Understanding Computer Science Teacher Capacity: A Case Study of Wisconsin Public High Schools

Sujeeth Goud Ramagoni
Department of Computer Science
Marquette University
Milwaukee, WI
sujeethgoud.ramagoni@marquette.edu

Dennis Brylow
Department of Computer Science
Marquette University
Milwaukee, WI
dennis.brylow@marquette.edu

Abstract—*Background:* **This research paper focuses on synthesizing state-level data sources on Computer Science (CS) education by creating algorithmic processes to aggregate the various data sources available. The expanding landscape of CS education (CSE), particularly at the high school level, has witnessed significant growth in participation in CS courses. However, to effectively prepare students for careers in engineering and computing fields, it is imperative to ensure the presence of highly qualified teachers to educate and guide them from the foundational level. Utilizing the C.A.P.E. theoretical framework, our research introduces a methodology to understand the CSE landscape through the lens of the teacher capacity model in WI public high schools.**

Research Question: **This research outlines a case study of Wisconsin (WI) public high schools, primarily focusing on utilizing the C.A.P.E. framework to answer: What methodological process should be considered to measure equity-focused capacity, access, and participation of the CSE landscape for WI public high schools?**

Methodology: **We obtained data from the WI Department of Public Instruction (DPI), encompassing course enrollment, student demographics, teacher certification, and staff reports. The data spans Academic Years (AY) 2017 through 2023. For consistent data reporting, our analysis focuses on 503 public high schools in WI, supplemented by data from the National Center for Education Statistics (NCES). This integration of data sources can offer valuable insights into the CSE landscape at the state level.**

Findings: **Access to certified CS teachers positively coincides with higher participation in CS courses across diverse racial and ethnic groups of the WI public high school student population. However, our analysis reveals a critical shortage of CS teachers, with nearly 40% of certified teachers in public high schools having over 25 years of teaching experience, suggesting an impending wave of retirements within the next 5-10 years.**

Contribution: **Our objective is to provide a case study of WI public high schools by integrating noisy and unlinked data sources to understand the algorithmic process we followed to grasp the meaning of the CSE landscape. This analysis can help guide stakeholders and policymakers in allocating resources to alleviate inequities and shortfalls in the current CSE landscape, aiming to secure increased funding and expanded opportunities for CSE.**

Index Terms—**C.A.P.E. framework, Capacity, Certification, CS teacher, Equity, DPI**

I. Introduction

The field of Computer Science (CS) is growing rapidly and has become the top source of new wages in the United States. The U.S. Bureau of Labor Statistics projects that jobs in STEM fields are expected to grow by 8% by 2029 [1], making CS-related jobs in high demand. However, a global shortage of tech workers emphasizes the need for efforts in secondary and post-secondary education [2]. In the U.S., students who learn CS in high school are six times more likely to major in CS in their post-secondary education, and women are ten times more likely [3]. This indicates the crucial need for computer science education (CSE) at the high school level to prepare post-secondary students in CS better, thereby reinforcing the tech workforce to meet the demands of ever-evolving technology.

In the past decade, the state of Wisconsin (WI) has achieved significant milestones in enhancing student access to CS and Computational Thinking (CT) curricula across all grade levels. Notably, in 2017, WI approved K-12 CS Academic Standards [4], joining the 41 states that had already implemented CS standards by 2023 [5]. Moreover, a legislative amendment in 2017 enabled a CS course to fulfill minimum high school graduation requirements in WI. By 2021, all 50 states and the District of Columbia had adopted similar measures, except for 13 states where graduation credit for CS courses is contingent upon district policies. Eight states now mandate all students to complete a CS course for high school graduation, while 30 states mandate the provision of CS courses in all high schools [5].

According to the 2023 CODE Report, in 35 states with available high school enrollment data, foundational CS courses account for 5.8% of total student enrollment [5]. In WI, public high schools experienced a notable 5% increase in participation for CS courses during the 2017-2023 Academic Years (AY), with nearly 60% of public high schools having access to CS courses by 2023 AY.

In a significant change from earlier eras, the most recent decade of computing and CS education innovations has produced a world in which nearly all high schools in WI can afford enough devices for their students to have routine access to Chromebooks or other inexpensive PCs, laptops, or tablet computers. Specialized and expensive software is no longer a prerequisite to teaching CS in the classroom. For these reasons, we will focus on understanding the CSE landscape through the lens of the teacher capacity model from the state Department of Public Instruction (DPI - the name of our state Department of Education). The following research questions frame our exploration of the CSE landscape in WI:

1) What is the algorithmic process to aggregate the data to understand the CSE landscape for WI public high schools?
2) Utilizing the C.A.P.E. theoretical framework:
   a) Capacity: How equitably distributed is the existing supply of certified CS teachers across different locales within the state? How does the CS teacher capacity differ by school size and locality?
   b) Access: How accessible are the certified CS teachers in WI public high schools based on their school sizes? How does the categorization of schools based on the presence of an active certified CS teacher influence student enrollment in CS courses based on locality?
   c) Participation: What is the breakdown of student demographics representing equitable participation in CS enrollment with and without certified CS teacher presence? How is the distribution of student gender in CS courses affected by the presence of certified CS teachers?

Our research exists in the context of a statewide project with the overall objective to understand the CSE landscape through the lens of the teacher capacity model. State reporting on CS enrollment is relatively new, and there has been minimal effort from the state to synthesize a high-level overview of CSE using this data. This research paper presents algorithmic processes for identifying high schools, student enrollment in foundational CS courses, demographics, and active certified CS teachers for AYs 2017-2023 to give a holistic view of the CSE landscape in WI. This paper contributes to the CSE research community by providing the context of a case study from WI to measure capacity, access, and participation with data available from DPI. We hope this research will benefit policymakers and stakeholders in WI and serve as a guide for other states seeking to understand and address their CS teacher capacity.

II. Prior & Related Work

A. C.A.P.E. Theoretical Framework

This study is founded upon the C.A.P.E. (Capacity, Access, Participation, and Experience) framework, tailored to investigate systemic and structural inequities concerning broadening participation (BPC) in CSE topics [6]. The C.A.P.E. framework proposes a comprehensive approach to investigating equity issues within education, emphasizing the examination of institutional capacity to deliver high-quality CSE through training and certifying teachers, the accessibility of CS opportunities afforded to students, the barriers hindering student participation in CS courses, and the actual experiences students encounter within their CS classrooms. This framework has gained traction as a valuable tool within the CSE research community, aiding researchers in examining equity in CSE landscape. In the U.S., references to the C.A.P.E. framework have surfaced in various analyses, spanning topics such as preservice training for CS teachers [7], state-level funding allocations for the expansion of CSE [8], the integration of CS into elementary school curricula [9], the inequities of student enrollment in CS courses [10], and the examination of gender disparities within higher levels of high school CS courses (AP CS Exams) [11].

A recent study identified that there are over 300 factors that contribute to each level of the C.A.P.E. framework [12]. In another study [13], the authors examine this framework at a deeper level to understand the subcomponents that affect the 'Capacity' level of the framework. The eight subcomponents are grouped into multiple categories that encompass the Capacity of the CSE ecosystem. This paper suggests a unique approach to understanding the CS teacher capacity at the state level, specifically focusing on the "Human Resource" subcomponent within the 'Teacher' categories. It is important to acknowledge that capacity is a foundational element influencing other aspects of the C.A.P.E. framework. This paper provides a quantitative analysis that utilizes data from WI DPI and publicly available sources to understand the 'Teacher' categories of the Capacity model. No prior work has been done at the state level to measure the C.A.P.E. framework through the lens of the teacher capacity model. We propose a methodology describing the process of data collection, manipulation, and analysis to gain a detailed understanding of the Capacity model.

B. CS Teacher Certification

The Computer Science Teachers Association (CSTA) has examined the issue of CS teacher certification in the United States and found it to vary greatly across the states [14], [15]. Many states have struggled to develop rigorous standards and expectations for teacher certification [16].

The certification requirements have evolved over the past decade in the United States in response to both a tightening overall teacher supply and heightened awareness of the growing importance of CS. A report from Expanding Computing Education Pathways (ECEP) Alliance [17] found that 12 states and the District of Columbia have approved preservice CS teacher preparation programs, and 30 states offer CS teacher certification programs [18]. In Indiana, teachers in the previous decade could teach CS with Computer Education, Business, or Career and Technical Education certifications. The requirements have evolved, resulting in teachers now being required to hold a specific CS certificate [19].

For any of the core courses (e.g. English, Math, Science, and Social Studies), teachers are required to be certified to teach their subject area. For over 30 years, WI has required that CS teachers hold a (1405/405) CS certification [20] to teach CS courses in public high schools. A certificate in CS for a teacher demonstrates that the individual has mastered the content and pedagogical standards specific to CS [21]. The certification requirement is mandated by WI state law; local educational authorities can be audited to comply with certification requirements and are frequently audited for core subjects. In practice, the system is not cracking down on off-certificate teaching of CS because of ongoing teacher shortages and the perceived greater importance of policing core subjects. High schools encounter challenges locating certified CS teachers, primarily due to the absence of well-defined pathways for teacher certification and the allure of high-paying industry positions that often divert individuals away from careers in education [22]. WI provides only two pathways for individuals to become certified in CS [23]: *Initial Teacher* [24] and *Additional Subject Area* Pathways [25], [26].

III. Methodology

The WI DPI serves as the primary entity responsible for collecting education data. DPI gathers and maintains essential information, such as teacher certification, staff assignments, student enrollment, and demographics. Moreover, DPI can provide more detailed, confidential data upon request, subject to appropriate safeguards (IRB approval). These data sources offer valuable insights into the questions outlined in this paper. Our methodology presents a case study suited for WI public high schools to measure the CSE landscape. We created five algorithmic processes to manipulate and aggregate unlinked data sources. While these processes can be replicated in other states, it may require additional steps as each state has a unique case in the data collection process. Some states may already possess clearly structured and linked data sources to understand and measure the CSE landscape.

A. Data Sources

Acquiring data through DPI to understand the CSE landscape presented challenges. The data sources used for this paper are not typically accessed at DPI; instead, they are primarily intended for budgeting or other reporting purposes. The lack of proper data structure made it difficult to clean, manipulate, and aggregate these sources. Despite DPI not having data pre-processing techniques in place, we identified appropriate algorithmic processes leveraging these data sources to understand and measure the CSE landscape in WI.

With IRB approval, we used the DPI public data request protocol to access “Confidential Data”. These “Confidential Data” included *Course Enrollment*, *Teacher Certification* (specifically for CS), *Student Enrollment*, and *Student Demographics* data sources. Additionally, we gathered two data sources that are publicly available *DPI All-Staff Report* [27] and *National Center for Education Statistics* (NCES) [28].

These data sources span the Academic Years (AYs) 2017 through 2023, providing a comprehensive overview of the high school CSE landscape in WI. Each year, between May and July, we expect to receive new data from the previous AY. This is why our data ends at the 2022-23 AY; we anticipate receiving data for the 2023-24 AY by the summer of 2025. The following section details the algorithmic processes to aggregate the above data sources. The ultimate objective of our process is to construct a single “Master Data” set that accurately represents the CSE landscape of WI public high schools.

B. Data Aggregation Algorithmic Process

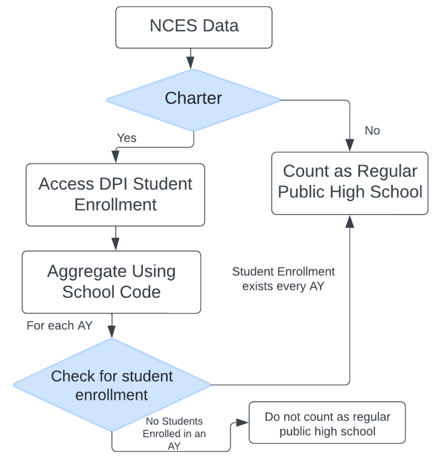

Fig. 1. Identifying Regular Public High Schools in WI

To ensure we use the most accurate data, our focus is on high schools (grades 9-12) in the state. An initial review of the list of high schools reveals that the DPI gathers data from virtual, vocational, and charter schools. Although these schools should be counted as high schools, some of these schools lack a physical building, and their inconsistent enrollment can lead to them shutting down during certain AYs. This inconsistency in enrollment and occasional shutdowns disrupts our ability to accurately answer the seemingly simple question: *What percentage of high schools teach CS in the state?* The total number of schools serves as the baseline denominator for this calculation. To clarify this uncertainty, we used a subset of the National Center for Education Statistics (NCES) data source [28], which exclusively gathers data on *regular public high schools* across the country. Regular public high schools, funded through public means and accounting for a significant portion of student enrollments, keep the school building open each AY and present more consistent data.

In Figure 1, we represent a flowchart of the algorithmic process to clean, manipulate, and aggregate NCES data to get a list of public high schools in WI. Upon initial observation, we noted that NCES categorizes virtual and charter schools as regular public high schools, totaling 582 schools. We created an algorithmic process that if the school is labeled as ‘Yes’ for the ‘Charter’ variable from the NCES data, then aggregate the ‘School Code’ variable from NCES dataset with the *Overall Student Enrollment* data to identify whether the charter school had any students enrolling at the school for each AY. If students were enrolled at the charter school for each AY, it is counted as a Regular Public High School and added to the list. Through this process, the “Master Data” centers around the 503 regular public high schools in WI. For the following processes, we will aggregate other data sources based on the ‘School Code’ variable in the “Master Data.”

in the “Master Data” for AYs 2021-2023.

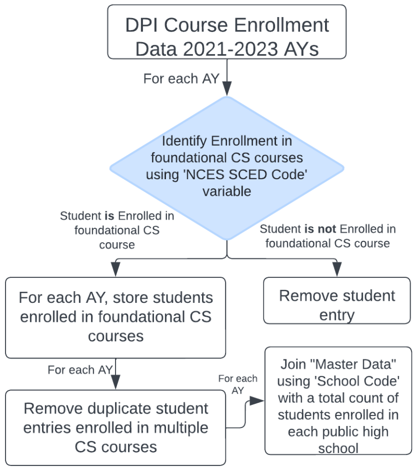

Fig. 2. Identifying Students Enrolled in a CS course from AYs 2021-2023

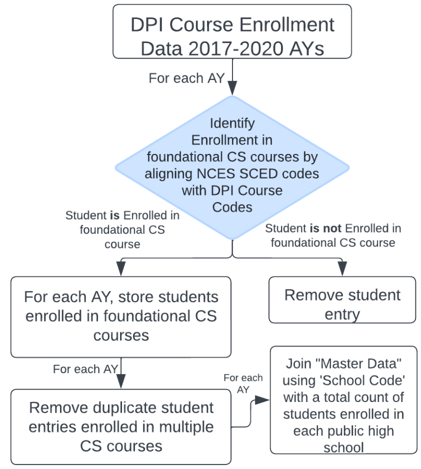

Fig. 3. Identifying Students Enrolled in a CS course from AYs 2017-2020

To ensure proper access to *Course Enrollment* data, DPI staff requested that we specify the ‘Course Subject Area.’ Our initial request focused on accessing CS course enrollment data. After discussions with DPI, it was revealed that there is no specific value in the ‘Course Subject Area’ variable with the value of ‘Computer Science.’ Rather, there is a value of ‘Computer and Information Sciences,’ and DPI staff noticed that CS courses could be listed under the values of ‘Engineering and Technology’ and ‘Computer Math for Algebra.’ To understand this discrepancy and ensure accurate measurement of CS courses, we have requested *K-12 Course Enrollment* data with student enrollment in all classes from AYs 2017 through 2023.

The 2023 CODE Report defines a “Foundational CS Course” as one that includes a minimum amount of time (at least 20 hours for grades 9-12) devoted to programming, aligning with the broader definition of computer science [5]. Although our data sources do not provide direct measures of programming hours, the report offers a valuable method that we adapted to our data sources using ‘NCES SCED’ Codes.

Figure 2 depicts the algorithmic process to identify foundational CS course enrollment for AYs 2021 through 2023. Starting from the 2020-21 AY, DPI altered the data collection structure for *Course Enrollment* data. For AYs 2021-2023, a variable named ‘NCES SCED Code’ was introduced. This code, part of the School Courses for the Exchange of Data (SCED) system used by NCES, facilitates the maintenance of longitudinal data on student coursework and the efficient exchange of course-taking records across states. SCED is based on a five-digit Course Code to categorize course content [29]. We used the ‘NCES SCED Code’ variable to align with the SCED codes referenced in the 2023 CODE Report [5], which allowed us to identify students enrolled in a foundational CS course. Once students are identified, duplicate student entries are removed and aggregated with the ‘School Code’ variable in the “Master Data” for AYs 2021-2023.

Figure 3 outlines the algorithmic process to identify students enrolled in foundational CS courses during 2017 through 2020 AYs. For these AYs, there was no direct connection between *Course Enrollment* data and ‘NCES SCED Code’ variable. However, we aligned the ‘NCES SCED’ Codes from 2021 AY with the DPI assigned ‘Course Code’ variable, allowing us to measure foundational CS courses reported in 2023 CODE report [5] for AYs 2017 through 2020. To ensure accuracy and equity, duplicate student entries were eliminated based on the ‘Student Key’ variable. Subsequently, for each AY, identified foundational CS course enrollments were aggregated with the “Master Data” using the ‘School Code’ variable. This allowed updating the “Master Data” with the total count of students enrolled in CS courses for each public high school and AY.

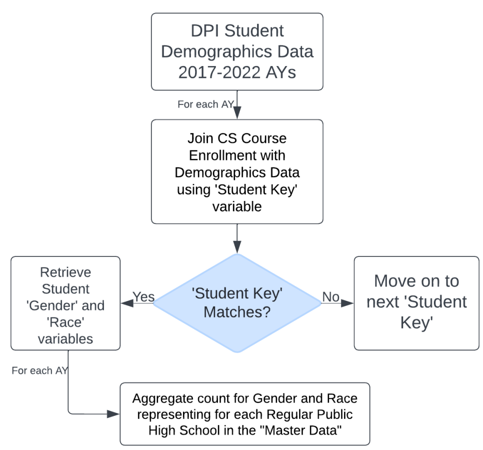

Fig. 4. Identifying Enrolled Student Demographics in Foundational CS

Figure 4 presents the demographic characteristics of students enrolled in foundational CS courses for each AY from 2017 to 2023. The ‘Student Key’ variable links *CS Course*

Enrollment data with *Student Demographics* data, allowing us to retrieve information on students' gender and race. Once identified, we aggregate this data with the 'School Code' variable into our "Master Data." This aggregation enables us to determine the total count of students representing each gender and race category for each public high school in WI, providing valuable insights into the demographic composition of CS course enrollment.

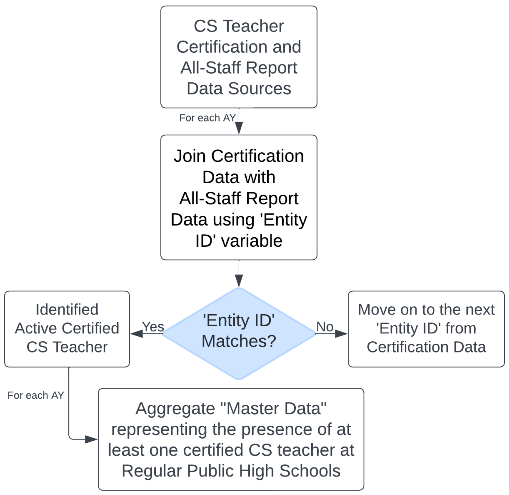

Fig. 5. Identifying Active Certified CS teachers as of the recent data

Figure 5 presents the algorithmic process of identifying "active" certified CS teachers in WI public high schools for each AY. When we say "active," we mean that the teacher holds a certification in CS and is actively teaching at a public high school. Through the DPI data request protocol, we obtained data on all teachers who have ever received certification in CS since 1980. To gather additional information, we developed a web scraping tool using Python to extract data from the publicly available *All-Staff Report* data for each AY, focusing specifically on 'Staff Assignment' data for teachers. This data provides comprehensive details about all teachers working at each public school for a specific AY, including gender, years of experience, highest degree attained, salary, and more. We integrated information about CS teachers from the *All-Staff Report* with the *Teacher Certification* Data, using a primary key known as the 'Entity ID,' a unique identifier assigned by DPI to each staff member in WI public schools.

To identify active certified CS teachers, we aggregated the 'Entity ID' from both the *All-Staff Report* and *Teacher Certification* data for each AY. If a match was found between the 'Entity ID' and a specific AY in the All-Staff Report, it indicated that the teacher was actively teaching at the assigned school. Using the 'School Code' variable, we aggregated the data into our "Master Data" to look for the presence of at least one certified CS teacher at each of the 503 regular public high schools for every AY.

IV. Findings

This section of the paper presents descriptive statistics/visualizations for capacity, access, and participation in the CSE landscape through the lens of the teacher capacity model. However, we are unable to measure the 'Experience' component of the framework due to a lack of additional data sources for assessing student experiences with enrolling in the CS courses. Our analysis is based on the algorithmic processes we developed. Although each state has its own data collection processes and policies, these methods may be applicable in other states where CSE researchers seek to collaborate with their Departments of Education to gain insights into the CSE landscape in their regions.

A. Capacity

TABLE I
Count of active certified CS teachers for each AY based on locale. More than 19% of the certified CS teachers have departed from the system in 7 academic years.

AY	City	Town	Rural	Suburb	Total	Net Δ
2016-17	75	71	118	103	367	
2017-18	70	64	118	106	358	-2.5%
2018-19	73	65	100	103	341	-4.7%
2019-20	62	62	97	99	320	-6.2%
2020-21	58	56	95	96	305	-4.7%
2021-22	61	52	98	99	310	+1.6%
2022-23	51	45	103	96	295	-4.8%
Net Δ	-32%	-36.6%	-12.7%	-6.8%	-19.6%	

To address *RQ2.A*, the locality for each school is determined using data from the National Center for Education Statistics (NCES), which defines locale as "a general indicator of the type of geographic area where a school is located" [30]. NCES further classifies this framework into three sub-sections for each school locale. For instance, city schools are categorized into small, midsize, and large sub-sections, where the Census Survey of Population determines each subsection. We simplified these sub-sections into four distinct locales within the state: *City*, *Town*, *Rural*, and *Suburb*. The distribution of the 503 regular public high schools is as follows: 86 schools in city areas, 91 in town, 249 in rural areas, and 77 in suburbs.

Table IV-A presents the number of active certified CS teachers in WI public high schools, categorized by locality and AY. Notably, over 19% of these certified CS teachers have left the system due to retirement, relocation, or transitioning to industry positions. The table highlights a net decrease in certified CS teachers from 2017 through 2023 AYs across all localities. Although there was a net increase of active certified CS teachers in the 2021-22 AY, our data indicates that 22 teachers still retired or moved out of the system, as deduced from their 'Total Years of Experience.' However, 27 teachers were either newly hired into the school, transferred from middle school to high school teaching positions, or obtained a new certification in CS. This analysis demonstrates that the certified CS teacher ecosystem is not static in Wisconsin; it is common for CS teachers to move. This highlights the need for policymakers and stakeholders to address teacher retention and improve pre-service teacher preparation programs, particularly given the number of certified CS teachers retiring or leaving the system within seven AYs.

TABLE II
TOTAL STUDENT ENROLLMENT TO CERTIFIED CS TEACHER RATIO AND THE AVERAGE CLASS SIZE PER GRADE LEVEL BROKEN DOWN BY SCHOOL SIZE AND LOCALITY IN 2022-23 AY, REPRESENTING THE CS TEACHER CAPACITY STATUS FOR WI PUBLIC HIGH SCHOOLS.

Metrics	**Student:Teacher Ratio**	**Avg Class Size/Level**
Small	659.1	27.5
Medium	839.8	35
Large	1259	52.5
Rural	619	25.8
Town	1180.6	49.2
Suburb	780.7	32.5
City	1467.6	61.2

There is no nationally recognized definition for categorizing schools as small, medium, or large, which likely contributes to why school size is not often considered in education policies. We follow the guidelines created in the 2023 CODE Report for school sizes [5]:

- Small schools: Overall enrollment with under 500.
- Medium schools: Overall enrollment of 500–1,200.
- Large schools: Overall enrollment of more than 1,200.

The distribution of the 503 regular public high schools is as follows: 321 schools in small size, 112 in medium size, and 70 in large size for 2023 AY.

An analysis of the total student enrollment-to-certified CS teacher ratio and the resulting average class size per grade level for WI high schools during the 2022-23 AY (as shown in Table II) reveals significant disparities in CS teacher capacity. The reported data is aggregated for each category, with the subsequent discussion assuming an equal distribution of teachers and students across the respective categories. Notably, WI demonstrates a more favorable student-to-teacher ratio in rural areas than other localities. We also calculated a conservative estimate of average class size based on the assumption that a student takes one CS course during their four years of high school and that each teacher handles a workload of six classes. The resulting average class sizes, calculated as $(student : teacher\ ratio/6/4)$, generally exceed the recommended cap of 23.5 students per class for WI, indicating inadequate teacher capacity across the board [31]. Specifically, medium and large schools exhibit substantial class sizes, falling out of compliance with standards necessary to ensure equitable access to CSE with certified CS teachers; class sizes in these schools are 35 and 52.5 students, respectively. Geographically, rural schools in WI have smaller class sizes (25.8), whereas city schools face significantly larger class sizes (61.2). Overall, WI does not meet the optimal teacher capacity required to maintain class sizes within the recommended cap. This analysis underscores the critical need to build a robust teacher pipeline as a foundational step toward providing equitable access to CSE for all students.

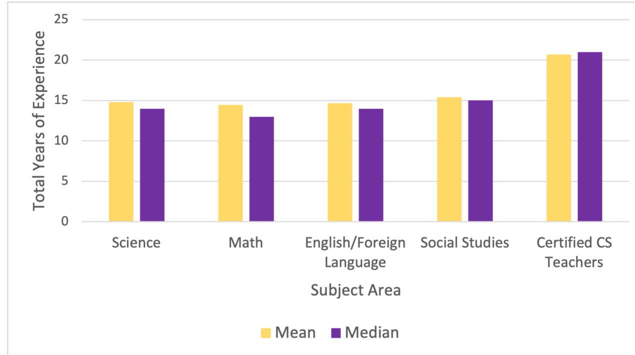

Fig. 6. Measures of central tendency of Contract Total Years of Experience compared with four core subject areas and certified CS teachers AY 2022-23.

Figure 6 shows the alarming reason for this research work progressing forward. The *All-Staff report* data has a field called the ‘Contract Total Years of Experience,’ showing a teacher’s total years of experience. Figure 6 displays that the average total years of experience a certified CS teacher has is 5+ years more than teachers in the four core subject areas; we are approaching a large wave of retirement in the state. In WI, a teacher may retire with full pension benefits at the age of 65 years or have 30 years of experience [32]. 36% (n=106) of certified CS teachers in public high schools have 25+ years of experience in 2023 AY; our state is on track for a large group of teachers to retire in the next 5-10 years. This analysis suggests that immediate attention is required from stakeholders and state policymakers to replenish new certified CS teachers.

B. Access

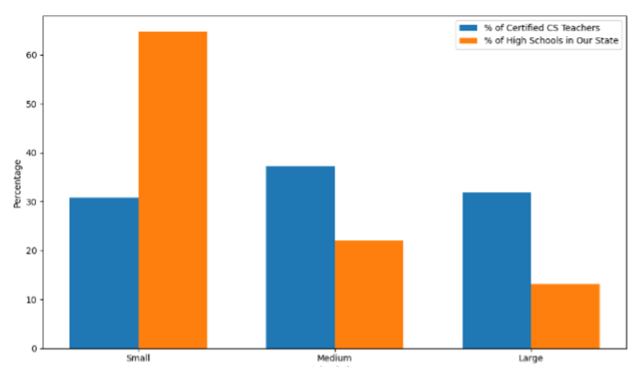

Fig. 7. Percentage of WI Public High Schools with Access to Certified CS teachers by School Size in 2022-23 AY.

Figure 7 and Table III address *RQ2.B*. Figure 7 represents the percentage of WI public high schools with access to certified CS teachers based on their school size in the 2022-23 AY. Although more than 60% of high schools in our state are small, only 30% of the certified CS teacher population serves in small schools. Conversely, medium and large schools typically have multiple certified CS teachers on staff. While this data alone should prompt policymakers to action, it is imperative to contextualize the significance of this issue. As of the 2022-23 AY, Wisconsin's small public high schools make up 64% (n=321), with nearly 65,000 students enrolled. It's noteworthy that small schools are not confined to rural regions; 12.5% are located in city and suburban areas of WI. However, a common characteristic among smaller schools is the presence of fewer certified CS teachers than in larger high schools. While teachers in all schools often juggle multiple responsibilities, this challenge is particularly pronounced in small schools. Therefore, WI policymakers must ensure that the resources allocated to these schools are adaptable and well-suited to their specific circumstances.

TABLE III

COUNT OF WI PUBLIC HIGH SCHOOLS BROKEN DOWN BY THE PRESENCE OR ABSENCE OF ACTIVE CERTIFIED CS TEACHERS PLUS THE EXISTENCE OF DPI-REPORTED CS COURSE ENROLLMENT FOR EACH AY BASED ON LOCALITY.

Academic Year	Rural		City		Town		Suburb	
	+C + E	-C + E	+C + E	-C + E	+C + E	-C + E	+C + E	-C + E
2016-17	50	53	35	11	35	14	42	11
2017-18	56	67	40	13	32	17	42	14
2018-19	62	77	38	17	34	18	47	16
2019-20	59	66	36	19	34	23	50	10
2020-21	47	72	33	23	33	24	49	15
2021-22	50	60	40	26	26	22	43	18
2022-23	57	66	32	26	24	25	42	18

Table III presents a detailed breakdown of WI public high schools over the AYs 2017 to 2023, categorized by the presence (+C+E) or absence (–C+E) of active certified CS teachers in schools that reported CS course enrollment, further segmented by locality. The data reveals a consistent trend where rural and suburban schools exhibit higher counts of active certified CS teachers than city and town schools. However, the prevalence of schools with CS enrollment but without identified certified CS teachers (–C+E) has also persisted across all localities, with notable increases from 2017 AY to 2023 AY. This indicates a growing disparity between the supply of certified CS teachers and the demand for CS education, particularly in rural areas. These findings carry significant implications for stakeholders and policymakers, emphasizing the urgent need for targeted interventions to ensure equitable access to certified CS instruction across different localities. Such interventions are essential to address disparities in CS education and ensure that all students, regardless of geographical location, can benefit from high-quality CS education.

C. Participation

Despite increasing access to CS over the years, student participation remains notably low when compared to the overall student population. To address *RQ2.C*, Table IV breaks down the student demographics into four categories, and Figure 8 represents the gender distribution analysis.

Table IV shows the demographic distribution of WI high school students and their participation in CS courses during the 2022-23 AY, categorized by the presence (+C+E) or absence (–C+E) of certified CS teachers. Among students in the +C+E archetype, White students represent the majority (52.88%), followed by Hispanic (54.59%) and Black (45.74%) students. Asian students, though a smaller percentage of the overall

TABLE IV

DEMOGRAPHIC DISTRIBUTION OF WI HIGH SCHOOL STUDENTS AND CS COURSE ENROLLMENT BY ACCESS TO CERTIFIED CS TEACHERS IN 2022-23 AY.

Category	White	Black	Asian	Hispanic	American Indian	Two or More
HS student population with +C+E archetype	52.88% (n=92,535)	45.74% (n=9,669)	62.85% (n=6,399)	54.59% (n=18,641)	34.77% (n=959)	56.35% (n=6,047)
Student participation in CS with +C+E archetype	5.14% (n=4,752)	3.05% (n=295)	10.30% (n=659)	3.60% (n=672)	3.44% (n=33)	5.40% (n=326)
HS student population with –C+E	23.05% (n=40,340)	29.97% (n=6,335)	19.77% (n=2,013)	22.58% (n=7,712)	24.62% (n=679)	23.76% (n=2,550)
Student participation in CS with –C+E archetype	3.59% (n=1,448)	6.91% (n=438)	6.71% (n=135)	3.29% (n=253)	1.62% (n=11)	2.94% (n=75)
Overall representation of HS students in the state	68.85% (n=174,973)	8.32% (n=21,141)	4.01% (n=10,182)	13.44% (n=34,147)	1.09% (n=2,758)	4.22% (n=10,731)

student population, are more likely to attend schools with certified CS teachers (62.85%). Notably, Asian students also show the highest CS course enrollment rate (10.30%) in the +C+E group, outpacing other racial and ethnic groups, aligning with the national trends [5]. In the –C+E archetype, Black and Hispanic students are more likely to attend schools without certified CS teachers, with 29.97% and 22.58% respectively. Despite the lack of certified CS teachers, Black students have a relatively high CS course enrollment rate (6.91%) in these schools.

The higher representation of Asian students in schools with certified CS teachers and their greater participation in CS courses may be attributed to factors such as strong parental encouragement to pursue CS, and the significant influence of Asian communities in STEM fields. Conversely, the higher CS enrollment rates among Black students in the –C+E archetype could indicate a strong interest in CS despite the absence of certified instructors, potentially driven by broader efforts to increase diversity in STEM or community-led initiatives.

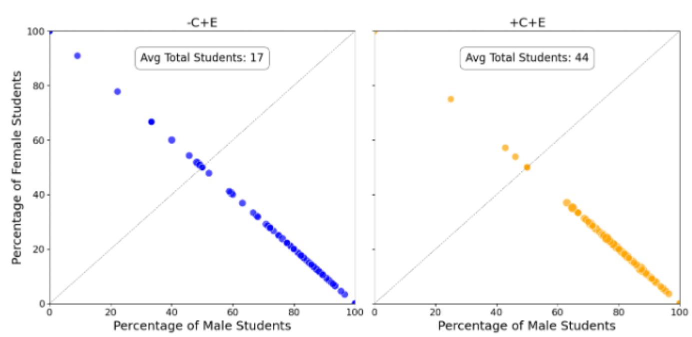

Fig. 8. Gender Distribution Analysis of WI public high schools with CS course enrollment based on the presence of an active certified CS teacher for the 2022-23 AY.

Figure 8 depicts the gender distribution of students in WI public high schools with +C+E (yellow) and –C+E (blue) archetypes for the 2022-23 AY. The dots on the graph represent two main aspects: each dot indicates the total number of students enrolled in a CS course proportional to its size, and the dot's placement determines the percentage of each school's male (x-axis) to female (y-axis) ratio. In Figure 8, an important annotation shows that the average total student enrollment in CS courses for the +C+E archetype is significantly higher (44 students) compared to schools in the –C+E category, which have an average of only 17 students. This difference suggests that the presence of a certified CS teacher is associated with greater student participation in CS courses. The data implies that having a certified CS teacher can be a crucial factor in encouraging more students to enroll in CS courses, potentially due to better teaching quality, a more structured curriculum, or increased student confidence and interest driven by the presence of a certified CS teacher.

An alarming concern for equitable gender participation in CS courses is the clustering of schools in the bottom right corner of Figure 8 for both the –C+E and +C+E archetypes, where nearly 80% (n=7,209) of the students enrolled in CS courses are male. School administrators, parents, teachers, and all stakeholders in WI need to address this disparity in the male-to-female ratio to ensure greater engagement of the female student population in CS activities.

Among the schools (n=22) with an overrepresentation (>50%) of female students enrolled in CS courses, 18 schools fall under the –C+E (blue) archetype. This indicates that even when schools have a higher participation rate of female students in CS courses, they often lack access to certified CS teachers. Despite the small number of students enrolling in CS courses at these schools, there is valuable information about why and how more female students are enrolling in CS courses than male students. Although there are a small number of schools in this scenario, they achieve more or near-equitable gender participation in CS courses, which needs to be further analyzed qualitatively.

V. Limitations

When a teacher is certified in CS and DPI *All-Staff Report* data shows their presence at a school; our model assumes that the certified CS teacher is indeed instructing the CS courses. However, there may be noise in the dataset, where someone else might be teaching the CS course instead of the certified CS teacher. Additionally, we know that dual enrollment options with higher education are available for high school students in WI, but these data sources do not indicate how this data is reported to the DPI. After polling a sample of high school principals, we learned that the current data collection methods by the DPI may be overlooked in instances where high schools engage certified CS teachers from nearby schools to teach CS courses. To rectify this, the DPI should consider incorporating reporting mechanisms that capture teachers actively involved in multiple schools, providing a more comprehensive representation of the educational landscape.

VI. Discussion/Future Work

Our preliminary analysis of CSE data highlights the crucial role of teacher certification in maintaining stable CS activities in WI public high schools. While recruiting or training the number of certified CS teachers seems like an obvious solution, current pathways for generating new certified CS teachers have proven insufficient. This analysis provides valuable insights for stakeholders and policymakers, guiding future resource allocation to address inequities and shortfalls in the current CS teacher ecosystem. To advance the CSE landscape in WI, DPI has recently hired a CS consultant and, in collaboration with the CSTA and WestEd, the CS Mentor/Mentee program [33] to enhance CSE accessibility and student participation across all public high schools.

This research lays the groundwork for future studies by integrating external data, such as College Board Advanced Placement Exam Data, to explore the impact of certified CS teachers on student enrollment and measure the 'Experience' component of the C.A.P.E. framework. Our immediate next steps include developing a data dashboard to visualize our findings and gather feedback from policymakers, DPI staff, teachers, students, and parents. This research paper offers valuable insights into the CSE landscape through the lens of the teacher capacity model, identifying multiple research problems relevant to WI public high schools, and serves as a blueprint for other CSE researchers to access data from their Departments of Education and implement appropriate algorithmic processes to understand the CS teacher capacity.

VII. Conclusion

The debate over teacher qualifications and certification is multifaceted, especially when addressing the pressing need for greater access to CSE. Our primary challenge is that too few teachers have earned the CS certification, and the pathways for producing more are too narrow, onerous, and expensive, compounded by the rapid retirement of existing certified teachers. Education policy mandates certification to teach CS courses in WI, yet the current system fails to produce enough teachers, likely leaving more than half of schools out of compliance. This teacher shortage is a critical issue globally, and our preliminary analysis aims to identify patterns and trends in the data to understand the landscape of CSE through the lens of the teacher capacity model. Despite significant progress in advancing access to CSE and increased demand for student participation in CS courses, schools with active certified CS teachers see more equitable growth in the CS ecosystem. However, if the certified CS teacher retires or leaves the system, most high schools struggle to replace them, risking the disintegration of their CS programs. Policymakers and stakeholders need to provide support for all CS teachers, whether certified or seeking certification, with adequate resources.

VIII. Acknowledgements

This work was supported in part by the National Science Foundation award #CNS-1923597, "PUMP-CS: Preparing Urban Milwaukee for Pathways in Computer Science".

References

[1] A. Zilberman and L. Ice, "Why computer occupations are behind strong STEM employment growth in the 2019-29 decade," *Computer*, vol. 4, no. 5,164.6, pp. 11–5, 2021.

[2] P. N. da Costa, "Tech talent scramble," *Finance & Development*, vol. 56, 2019.

[3] Code.org, "State Advocacy Sheet." https://advocacy.code.org/, accessed 2023 May 14.

[4] Wisconsin Department of Public Instruction, "Wisconsin Standards for Computer Science," June 2017. https://dpi.wi.gov.

[5] E. A. . Code.org, CSTA, "2023 state of computer science education." https://advocacy.code.org/stateofcs.

[6] C. L. Fletcher and J. R. Warner, "CAPE: A Framework for Assessing Equity Throughout the Computer Science Education Ecosystem," *Communications of the ACM*, vol. 64, no. 2, pp. 23–25, 2021.

[7] M. Karlin, Y.-C. Liao, and S. Mehta, "Exploring computer science understanding and rationales in preservice teacher pathways through faculty professional development," *Journal of Research on Technology in Education*, pp. 1–15, 2023.

[8] M. Saffar Perez and P. Bruno, "Analyzing the effects of cte grant funding on cs course offerings and enrollment in california," in *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, pp. 46–52, 2023.

[9] W. R. Adrion, K. Bevan, P. Foster, D. Matuszczak, R. Miller, L. Rita, F. R. Sullivan, S. Veeragoudar, S. Wohlers, and M. Zeitz, "How a research-practice partnership refined its strategy for integrating cs/ct into k-5 curricula: An experience report," in *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education-Volume 1*, pp. 592–598, 2022.

[10] R. Torbey, "Inequities of enrollment: A quantitative analysis of participation in high school computer science coursework across a 4-year period," in *Proceedings of the 2023 ACM Conference on International Computing Education Research-Volume 1*, pp. 344–355, 2023.

[11] A. K. Bahar, E. Kaya, and X. Zhang, "Gender disparities in ap computer science exams: Analysis of trends in participation and top achievement," *Journal of Advanced Academics*, vol. 33, no. 4, pp. 574–603, 2022.

[12] I. Gransbury, M. M. McGill, A. Thompson, S. Heckman, J. Rosato, and L. Ann Delyser, "A framework of factors that influence academic achievement in computer science within capacity, access, participation and experience," in *Proceedings of the 2023 ACM Conference on International Computing Education Research-Volume 2*, pp. 28–29, 2023.

[13] M. M. McGill, A. Thompson, I. Gransbury, S. Heckman, J. Rosato, and L. A. Delyser, "Building upon the cape framework for broader understanding of capacity in k-12 cs education," in *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, pp. 577–582, 2023.

[14] M. Armoni, B. Ericson, J. Gal-Ezer, D. Seehorn, C. Stephenson, and F. Trees, "Ensuring Exemplary Teaching in an Essential Discipline: Addressing the Crisis in Computer Science Teacher Certification – Final Report of the CSTA Teacher Certification Task Force," tech. rep., The Weizmann Institute of Science, 2008.

[15] K. Lang, R. Galanos, J. Goode, D. Seehorn, F. Trees, P. Phillips, and C. Stephenson, "Bugs in the System: Computer Science Teacher Certification in the US," *The Computer Science Teachers Association and The Association for Computing Machinery*, 2013.

[16] Computer Science Teacher Association, "2020 Standards for Computer Science Teachers.." https://csteachers.org/teacherstandards.

[17] Expanding Computing Education Pathways (ECEP) Alliance, "Broadening participation in computing state by state." https://ecepalliance.org/.

[18] J. Stanton, L. Goldsmith, R. Adrion, S. Dunton, K. Hendrickson, A. Peterfreund, P. Yongpradit, R. Zarch, and J. Zinth, "State of the States Landscape Report: State-level Policies Supporting Equitable K-12 Computer Science Education," *Education Development Center*, 2017.

[19] J. Koressel, A. Ottenbreit-Leftwich, K. Jantaraweragul, M. Jeon, J. Warner, and M. Brown, "Investigating CS Teacher Licensure in Indiana," *TechTrends*, pp. 1–11, 2022.

[20] Wisconsin Department of Public Instruction, "What Can I Teach with My License?." https://dpi.wi.gov/licensing/general/what-can-i-teach, accessed 2023 Jan 15.

[21] Teaching Certification, "Computer Science Teacher Certification," May 2022. https://teaching-certification.com/computer-science-teacher-certification-2/.

[22] P. Bruno, M. S. Perez, and C. M. Lewis, "Four practical challenges for high school computer science.," *Policy Analysis for California Education, PACE*, 2022. https://edpolicyinca.org/publications/4-practical-challenges-high-school-computer-science.

[23] Wisconsin Department of Public Instruction, "Pathways to licensure." https://dpi.wi.gov/licensing/pathways-licensure.

[24] Wisconsin Department of Public Instruction, "Initial educator and provisional licenses." https://dpi.wi.gov/licensing/initial-educator-and-provisional-licenses.

[25] Wisconsin Department of Public Instruction, "Additional subject area certification." https://dpi.wi.gov/licensing/pathways-licensure/additional-certification.

[26] Wisconsin Department of Public Instruction, "School District Support License Pathways." https://dpi.wi.gov/licensing/pathways-licensure/district-support-pathways.

[27] Wisconsin Department of Public Instruction, "Public all staff report - public reports." https://publicstaffreports.dpi.wi.gov/, accessed 2024 Jan 5.

[28] National Center for Education Statistics, "Search for public schools." https://nces.ed.gov/ccd/schoolsearch/.

[29] National Center for Education Statistics, "School courses for the exchange of data (SCED)." https://nces.ed.gov/forum/sced.asp.

[30] D. E. Geverdt, "Education Demographic and Geographic Estimates Program (EDGE): Locale Boundaries User's Manual. NCES 2016-012.," *National Center for Education Statistics*, 2015.

[31] National Center for Education Statistics, "Average class size in public schools, by class type and state: 2017–18." https://nces.ed.gov/surveys/ntps/tables/ntps1718$_fltable06_t1s.asp$.

[32] "Teaching in Wisconsin." https://www.masters-education.com/teaching-in-wisconsin/.

[33] Computer Science Teacher Association - Wisconsin-Dairyland Chapter, "Mentors in cs." https://www.cstawisconsin.org/page/mentors.