



Predictors of K-12 CS Teacher Isolation and Course Offerings

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ABSTRACT

Teacher isolation, where only one teacher at a school is teaching a particular subject, has been reported as one of the biggest challenges for computer science (CS) teachers in the US. However, the extent of CS teacher isolation has not been documented beyond teachers' self report. We use 14 years of middle and high school data from California to determine factors affecting the likelihood of CS being offered or a CS teacher being isolated at a school. We find that teachers in CS experience isolation at a higher rate than almost all other subjects and that larger schools are more likely to have one or more CS teachers. We extend prior work by showing that schools with a greater proportion of students underrepresented in computing are less likely to offer CS even when controlling for school size.

CCS CONCEPTS

• **Social and professional topics** → **K-12 education**.

KEYWORDS

teacher isolation, CS education, education policy, equity

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1 INTRODUCTION

Research has found that access to K-12 CS learning opportunities is unequally available in the US by race, ethnicity, socio-economic status, and urbanicity (i.e., population density) [16]. These patterns of disparate access mirror patterns of underrepresentation of racial/ethnic groups in CS majors and CS careers [47]. Equitable access to CS learning opportunities is imperative because CS is a relatively new field [20, 21, 35] with an enormous impact that is not equitable across society [10, 22, 32]. Students could benefit from CS learning opportunities to understand and shape the computational world around them [31].

Scholars have sought to understand K-12 CS inequity using the CAPE Framework [23, 46]. The CAPE Framework focuses on how inequality can be present in the *Capacity* of a district to offer CS,

the *Access* students have to CS courses, the *Participation* of students in CS courses, and the *Experiences* of students in CS courses. Our research focuses on CS teachers as they are central to understanding equity and inequity in Capacity, Access, Participation, and Experiences. CS teacher isolation can limit the *Access* to CS and negatively impact the *Experience* of both students and teachers. We focus specifically on the reported problem of CS teacher isolation (i.e., being the only CS teacher at their school) [15] due to its importance in improving CS education.

In the United States, isolation was identified as one of the five main challenges for CS teachers, with 55% of CS teachers reporting being the only CS teacher at their school in 2013 [15]. However, survey self-reports may be inaccurate or non-representative and therefore may not reflect the true rates of CS teacher isolation at the time of that study. Additionally, current rates of CS teacher isolation and how they have changed as CS education has expanded in the subsequent decade are unknown. Accurately measuring rates of CS teacher isolation is important because teacher isolation can negatively impact teachers and their students. In contrast to isolated CS teachers, non-isolated CS teachers have the potential to collaborate, and the resulting teacher social networks can benefit students' exam scores [39, 41]. Having opportunities to collaborate with and learn from other CS teachers at their school may address some of the insufficient training for CS teachers [18], many of whom are credentialed in other disciplines [12]. Additionally, non-isolated CS teachers indicate a larger capacity to allow more students to participate in CS coursework.

Our work is inspired by analyses from physics education because K-12 physics education suffers from similar problems of inequitable access [28] and additional challenges caused by isolated teachers. In particular, Kelly and Sheppard [29] found that small schools of a few hundred students were less likely to have physics courses. These small schools were created as part of the Small Schools Movement and were meant to improve the experience of students from underrepresented groups. Previous work has focused on relationships between student demographics and CS access [44, 45] but has not considered school size. Some districts in California participated in the Small Schools Movement as well [14], which created the possibility that disparities in access to CS could be attributed to more students in underrepresented groups being in these smaller schools. Ultimately, larger schools may have more capacity to offer CS courses or other electives due to being able to hire more teachers.

Our work explores how school characteristics, such as school size and urbanicity, impact a school's capacity to offer CS. We also investigate whether these school characteristics impact whether the school has an isolated CS teacher, further exacerbating issues of equity and access. We use data from California because we can access fourteen years of teacher, course, and student data from

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over 1,000 districts, over 10,000 schools, and over six million students. Additionally, different regions in California vary in their demographics, financial resources, and population density.

Motivated by the goal of understanding and addressing current patterns of inequity, our research extends prior work to document the current state of CS teacher isolation and takes into account the impact of school size to address the following research questions:

RQ1: How do rates of CS teacher isolation vary over time and compare to other subjects?

RQ2: To what extent do school size, urbanicity, or student demographics affect the likelihood that a school:

- (a) does not offer CS?
- (b) has only a single (i.e., isolated) CS teacher?
- (c) has more than one (i.e., non-isolated) CS teacher?

We find that teachers in CS experience isolation at a higher rate than almost all other subjects. We provide a more comprehensive view of teacher isolation than is possible from survey data. We also illustrate differences between middle school and high school teachers. While prior research has documented teacher isolation in other subjects in other states [34], these rates of isolation had previously not been demonstrated in CS. Our findings illustrate that despite recent improvements, California shows a high rate of CS teacher isolation. Based upon previous work highlighting the benefits of social networks [7, 38] and the negative impacts of teacher isolation [8], supporting CS teachers who experience isolation may improve their work experience and lead to better student outcomes. Our findings support previous work documenting disparities in CS education access and additionally demonstrate that these access disparities persist even when accounting for school size. We suggest that when expanding the number of CS teachers in a school or district is not possible, support could be offered through targeted professional development funding and additional resources.

2 PREVIOUS RESEARCH

Prior research has looked at who is taking computer science at a high school level and have highlighted disparities in access for Black and Hispanic students when compared to white students [44, 45]. There is further evidence of disparities in terms of access within underrepresented populations when considering intersectionality [45]. Additionally, there is research that has looked to determine school characteristics that might aid in expanding access or help further explain disparities, such as course modality and urbanicity [17]. However, there is no research to the authors' knowledge that considers access to CS courses while accounting for student demographics, school size, and urbanicity simultaneously.

We use the CAPE Framework [23] to help us understand factors that impact equality in K-12 CS education. Notably, the CAPE framework expands beyond typical measures of *Access* and *textit{Participation}* to consider the underlying *Capacity* within educational systems to teach CS as well as student *Experience*. Some of the components of capacity are having the resources, teachers, and the facilities to teach CS. Teacher isolation both affects the access to CS, as one CS teacher may not be enough to provide all students in a school the opportunity to take a course, and experience, as it can affect both teacher and subsequently student experience.

2.1 Teacher Isolation and Social Networks

Teacher isolation has the potential to negatively impact teachers in a variety of ways. Researchers have classified teacher isolation along different dimensions: geographic isolation (i.e., how geographically distant teachers are from other teachers or resources), intellectual isolation (i.e., how there is a lack of access to teachers they could collaborate with), and social isolation (i.e., how distant they feel to the community outside of work) [4]. Prior work has focused primarily on geographic and intellectual isolation as it has the potential to cause teachers to burn out, leave their current school, or exit the profession entirely [4, 8, 9]. Geographic and intellectual isolation are also the types of teacher isolation where policymakers have the greatest opportunity for impact; social isolation is more difficult to legislate solutions for. This paper focuses on intellectual isolation, particularly on lacking access to teachers to collaborate with on the same subject.

Research has found that teacher social networks can lead to an increase in teacher self-efficacy [40, 42] and retention [7, 38], and positively influence student performance [2]. For example, professional development provided by the Exploring Computer Science (ECS) program specifically for the US-based high school course ECS after “[r]ecognizing that teachers who teach CS are often isolated within their schools without organized academic departments of colleagues” [36, p. 352]. Teachers that attended this professional development reported “increased understanding, confidence, and application of inquiry and equity-based teaching practice” [36, p. 356]. Understanding CS teachers’ intellectual isolation and the corresponding challenges of not having a social network is important. While some of these CS teachers might have experience teaching other subjects, many could benefit from resources and other teaching support specific to CS teaching.

2.2 Social networks and teacher self-efficacy

Formal social networks can foster communities to improve teachers’ confidence in their curriculum and their self-efficacy [40, 42]. Bandura argued that successful learning environments rest heavily on teacher’s self-efficacy [6]. Researchers examined 20 middle school math departments across two districts and found that more connections in a teacher social network were associated with higher collective efficacy among school staff [11]. However, researchers have found that social connections are not always enough and that providing curriculum strategies and specific guidance have the most positive impact on instructional practices and self-efficacy [42].

2.3 Social networks and teacher retention

Teachers report that collaborations and professional learning communities (PLCs) were important for their learning and their decision to stay in the profession [7]. In the U.S. from 2007 to 2012, around 17% of new teachers left teaching every year [25]. However, new teachers appear to be less likely to leave their schools where there is high engagement among teachers [37]. Reducing teacher turnover is important because it is expensive to recruit and train new hire teachers. These costs are more recurrent for lower-resource schools where turnover is more common [3]. Teacher retention is also a particular concern for increasing the number of teachers of color as

data suggests that non-white teachers have higher turnover rates than white teachers [1]. Workforce morale is also influenced by teacher turnover as being in a school with high turnover rate is reported by teachers to be stressful [27].

2.4 Social networks and student performance

Researchers found that teachers who interact with higher performing peers improve their own students' performance [26], and that the addition of a higher performing teacher to a school improves the performance of all teachers in it [41]. One explanation as to why higher performing teachers seem to benefit all teachers is that higher performing teachers are more likely to initiate pedagogical discussions which in turn improved their instructional practices [39]. However, teacher interactions seem to influence teaching practices more when these are from the same school, with across school teacher interactions providing less curriculum support [5].

In summary, teacher social networks appear to benefit teacher self-efficacy, teacher retention, and student achievement. Collectively, teacher isolation can impact student experience. Additionally, teacher isolation can impact capacity and access within schools because fewer teachers in a school reduces the ability of the school to offer sufficient CS courses for all students. There is limited research looking to measure teacher isolation with longitudinal, statewide data. Analyzing the extent of CS teacher isolation is relevant to be able to better support them and to improve access to social networks and their benefits.

3 DATA

3.1 Data Source

The data used is from the California Department of Education. California has detailed, privacy-compliant, non-traceable data that includes the courses taught in schools (see Section 3.1.2), numeric identifiers for who teaches them (see Section 3.1.3), and details on school size, urbanicity, and students' demographics (see Section 3.1.1). There is annual data available from Fall 2003 until Fall 2018 with the exception of Fall 2010. We use California data in large part because it is public data with a fourteen year time frame. As of the 2019-2020 school year, in California there are 1029 districts and 10,545 schools serving over 6 million students. To add context to our results, the number of high schools offering CS has doubled in the fifteen years from 2003 until 2018, reaching 1120 schools in 2018.

3.1.1 School information: size, student demographics, urbanicity. The dataset provides the total enrollment per school, which refers to how many students are registered at that school, and is what we refer to as school size. The dataset also provides the percentage of the enrollment of students of various demographics by school and district. Specifically, there is both the percentage based on race/ethnicity as well as percentage of students receiving free or reduced-price lunch (FRPL).¹ The percentage of students receiving FRPL is used in the literature as a common, but coarse, proxy for estimating the percentage of students from low-income households

¹Students are eligible to receive lunch prepared at their school for free or at a reduced price when their household income is at or below the eligibility guidelines provided by the US Department of Agriculture.

[30]. The dataset provides the urbanicity of the school districts. Urbanicity is divided into four categories from least to most densely populated: rural, town, suburban, and urban [24]. This is calculated by the average population density of the district.

3.1.2 Course Classification. California provides course data per school. At the middle school and high school levels, California provides the names of courses offered in each school in each year. California does not provide a specific classification for CS courses and so a category was created based on previous work [12]. This category was created by classifying course codes based on their title and course description. In our analysis, the subjects considered are CS, math, English Language Arts (ELA), art, and science; we further split art and science. Science teachers were grouped by five class categories: general science, life science, earth and space science, physics, and chemistry. These were chosen as they are the categories that are involved in California's science graduation requirements for middle schools and high schools [33]. Art was classified under the five categories specified by California: Music, Theater, Visual Arts, Media Arts, and Dance. Math and ELA teachers require a single certification to teach any courses from their subject. In contrast, science and art teachers teach substantially different courses with varied certification requirements, and were given a narrower definition of isolation than math or ELA teachers.

3.1.3 Teacher Information. Each teacher has a unique identifier across their courses from each year, but not across years. This means that we can identify the courses a teacher taught within a year but cannot track a teacher over multiple years. We classify a teacher with their given subject by what courses are associated with each unique teacher identifier. For example, we considered the number of CS teachers in a school to be the number of unique teacher identifiers to be associated with at least one CS course in a given year.

3.1.4 Defining Peers and Isolation. We consider a teacher isolated in their school if they had no peers at their school teaching the same subject. Since some teachers teach multiple subjects, we classified teachers by the subjects they teach, such that a teacher might be considered isolated in some subjects but not others.

4 METHODS

To answer RQ1, we focused on comparing rates of isolation across time and subject. To answer RQ2, we use the following three outcomes (i) there being no CS teacher at the school, (ii) there being an isolated CS teacher, and (iii) there being more than one CS teacher at the school. We predict our three outcomes across five distinct linear regression models, with outcomes represented below by $Outcome_{st}$ for school s and year t . These outcomes were all coded to be binary. That is, schools were coded as 1 for our third outcome if they had more than one CS teacher at their school, and coded 0 otherwise. Our resulting linear probability model is presented below:

$$Outcome_{st} = \beta_1 schoolSize_{st} + \beta_2 \sqrt{schoolSize_{st}} + \beta_3 \%minority_{st} + \beta_4 \%FRPL_{st} + \beta_5 \%ELL_{st} + \beta_6 rural_town + \beta_7 urban + \gamma_t + \epsilon_{st}$$

We consider school size because of how school size can serve as a capacity and access constraint to course offerings. California has extremely varied school sizes; to account for potentially diminishing returns to size we use school size as a quadratic term, seen in the variable $sqr(schoolSize)$. There are three variables relating to student demographics with $\%minority_{st}$, referring to the percentage of students at a school s in year t that are neither white nor Asian, $\%FRPL$ referring to students receiving free or reduced priced lunch (as a proxy for socioeconomic status), and $\%ELL$ referring to English Language Learners. These were included due to there being evidence of disparities in CS access across these different groups.

We also consider urbanicity represented in our model by *urban* and *rural_town*. We chose suburban as the reference group as it is the most represented in the dataset. Urbanicity is considered in some of our models as schools in rural and urban areas have been shown to offer less CS than their suburban counterparts [16]. We use year fixed effects (i.e., a dummy variable per year) to account for changes all schools might experience each year, such as statewide regulatory changes. School fixed effects are used to isolate changes within schools. We cluster standard errors on schools, to account for a lack of independence between observations of the same school in multiple years.

Model 0 includes only student demographics and year fixed effects, and provides an initial estimate of how student demographics within a school predict whether CS is offered and if CS teachers are isolated or not. Model 0 does not include school factors or school fixed effects. Model 1 additionally includes school size because smaller schools may have less capacity to offer additional courses. Model 2 is Model 1 with the addition of school fixed effects. Model 3 adds urbanicity and removes school size and school fixed effects because we only want to consider the effects of urbanicity without considering other school factors to better understand the relationship between our school factors. Finally, Model 4 uses all variables from the previous models except for school fixed effects due to concerns of collinearity between all of our school level factors.

5 LIMITATIONS

While our dataset covers a 14 year period and allows us to consider time-varying school characteristics, there is still the possibility that there are other factors unaccounted for relating to teacher isolation and course offerings. The fact that our dataset ends in 2018-2019 is because later years of data are not available. Additionally, data from 2020 and 2021 would have been challenging to interpret due to the effects of Covid-19. Our analysis also only considers access to one or more CS courses, and not the participation or experience within them. This is also data strictly from California and the results, with the exception of perhaps school size, cannot necessarily be generalized, as many states approach CS course offerings differently. For example, some states have CS as a graduation requirement.

6 POSITIONALITY STATEMENT

The first author is a PhD student, who is half Latina and half Middle Eastern. Both her parents are educators, in particular, her mother is a science teacher at a public school and her mother actively participates in and has provided professional development. Seeing the

impact her mother has had on other teachers and students has influenced the first author's interest in supporting and documenting teachers' experiences. Growing up in an area where access to CS education is currently limited, also influenced the author's particular interest in identifying disparities in access to CS. The second author is a professor who is a white woman who participated in *compulsory* CS education learning opportunities that were integrated within her public school in California. This pre-college background was essential in allowing her to pursue CS in higher education. In her research, she has participated in several activities to support CS-teacher collaboration and sees how such collaboration can benefit teachers and students.

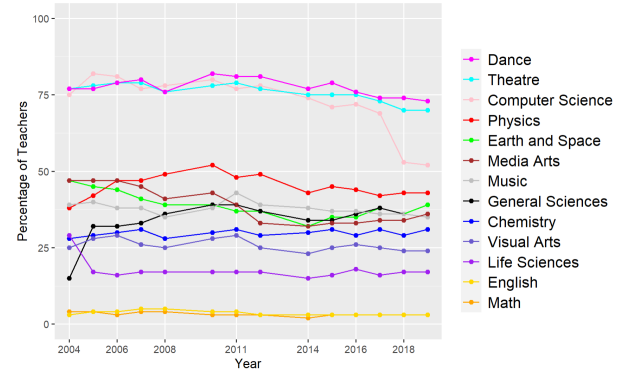


Figure 1: Percentage of teachers isolated at their high school in California. Subjects are listed in descending order based on their rate of isolation in the most recent year.

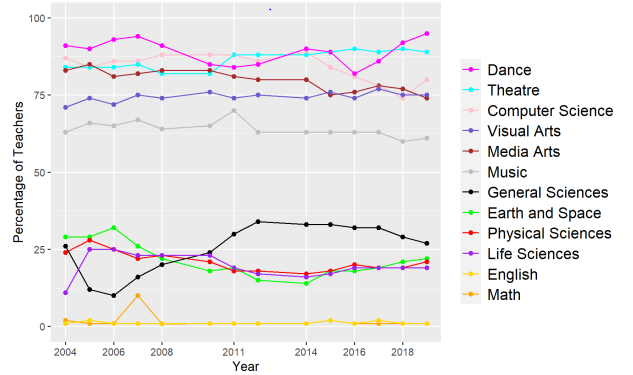


Figure 2: Percentage of teachers isolated at their middle school in California. Subjects are listed in descending order based on their rate of isolation in the most recent year.

7 RESULTS

7.1 RQ1: Rates of Isolation

RQ1: Do high school and middle school CS teachers experience a higher rate of isolation compared to teachers of other subjects?

The percentage of isolated CS teachers has decreased over time. The percentage of high school CS teachers isolated at their school, shown in Figure 1, has decreased from 75% in 2004 to 52% in 2019.² Figure 2 shows that while the proportion of middle school CS teachers isolated at their school started to decrease in 2014, it has plateaued at around 80%, which is higher than it was for high school teachers in 2004.

As shown in Figures 1 and 2, we found that high school and middle school CS teachers experience a higher rate of isolation than teachers of most other subjects. Math and English teachers in both high schools and middle schools experience isolation at a drastically lower rate than CS teachers, with less than 5% isolated at their school. High school Physics teachers experience a rate of isolation similar to CS teachers. In 2019, approximately 50% of high school CS and Physics teachers were isolated. In middle school, General Sciences is the subset in science with the highest rates of isolation but those teachers still experience isolation at less than half the rate of CS teachers. Within the arts, Theatre and Dance teachers experience higher rates of isolation than high school and middle school CS teachers, and Visual Arts, Media Arts, and Music teachers experience isolation at a lower rate. This is the first study to capture these high rates of CS teacher isolation without the use of self-reported surveys.

7.2 RQ2: Isolation, School and Student Factors

RQ2: Do school size, urbanicity, and student demographics affect the likelihood that a CS teacher is isolated at their school or that the school does not offer CS?

Table 1 shows the relationships between our five models and our three outcomes. To facilitate the explanation of the models, they will be grouped in this result section by independent variables.

7.2.1 Percentage of students who are ELL or receive FRPL results show disparities in access. Model 0 shows that schools with higher representations of students who are ELLs (%ELL) and who receive FRPL (%FRPL) are less likely to offer CS. These results are fairly consistent across all models. In models that control for school size (i.e., Models 1, 2, and 4) our estimates shrink slightly. Model 4 shows that a 10 percentage point increase in representation of ELLs or students receiving FRPL is associated with a 1.8 or 0.6 percentage point increase, respectively, in the likelihood of CS not being offered.

In some of the models that predict an isolated or non-isolated teacher, the coefficient for %FRPL is not significant. This may be in part due to the effects of the Community Eligibility Provision [43]. Starting in 2010, this provision allows schools that already have 40% of their students receiving free lunch [43] to classify all students as eligible, making %FRPL an even coarser proxy to estimate how many students come from low-income households [30].

7.2.2 Race/Ethnicity results show disparities in access when controlling for school size. In Model 0, we see that the representation of students from minority groups is a positive predictor of CS being offered. This is while controlling for the representation of ELLs and students receiving FRPL. In Model 0, a 10 percentage point increase

in the percentage of students from minority groups is associated with a 1.1% increase in the likelihood that CS is offered. However, once we control for school size in the subsequent models (1, 2, 4), the sign is reversed. We see a positive relationship between %minority and there being no CS offered at the school, and a negative relationship with there being one or more CS teachers. Based on Model 4, which includes student demographics and school factors, a 10 percentage point increase in representation from students from minority groups is associated with a 0.6 percentage point increase in the likelihood of there being no CS offered at the school.

7.2.3 School size is a positive predictor for CS. Our Model 1 adds school size. Changes between Model 0 and Model 1 show differences in sign for %minority that are discussed above. Additionally, across all models with school size (1, 2, 4), school size is a positive predictor for a school offering CS, as well as having more than one CS teacher. Model 4 shows that every increase of 100 students is associated with a 2 percentage point decrease in there being no CS offered and a 0.8 percentage point increase in there being more than one CS teacher. This affirms that larger schools are more likely to offer CS, however, it should be noted that the results signal a diminishing return to additional enrollment.

7.2.4 Rural schools are less likely to offer CS. Model 3 adds urbanicity through our *rural_town* and *urban* variables. The variable *rural_town* shows a positive relationship with there being no CS offered at a school and a negative relationship with there being more than one CS teacher. This implies that schools in rural and town areas are less likely to offer CS than schools in suburban areas. In particular, schools in rural and town areas have a 3.6 percentage point increase in the likelihood there is no CS compared to schools in suburban areas. When we compare Model 3 and 4, where Model 4 includes school size, we see the sign reversed for rural/town. This can imply that among schools of similar sizes, rural and town schools are more likely to offer CS than urban schools.

8 DISCUSSION

The results from our first research question affirm that CS teachers are largely isolated at their school and experience isolation at higher rates than teachers of most other subjects. 30% of CS teachers in the last year of our dataset were also isolated in their district. These results indicate capacity issues at a district level, and an access and experience issue at a district and school level. Capacity can in part be addressed through policy changes such as requiring every school to offer CS and then offering dedicated funding for such initiatives. Additionally, while this does not fully address issues caused by isolation, providing teachers with resources and support may improve student experience.

Reducing teacher isolation through providing more avenues for teacher social networks has been shown to improve work experience [7] and can lead to better student outcomes [2]. When hiring new staff is not possible, districts and states can attempt to compensate for isolation at a school by providing professional development and CS teacher communities. There is evidence that supports that professional development positively impacts student performance [2, 13], including when teachers are tasked with teaching a new curriculum [19]. To provide professional development equitably,

²Although not the focus of our analysis, we also looked at isolation at a district level and found that 30% of CS teachers were isolated in their district.

Table 1: Isolation, course offering, school and student factors

	Independent variable	Model 0	Model 1	Model 2	Model 3	Model 4
No CS Offered	Percentage minority	-0.0011*** (0.0003)	0.0008** (0.0003)	0.0012. (0.0006)	-0.0009** (0.0003)	0.0006* (0.0003)
	Percentage receiving FRPL	0.0023*** (0.0003)	0.0004. (0.0003)	-0.0005 (0.0003)	0.0021*** (0.0003)	0.0006* (0.0002)
	Percentage ELL	0.0026*** (0.0004)	0.0018*** (0.0004)	0.0019*** (0.0005)	0.0026*** (0.0004)	0.0018*** (0.0004)
	School Size	—	-0.0204*** (0.0008)	-0.0142*** (0.0022)	—	-0.0212*** (0.0009)
	School Size^2	—	0.0001 (0.0000)	0.0002. (0.0001)	—	0.0001* (0.0000)
	Urban	—	—	—	-0.0032 (0.0126)	-0.0007 (0.0010)
	Rural/Town	—	—	—	0.0363* (0.0146)	-0.0497*** (0.0134)
Isolated CS Teacher	Percentage minority	0.0007** (0.0002)	-0.0004. (0.0002)	-0.0016** (0.0006)	0.0006* (0.0002)	-0.0002 (0.0002)
	Percentage receiving FRPL	-0.0016*** (0.0002)	-0.0005* (0.0002)	-0.0000 (0.0003)	-0.0015*** (0.0002)	-0.0007** (0.0002)
	Percentage ELL	-0.0016*** (0.0003)	-0.0012*** (0.0003)	-0.0009. (0.0005)	-0.0016*** (0.0003)	-0.0012*** (0.0003)
	School Size	—	0.0124*** (0.0007)	0.0055** (0.0018)	—	0.0131*** (0.0007)
	School Size^2	—	-0.0001** (0.0000)	-0.0001 (0.0001)	—	-0.0131*** (0.0007)
	Urban	—	—	—	-0.0001 (0.0093)	-0.0002 (0.0085)
	Rural/Town	—	—	—	-0.0124 (0.0120)	0.0413*** (0.0115)
2+ CS Teachers	Percentage minority	0.0004** (0.0001)	-0.0004** (0.0001)	0.0004 (0.0004)	0.0003. (0.0001)	-0.0004** (0.0001)
	Percentage receiving FRPL	-0.0007*** (0.0001)	0.0000 (0.0001)	0.0005** (0.0002)	-0.0006*** (0.0001)	0.0000 (0.0001)
	Percentage ELL	-0.0010*** (0.0002)	-0.0006*** (0.0002)	-0.0010*** (0.0003)	-0.0010*** (0.0002)	-0.0006*** (0.0002)
	School Size	—	0.0080*** (0.0005)	0.0086*** (0.0014)	—	0.0081*** (0.0005)
	School Size^2	—	0.0000 (0.0000)	-0.0001 (0.0001)	—	0.0000 (0.0000)
	Urban	—	—	—	0.0033 (0.0063)	0.0099 (0.0056)
	Rural/Town	—	—	—	-0.0240*** (0.0066)	0.0083 (0.0063)
	Year FE	X	X	X	X	X
	School FE	—	—	X	—	—

Note. Standard errors clustered on schools in parentheses. FEs = Fixed effects. Adjusted R^2 varied from 0.04-0.43. + $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

they can provide incentives for teachers to attend these. Such incentives or virtual options may be important for teachers far from the meeting location.

School size is a positive predictor of there being one or more CS teachers but is not frequently considered in analyses of this kind. School size is an understandable capacity and access constraint that

can potentially be addressed by policy change. However, inequity in CS access by race/ethnicity remains even after controlling for urbanicity, students' average socioeconomic status, and school size. This indicates that differences in access cannot be fully explained by factors such as the Small Schools Movement. This supports existing

efforts to address inequity by race/ethnicity and previous research that has highlighted disparities by race/ethnicity.

9 CONCLUSION

Despite teacher isolation being reported as one of the biggest challenges for CS teachers in the US, the extent of CS teacher isolation has not been documented beyond teachers' self-report. Using data from California, we determine how CS teacher isolation has varied over time and how this variation compares to teachers in other subjects. We use linear regression to determine what factors affect the likelihood of CS being offered or there being an isolated CS teacher. We find that CS teachers do experience a higher rate of isolation when compared to other subjects. We also find that school size is a positive predictor of the presence or quantity of CS teachers. However, even when controlling for school size, schools with higher representation of students from groups underrepresented in computing are less likely to offer CS at all. These findings suggest that policymakers should support efforts to reduce the impact of teacher isolation, such as professional development. It also illustrates that more work is needed to provide students equitable access to CS.

REFERENCES

- [1] Betty Achinstein, Rodney T Ogawa, Dena Sexton, and Casia Freitas. 2010. Retaining teachers of color: A pressing problem and a potential strategy for “hard-to-staff” schools. *Review of Educational Research* 80, 1 (2010), 71–107.
- [2] Motoko Akiba and Guodong Liang. 2016. Effects of teacher professional learning activities on student achievement growth. *The Journal of Educational Research* 109, 1 (2016), 99–110.
- [3] Elaine Allensworth, Stephen Ponisciak, and Christopher Mazzeo. 2009. The schools teachers leave: teacher mobility in Chicago public schools. *Consortium on Chicago School Research* (2009), 52 pages.
- [4] Ken Appleton. 1998. Putting Rurality on the Agenda: Beginning Teachers in Rural Schools. (1998), 8 pages.
- [5] Kira J Baker-Doyle. 2012. First-year teachers' support networks: Intentional professional networks and diverse professional allies. *The New Educator* 8, 1 (2012), 65–85.
- [6] Albert Bandura. 1993. Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist* 28, 2 (1993), 117–148.
- [7] Joan Barnatt, Dianna Gahlsdorf Terrell, Lisa Andries D'Souza, Cindy Jong, Marilyn Cochran-Smith, Kara Mitchell Viesca, Ann Marie Gleeson, Patrick McQuillan, and Karen Shakman. 2017. Interpreting early career trajectories. *Educational Policy* 31, 7 (2017), 992–1032.
- [8] Alfredo Bautista, Ann Marie Stanley, and Flavia Candusso. 2021. Policy strategies to remedy isolation of specialist arts and music teachers. *Arts Education Policy Review* 122, 1 (2021), 42–53.
- [9] Catherine G Bell-Robertson. 2014. “Staying On Our Feet” Novice Music Teachers' Sharing of Emotions and Experiences Within an Online Community. *Journal of Research in Music Education* 61, 4 (2014), 431–451.
- [10] Ruha Benjamin. 2020. *Race After Technology: Abolitionist Tools for the New Jim Code*. Oxford University Press.
- [11] Dan Berebitsky and Serena J Salloum. 2017. The relationship between collective efficacy and teachers' social networks in urban middle schools. *AERA Open* 3, 4 (2017).
- [12] Paul Bruno and Colleen M. Lewis. 2022. Computer Science Trends and Trade-offs in California High Schools. *Educational Administration Quarterly* 58, 3 (2022), 386–418. <https://doi.org/10.1177/0013161X211054801>
- [13] Patricia F Campbell and Nathaniel N Malkus. 2011. The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal* 111, 3 (2011), 430–454.
- [14] CBS. 2022. OUSD School Closures Would Dismantle “Small School Movement” That Created Them. <https://www.cbsnews.com/sanfrancisco/news/ousd-school-closures-would-dismantle-small-school-movement-that-created-them/>
- [15] J Century, M Lach, H King, S Rand, C Heppner, B Franke, and J Westrick. 2013. *Building an Operating System for Computer Science*. Technical Report. CEMSE, University of Chicago with UEI, Chicago, IL. https://d30clwvkkpijyx.cloudfront.net/teacher_capacity_study/teacher_capacity_study_report.pdf
- [16] Code.org, CSTA, and ECEP Alliance. 2022. 2022 State of Computer Science Education: Understanding Our National Imperative. <https://advocacy.code.org/>
- stateofcs
- [17] Bryan Cox, Lauren Margulieux, and Jennifer Darling-Aduana. 2022. Georgia online education option for broadening participation in K-12 computer science. *Policy Futures in Education* (2022).
- [18] Leigh Ann DeLyser, Joanna Goode, Mark Guzdial, Yasmin Kafai, and Aman Yadav. 2018. *Priming the computer science teacher pump: Integrating computer science education into schools of education*. Technical Report. CSforAll. <https://www.csfored.org/report2018>
- [19] Yaron Doppelt, Christian D Schunn, Eli M Silk, Matthew M Mehalik, Birdy Reynolds, and Erin Ward. 2009. Evaluating the impact of a facilitated learning community approach to professional development on teacher practice and student achievement. *Research in Science & Technological Education* 27, 3 (2009), 339–354.
- [20] Nathan L Ensmenger. 2010. Making programming masculine. In *Gender codes: Why women are leaving computing*. John Wiley & Sons, Inc., Hoboken, NJ, USA, Chapter 6, 115–141.
- [21] Nathan L Ensmenger. 2012. *The computer boys take over: Computers, programmers, and the politics of technical expertise*. MIT Press, Cambridge, MA, USA.
- [22] Virginia Eubanks. 2018. *Automating inequality: How high-tech tools profile, police, and punish the poor*. St. Martin's Press.
- [23] Carol L. Fletcher and Jayce R. Warner. 2021. CAPE: a framework for assessing equity throughout the computer science education ecosystem. *Commun. ACM* 64, 2 (Jan. 2021), 23–25. <https://doi.org/10.1145/3442373>
- [24] National Center for Education Statistics. [n.d.]. Locale classifications. <https://nces.ed.gov/programs/edge/Geographic/LocaleBoundaries>
- [25] Lucinda Gray and Soheyla Taie. 2015. Public School Teacher Attrition and Mobility in the First Five Years: Results from the First through Fifth Waves of the 2007-08 Beginning Teacher Longitudinal Study. First Look. NCES 2015-337. *National center for education statistics* (2015).
- [26] C Kirabo Jackson and Elias Bruegmann. 2009. Teaching students and teaching each other: The importance of peer learning for teachers. *American Economic Journal: Applied Economics* 1, 4 (2009), 85–108.
- [27] Susan M Johnson, Matthew A Kraft, and John P Papay. 2012. How context matters in high-need schools: The effects of teachers' working conditions on their professional satisfaction and their students' achievement. *Teachers College Record* 114, 10 (2012), 1–39.
- [28] Angela M Kelly and Keith Sheppard. 2009. Secondary school physics availability in an urban setting: Issues related to academic achievement and course offerings. *American Journal of Physics* 77, 10 (2009), 902–906.
- [29] Angela M Kelly and Keith Sheppard. 2010. The relationship between the urban small schools movement and access to physics education. *Science Educator* 19, 1 (2010), 14–25.
- [30] Cory Koedel and Eric Parsons. 2021. The Effect of the Community Eligibility Provision on the Ability of Free and Reduced-Price Meal Data to Identify Disadvantaged Students. *Educational Evaluation and Policy Analysis* 43, 1 (2021), 3–31. <https://doi.org/10.3102/0162373720968550>
- [31] Colleen M. Lewis. 2017. *Good (and Bad) Reasons to Teach All Students Computer Science*. Springer International Publishing, Cham, 15–34. https://doi.org/10.1007/978-3-319-54226-3_2
- [32] Safiya Umoja Noble. 2018. *Algorithms of oppression*. New York University Press.
- [33] California Department of Education. [n.d.]. State minimum high school graduation requirements. <https://www.cde.ca.gov/ci/gs/hs/hsgsrmin.asp>
- [34] Susan Kemper Patrick. Unpublished. All By Myself? Instructional Isolation and Teachers' Collaborative Learning Opportunities. *Unpublished Manuscript* (Unpublished).
- [35] Joy Lisi Rankin. 2018. *A people's history of computing in the United States*. Harvard University Press.
- [36] Jean Ryoo, Joanna Goode, and Jane Margolis. 2015. It takes a village: Supporting inquiry-and equity-oriented computer science pedagogy through a professional learning community. *Computer Science Education* 25, 4 (2015), 351–370.
- [37] Matthew Shirrell. 2021. On their own? The work-related social interactions and turnover of new teachers. *American Journal of Education* 127, 3 (2021), 399–439.
- [38] Matthew Shirrell and Michelle Reininger. 2017. School working conditions and changes in student teachers' planned persistence in teaching. *Teacher Education Quarterly* 44, 2 (2017), 49–78.
- [39] James P Spillane, Matthew Shirrell, and Samrachana Adhikari. 2018. Constructing “experts” among peers: Educational infrastructure, test data, and teachers' interactions about teaching. *Educational Evaluation and Policy Analysis* 40, 4 (2018), 586–612.
- [40] Carol Sue Englert and Kathi L Tarrant. 1995. Creating collaborative cultures for educational change. *Remedial and special education* 16, 6 (1995), 325–336.
- [41] Min Sun, Susanna Loeb, and Jason A Grissom. 2017. Building teacher teams: Evidence of positive spillovers from more effective colleagues. *Educational Evaluation and Policy Analysis* 39, 1 (2017), 104–125.
- [42] Jonathan A Supovitz and Jolley Bruce Christman. 2003. Developing communities of instructional practice: Lessons from Cincinnati and Philadelphia. (2003).
- [43] USDA. [n.d.]. <https://fns-prod.azureedge.us/sites/default/files/cn/CEFactsheet.pdf>

- [44] Jennifer Wang and Sepehr Hejazi Moghadam. 2017. Diversity barriers in K-12 computer science education: Structural and social. In *Proceedings of the 2017 ACM SIGCSE technical symposium on computer science education*. 615–620.
- [45] Jayce R Warner, Joshua Childs, Carol L Fletcher, Nicole D Martin, and Michelle Kennedy. 2021. Quantifying disparities in computing education: Access, participation, and intersectionality. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*. 619–625.
- [46] Jayce R Warner, Carol L Fletcher, Nicole D Martin, and Stephanie N Baker. 2022. Applying the CAPE framework to measure equity and inform policy in computer science education. *Policy Futures in Education* (Feb. 2022). <https://doi.org/10.1177/14782103221074467> Publisher: SAGE Publications.
- [47] Stuart Zweben and Betsy Bizot. 2022. 2021 Taulbee survey. *Computing Research News* (2022). <https://cra.org/wp-content/uploads/2022/05/2021-Taulbee-Survey.pdf>