, 0.67	0.00
Number of students participating in non-CS related ec activities	3%	25%	72%	t(64)=10.23	0.54, 0.81	0.00
Number of students participating in multiple ec activities	5%	22%	73%	t(70)=10.27	0.54, 0.81	0.00

4 Discussion

The previous section presents the results of participants' perceptions of the pandemic's impact on schools' the capacity to offer computer science, students' equitable access to CS education, student participation in CS, and students' experiences in CS courses. Overall, the student impact findings match what has been stated in early reports–that students have been adversely affected in several ways and that schools serving majority BIPOC students were more heavily impacted. In this section, we take a deeper, reflective look at the findings.

4.1 Observations

4.1.1 Capacity

When asked about the impact the pandemic had on their school's capacity to offer equitable access to CS courses over the past 12 months, participants reported that they saw significant *increases* in their schools' funding, policy, and curriculum changes. Specifically, schools *increased* their plans to add additional CS courses, as well as their strategies to make CS curriculum more equitable, improve CS curriculum, recruit more diverse students into CS, and add CS A or CS Principles courses. Improvements in these areas were consistent across all schools and did not differ based on the race/ethnicity of the majority of the students. However, physical resources suffered. There were statistically significant *decreases* in stable environments for learning, reliable internet with appropriate bandwidth suitable for learning CS for students who need it, and physical tools used to teach CS across the schools. This supports earlier evidence of the pandemic's impact by Onyema et al. and Adnan and Anwar, who found that online learning was negatively impacted by poor access to technology and weak digital skills [17], [16]. Additionally, schools serving majority BIPOC students were *more adversely affected* in the area of the physical tools used to teach CS than those serving majority non-BIPOC students.

Table 8: Experience measured by participants' perceptions of student learning.

	Inc.	Same	Decr.	t-test	CI	p
Content knowledge students gained in CS classes	21%	28%	51%	t(80)=3.28	0.11, 0.46	0.00
Grades given in CS classes	18%	51%	31%	t(79)=2.27	0.02, 0.33	0.03
Completion of CS homework assignments	10%	27%	63%	t(78)=8.13	0.45, 0.74	0.00
Number of instructional hours in CS students received	7%	29%	64%	t(81)=8.12	0.41, 0.68	0.00
Number of students receiving college credit for dual-credit CS courses	18%	50%	32%	t(367)=1.36	-0.08, 0.39	0.18
Number of students achieving awards in CS	20%	56%	24%	t(52)=1.23	-0.07, 0.30	0.22

Table 9: Experience as measured by participants' perceptions of student engagement.

	Inc.	Same	Decr.	t-test	CI	p
Willingness to share their knowledge during class	17%	26%	57%	t(79)=5.12	0.26, 0.59	0.00
Engagement during CS classes	19%	22%	58%	t(79)=5.72	0.32, 0.66	0.00
Engagement with other students	16%	19%	65%	t(78)=7.48	0.44, 0.75	0.00
Engagement in help-seeking behaviors	26%	15%	58%	t(78)=4.24	0.21, 0.58	0.00
Engagement during pair programming exercises	18%	25%	57%	t(69)=5.51	0.31, 0.66	0.00
Engagement during CS related extracurriucular activities	10%	33%	57%	t(59)=6.56	0.38, 0.72	0.00
Attendance in CS classes	16%	46%	38%	t(82)=4.20	0.16, 0.46	0.00

Table 10: Experience measured by participants' perceptions of student interest, belongingness, and other factors.

	Inc.	Same	Decr.	t-test	CI	p
Interest in CS	33%	54%	13%	t(69)=-0.35	-0.19, 0.13	0.73
Belonging in CS courses	29%	52%	19%	t(67)=-0.18	-0.17, 0.14	0.85
Understanding of the relevance of technology	48%	46%	7%	t(75)=-4.02	-0.43, -0.15	0.00
Confidence using technology	48%	48%	5%	t(75)=-3.47	-0.41, -0.11	0.00
Number of students interested in taking add'l CS courses	40%	56%	4%	t(61)=-1.53	-0.30, 0.04	0.13

Table 11: Experience measured by students taking AP exams.

	Inc.	Same	Decr.	t-test	CI	p
Number of students taking the AP CS A exam	18%	32%	50%	t(41)=3.19	0.13, 0.58	0.00
Number of students taking the AP CS Principles exam	20%	47%	33%	t(50)=1.94	0.-00, 0.40	0.06

Participants reported that over the past 12 months the pandemic caused statistically significant *decreases* in seven Human Resource items: teacher availability to offer extra instructional help to students, teacher/staff availability to offer CS-related extracurricular activities, teacher/staff availability to encourage CS participation, teacher/staff availability to attend CS professional development, teacher/staff availability to discuss taking CS courses with parents/guardians, teacher/staff availability to train parents of CS students, and specialized training to teachers on equity. These findings are consistent with recent reports of pandemic-related teacher shortages overall and specifically in CS [22], [23], [24]. These decreases were equitable across both school types (majority BIPOC and majority non-BIPOC).

4.1.2 Access

Participants reported mixed results about the impact the pandemic had on schools' ability to offer equitable access to CS courses during the 2020-21 school year. While there were statistically significant *increases* in the number of CS courses offered, there were also significant increases in the fees required to take CS courses in 2019 or 2020 and in the number of classes conflicting with CS classes-both negative outcomes.

Similar to other studies [25], we found statistically significant *decreases* in the number of CS related and non-CS related *extracurricular activities* offered. Additionally, schools serving majority BIPOC students showed significantly greater decreases in the number of CS related extracurricular activities than those serving majority non-BIPOC students.

4.1.3 Participation

When asked about the impact the pandemic had on students' equitable participation in CS courses over the past 12 months, participants reported that there were statistically significant *increases* in the numbers of students participating in CS A courses, CS related and non-CS related extracurricular activities, and multiple extracurricular activities. These results also indicated that there was not a significant difference between CS related and non-CS related activities. Schools serving majority non-BIPOC students had significantly greater increases in the number of students taking additional CS courses and in the number of students participating in CS related extracurricular activities than those serving majority BIPOC. The disparities found here are in line with other studies that report schools with higher percentages of underrepresented minority students are less likely to teach CS and were more likely to suspend CS instruction in light of the pandemic [19, 26].

4.1.4 Experience

When asked about participants' perspectives on the impact the pandemic had on students' experiences in CS courses over the past 12 months. They reported statistically significant *decreases* in four learning areas: Content knowledge students gained in CS classes, grades given in CS classes, completion of CS homework assignments, and number of instructional hours in CS students received. These items did not impact majority BIPOC serving schools differently than those serving majority non-BIPOC students. Reports of educational losses due to COVID have been cited in several other studies [13], [12], [27].

Participants reported that student engagement was not significantly affected. Regarding other non-cognitive factors, participants reported statistically significant *increases* in students' understanding of the relevance of technology and confidence using technology. Additionally, the number of students interested in taking additional CS courses was *significantly higher* in schools serving majority non-BIPOC students than in those serving majority BIPOC students. Last, participants reported statistically significant *decreases* in the numbers of students taking the AP CS A and AP CS Principles exams, but there was no statistically significant differences in these items based on school racial/ethnic composition. The College Board [28] reported a similar decline.

4.2 Limitations

One study limitation is that these data only represent practitioners' *perspectives* of the pandemic's impact on equitable CS education, rather than examining objective, factual data (e.g., enrollments, grades, and homework completion rates) about what is happening across the CAPE components. Similarly, we relied on participants' perceptions of their schools' racial/ethnic composition rather than the raw data to determine which schools served majority BIPOC and majority non-BIPOC students, obviously an imperfect measure.

Another limitation is that the margin of error on responses is 10%, which means that the tests for significance (greater than 25%) on the percentages more likely reflect a range of 15-35%. Additionally, survey participants were not representative of the overall population of participants were primarily people who self-identified as White and were active in CS networks. Most (86%) of participants were also affiliated with a CS network, meaning that we lack representation from schools that are not part of a network that is designed to grow and strengthen CS education.

Last, we did not attempt to provide a baseline for comparing their actual capacity prior to COVID-19. Based on prior literature, we know that schools that serving historically marginalized students offer fewer, if any, CS courses [7].

5 Conclusion and Future Work

The shifting landscape of what was possible in CS education was contingent upon high school administrators' commitments to provide CS education equitably. This included continuing with the same number of CS courses and extracurricular activities that would have been offered in the absence of the pandemic. Students and families made critical choices around course enrollment, perhaps prioritizing "core" academic subjects and family obligations while dealing with the stress and limited resources the pandemic caused. We acknowledge the challenge in self-reported information, especially at a time when racial justice and inequity emerged in the wider public conscience due to the Black Lives Matter movement and a national response to the numerous killing of Black and Brown individuals.

This work will continue to inform the research team as they seek to evaluate school-based interventions to broaden participation, especially equitable participation, in computer science education. We hope that the findings in this paper will inform future studies and will be useful to the larger community as they continue to study the effects of the pandemic on student outcomes.

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