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Minding the Gap: Methods for Understanding Teacher Capacity when Developing High School Computer Science Graduation Requirements

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Minding the Gap: Methods for Understanding Teacher Capacity when Developing High School Computer Science Graduation Requirements (Work in Progress)

Abstract:
This evaluation Work In Progress paper advances the discussion of methods used for understanding computer science (CS) teacher capacity in the K–12 public school system in light of rapidly changing policy context. Between 2021 and 2024, eleven states created computer science graduation requirements for high school students, with more states planning to follow suit. Among many implementation challenges, ensuring and supporting sufficient teacher capacity to offer high quality and equitable CS is paramount but difficult. States are particularly concerned that a requirement include sufficient resources for building teacher capacity. In a country where education decisions are made at the state and local level, these calculations must factor in preservice and in-service professional development, credentialing, geographic dispersion of the state and the amount and type of computer science built into the policy. This paper provides a review of how five states are evaluating their teacher capacity to offer computer science, including their calculations and the opportunities and limitations associated with the approaches. The ultimate goal of this work is to provide robust and flexible guidance to other states to ensure that any policy is well planned and supported to promote equitable implementation.

Introduction

As states increasingly recognize computer science (CS) as essential for preparing students for the digital future, the push to make CS a graduation requirement has unveiled a significant challenge: the shortage of qualified CS teachers, especially in high schools. Teacher shortages are a universal problem [1], [2], [3] and are exacerbated in science, technology, engineering and math (STEM) fields, particularly for underserved schools [4]. As states propose CS policies [5], many groups are concerned with how well the state will be able to implement the policy.

One group that has explored this CS teacher shortage and policy concern is the Expanding Computing Education Pathways Alliance (ECEP), a National Science Foundation (NSF) Broadening Participation in Computing Alliance dedicated to increasing equitable capacity for, access to, participation in, and experiences of computing education. One of the many questions the community has taken up is teacher capacity. For the purposes of this paper, “teacher capacity” refers to the availability of an adequate number of teachers well-prepared to teach computer science, which includes their credentials and content knowledge. Specifically these states ask: How do we evaluate the gap in teacher capacity should our state pass a graduation requirement?

Pursuing a CS graduation requirement involves several interlocking challenges: defining CS and eligible courses, ensuring enough qualified teachers despite varying credentialing rules, monitoring implementation to address equity, and securing ongoing financial and personnel support to avoid uneven or short-lived outcomes.

The goal of this work in progress paper is to frame the ways in which a subset of ECEP states are grappling with evaluating the gap in teacher capacity in light of a potential graduation requirement. The school system in the United States values local control of education; therefore, this paper will provide examples for how states are assessing the capacity needed should CS become a graduation requirement, and how the computer science education (CSEd) community can build off of each other rather than endorse a model for calculation. We encourage others to use these examples as a starting point to understand their own needs.

This paper is particularly relevant to the Pre College Engineering Education community. Like engineering, CS has traditionally been offered as an elective course, if it is available at all [6]. In recent years, the push to expand access to more students, particularly through graduation requirements, means that more students, and potentially all, will have additional exposure to a technology-rich course. Research indicates that taking more units in CS significantly influences the decision to pursue STEM majors [6] and pre-college programming in particular can lead to greater self-efficacy in engineering [7].

Methodology

This study emerged from a set of conversations within the ECEP community. As part of an independent study being conducted in Massachusetts to make recommendations to the Department of Elementary and Secondary Education (DESE) concerning the feasibility of a graduation requirement for the state, the study team utilized the ECEP community for advice on how to calculate this gap. For the purpose of this paper, "teacher gap" is the number of additional teachers needed to ensure a graduation requirement can be fulfilled. Most simply it can be calculated by identifying the number of teachers needed to meet a graduation requirement (T_N), subtracting the number of teachers available to offer CS (T_A) to calculate the Teacher gap (T_G):

$$T_G = T_N - T_A$$

Leveraging an iterative refinement interview approach [8] the study team explored five states' approaches to calculating this gap. These five states have different perspectives and approaches, giving a breadth of historical and anticipatory reflection on CSEd policy. They were active participants in the ECEP-wide conversations. The team also utilized information collected through monthly ECEP Alliance calls in which states discussed these challenges.

Position Statement: The impetus for this work in progress emerged out of conversations with the Massachusetts team and the questions they brought to the larger community. The first author of this paper led the research in Massachusetts and is on the ECEP leadership team and the second author is the Director of the ECEP Alliance. This experience positioned the authors to recognize the need for understanding teacher capacity in light of policy changes but they are not in positional power to make any recommendations or changes.

Preliminary Findings or Insights

States with a CS requirement:

Nevada: Existing Technology Requirement
Since the 1990s, Nevada has required a ½ credit (1 semester) technology course for high school graduates. Originally focused on keyboarding and productivity skills, the course was redefined to a CS requirement after passage of Senate Bill 200 in 2017, shifting the course to include 50% CS and computational thinking and 50% technology applications (productivity tools), requiring the application of newly adopted CS standards.

Whereas T_C equals the number of teachers currently teaching the required technology course and T_T equals the number of teachers requiring CS training, Nevada calculated the teacher gap (T_G) for the CS graduation requirement as:

$$T_C = T_T = T_G$$

Teachers currently teaching the required technology course is equal to the number of teachers needing training ($T_C = T_T$) because all teachers need training to improve their ability to offer high quality computing to students that align with the newly adopted course requirements that include CS standards.

Many existing teachers of this course lacked the CS knowledge to teach the course. An abrupt implementation risked schools' ability to offer the course and thousands of students' ability to meet the graduation requirement. To ease the transition, an on-ramp approach was adopted with the graduating class of 2024 being the first to complete the updated ½ credit CS course requirement. Existing teachers could continue teaching the course, but professional development was strongly encouraged to fill knowledge gaps in CS. New teachers of the graduation requirement course were required to add one of the CS endorsements to their teaching license, which requires completion of college courses.

South Carolina: Repurposed ½ credit course
Similar to Nevada, South Carolina's existing technology course requirement for high school graduation opened the door for a CS requirement. Ironically, the required course was named "Computer Science" since the 1990s, but the course focused on keyboarding skills. A push to refine the definition of CS led to revised course content aligned with the new definition of CS and the new CS standards.

The calculation of the teacher gap in South Carolina mirrors that of Nevada, whereas the number of teachers currently teaching the required technology course (T_C) is the number of teachers needing computer science training (T_T) and also the teacher gap (T_G) in South Carolina:

$$T_C = T_T = T_G$$

There is significant flexibility in courses to meet the CS graduation requirement in South Carolina, including Exploring CS, CS Discoveries, and Fundamentals of Computing, helping schools adapt to their unique needs and resources, easing some of the challenges in filling teaching positions of the CS graduation requirement course. To address teacher shortages, Business Education teachers were repurposed or reassigned to fill CS teacher vacancies, with the caveat that those teachers complete professional development to ensure they were prepared to teach CS effectively. South Carolina partnered with the Computer Science Teachers Association (CSTA) to prepare CS teachers, requiring 30 hours of professional development focused on program-specific implementation, allowing teachers to focus on delivering the program materials. The concentration on practical, program-based training, helped address immediate gaps in teacher capacity for the CS graduation requirement.

States exploring a graduation requirement:

Hawai'i: Capacity: 140–150 teachers
To predict the number of teachers needed should a high school CS requirement go into effect, the Hawai'i Department of Education was advised to look at a comparable requirement. In Hawai'i there is one required unit and one elective unit of Physical Education (PE) to graduate. Each unit is 0.5 credits. By comparing the number of teachers who teach the one required unit PE course — supported by about 150 high school PE teachers across 47 high schools in academic year (AY) 22–23 — the state could make a clear, data-driven projection for CS teacher needs. This approach provides insights into their CS teacher pipeline by analyzing trends in PE teacher hiring, preparation, and support, offering a comparable framework to anticipate similar dynamics for a CS graduation requirement. However, the state needs to take into account that PE has one additional unit where students can elect which PE course to take to fulfill that requirement. Additionally, the state is also mindful of teacher professional development needed in CS and those teachers who might be teaching CS "out of field" in high school, middle, and elementary schools. An estimation of middle and elementary CS teachers requires different considerations.

$$T_G = T_N - T_A$$

Washington State: Capacity Need: 600 teachers
Washington State is considering a CS requirement in high school. In preparation for this potential change, CS education advocates estimated the number of teachers needed to support a new course requirement. As an initial approach to calculate the number of teachers needed, the state team used the following approach:

1) The assumption that the requirement would be met with a single high school CS course (which they acknowledge is not a sound assumption given the ambiguity of the law, but does offer the most feasible implementation path).
2) Determine the average number of graduating students in the state in a 4-year window (S).
3) Subtract the average number of high school students per year taking a CS course (currently about ~8% of WA students) (S_C).
4) Divide that average number of students by the state average class size of 27 (C).
5) Divide that by 4 courses, which is a full time teaching load, (L) to get the number of "teachers" needed to fill the teacher gap.

$$T_G = \left(\frac{S - S_C}{C}\right)/L = \left(\frac{S - S_C}{27}\right)/4$$

Massachusetts: Capacity need: 284 teachers needing training
Expanding on the Washington example, the Massachusetts team established a baseline of current student participation that includes students taking any Digital Literacy or Computer Science (DLCS) courses (approximately 30% of students during their 4 years of high school) instead of only considering the foundational CS classes reported by Code.org (7.9%) [4]. Although some DLCS courses may not fit an eventual definition of a "foundational" CS class, the state team assumed the transition of these existing courses to a CS course would be relatively lower cost than establishing a new course.

Upon review, however, the team decided to expand the model to consider what may be happening at the school level. Massachusetts, like other states, has both large urban schools and smaller rural schools, each with unique staffing needs. The new model examines each school in the state (excluding Chapter 74 schools which are stand-alone vocational-technical schools and which would likely be exempt from a graduation requirement) to calculate the number of full-time equivalent (FTE) teachers needed to ensure every high school student can take one DLCS course before graduation (See Table 1 for examples). This provides two critical pieces of information for budgeting purposes: 1) Guiding schools in planning coverage for CS classes, which could mean hiring a teacher or rescheduling an existing teacher to cover some CS sections and 2) The number of teachers who would need training. Additionally, in Massachusetts you must have a license to teach computer science if you are teaching it more than 20% of your time.

Table 1: Examples of school-level teacher need

School	**Class sections needed**	**FTE units needed**	**People needing training**	**Possible approach**
School A	1	.2	1	Have an existing teacher teach one class section of computer science, rather than another existing math, lab science, or elective class.
School B	9	1.4	2	Hire one teacher; re-assign an existing teacher
School C	4	.8	1	Hire a teacher predominantly to teach foundational computer science, and also one extra elective (higher level computer science, digital art, music production, etc)
Total	**12**	**2.4**	**4**	

For each district (D) the number of students taking CS across grades 9–12 (S_C) was identified and subtracted from the total number of students in the school (S) to identify the number of students not in a CS class. That number was then divided by the number of grades in the school (G) to get an average yearly number of additional students who would need to take CS. This number was then divided by 115 (average of 23 students per class × 5 classes per teacher) to get the number of additional teachers needed.

$$T_G = \sum_D \left(\left(\frac{S - S_c}{G} \right) / (23 \times 5) \right)$$

With the assumptions presented above, the team calculated a gap of the cumulative equivalent of 140.6 courses to be covered across the state. Within a school, however, many teachers could have a fractional CS position (not teaching CS full time). See table 2 for an example of this calculation. Therefore, 284 unique individuals would need professional development in CS. The approach resulted in a similar number to Washington state for teachers to be trained, but a lower burden on the number of full-time teachers needed. The number of fractional teachers needed might be low as some schools may choose to hire a teacher rather than reallocate an existing teacher's time but it gives a starting point for understanding the statewide burden.

Table 2: Class section calculation School A example

<table>
<tr><td colspan="5">Students taking CS</td><td rowspan="2">Total students in School A</td></tr>
<tr><td>9th grade</td><td>10th grade</td><td>11th grade</td><td>12th grade</td><td>Total</td></tr>
<tr><td>85</td><td>100</td><td>60</td><td>60</td><td>305</td><td>1,240</td></tr>
<tr><td colspan="6">1,240 total students − (4 years × 305 students per year) = 20 additional students would need a CS class.

One additional section of CS per year would be needed to ensure all students are able to participate in a CS course once during their 4-year high school experience.</td></tr>
</table>

The Massachusetts team notes that these calculations would provide enough sections of CS for students to meet meet the requirement, and does not allow for the additional capacity to offer additional or advanced pathway CS courses

Discussion and Next Steps

Through shared experiences, collaborative problem solving, and access to expertise, the ECEP community has been invaluable for states as they consider complex policy options. The conversations about teacher capacity have only begun. Additional questions states are exploring that influence this teacher calculation model are:

- How many current teachers are close to retirement? This will help plan for long-term sustainability for teacher preparation and classroom investment.
- When in the high school curriculum should a foundational class be taught? If for example the requirement is for all freshmen or all sophomores versus any time in high school, the teacher needs may change.
- What is the role of an out-of-field placement on teacher capacity?
  - If an existing teacher offers one class section of computer science, it is important to understand when the class is a swap (elective) versus replacing a required class (math).
  - Could there be an equity issue if students are taking the course from a teacher who is not as knowledgeable or licensed in computing?
- What are the consequences of removing elective courses (including elective CS) to accommodate CS?

- When would the requirement take effect? During transition years there might be a need for more teachers to accommodate all students that are more advanced in their studies (juniors and seniors) and might need a CS course to graduate.
- How do we incentivize individual teachers to develop their CS teaching capacity? There are many PD opportunities in place for CS teachers but they are often undersubscribed.

Enacting a CS graduation requirement without carefully assessing the number of teachers needed and their readiness to teach the course undermines equity in CS education and the ongoing support available to those CS teachers. Insufficient or unprepared teachers can lead to inconsistent or substandard learning experiences, disproportionately affecting students in under-resourced schools, thereby widening existing gaps in access to quality education and access to a high school diploma.

CS teacher capacity goes beyond credentials and content knowledge. Other factors such as working conditions, compensation, school resources and culture influence the ability of a system to attract, train, employ, retain and support computer science teachers [3]. Additional factors such as where computer science fits into education preparation programs (pre-service teacher training) should also be considered.

True to the ECEP guiding principles, equity is always centered in these conversations. State teams are engaged in deep conversations that consider how to address the teacher gap so that districts, schools, teachers and students are well supported to ensure equitable access, participation and experiences.

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