MASSACHUSETTS
Business Alliance for Education

A STATE-LEVEL STRATEGY

Expanding Access to and Participation in Computer Science Across Massachusetts

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TITLE AND ORGANIZATION	ACRONYM FOR CITATION PURPOSES
Arkansas Division of Elementary and Secondary Education	AR
Bootstrap	Bootstrap
Bristol Meyers Squib	BMS
Burlington Public Schools	BPS
Code.org	Code.org
Connecticut State Department of Education	CSDE
CSforMA	CSforMA
CS4RI	CS4RI
Education Development Center (EDC)	EDC
Expanding Computing Education Pathways (ECEP) Alliance	ECEP
The Harvard Graduate School of Education	HGSE
Maryland Center for Computing Education (MCCE)	MCCE
Massachusetts Department of Elementary and Secondary Education	MADESE[A]
Massachusetts Executive Office of Education	MEOE
The Massachusetts High Tech Council	MHTC
Microsoft Philanthropies	TEALS/TEKsystems
South Carolina Department of Education	SCDE[B]
Springfield Public Schools	SPS
UMass Amherst CS Department	UMass

Note: Individuals quoted in this report have agreed to be named.

The Massachusetts Business Alliance for Education (MBAE) is a non-profit, non-partisan organization that, together with its members, promotes and supports continuous improvement and innovation in our schools to ensure that EVERY student receives a high-quality education that prepares them for success in college, career and citizenship.

A Massachusetts Department of Elementary and Secondary Education is routinely shortened to MA DESE in text and MADESE in citations.

B Employees at the South Carolina Department of Education were interviewed together and are cited as a group: SCDE.

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EXECUTIVE SUMMARY

Computer science (CS) is a critical area of study, both for the present and for the future, providing students with skills they need to understand technology and its applications across numerous sectors and social contexts. However, too few students in the Commonwealth are taking CS courses.

According to the Massachusetts Technology Leadership Council (MassTLC), CS and related skills (including agile methodology, Python and software engineering) are the most in-demand tech skills in the Commonwealth. However, only a fraction of job candidates possesses these skills—limiting the ability of employers to fill computer science-related occupations.[1] CS knowledge is also highly demanded across other industry sectors beyond technology. Jobs in science, media, security and other areas increasingly demand workers who have participated in the study of CS.[2] Access to CS education can thus prepare students to be informed and active citizens of the digital age in any field they choose to pursue.

Furthermore, national salaries for computer and information technology jobs are skyrocketing. Nationally, the median annual wage for computer and information technology occupations was $91,250 in May 2020, while the median annual wage for all occupations was $41,950.[3]

Exposure to CS in high school is a critical way to put more students on pathways to careers that provide job security and opportunity while ensuring the growth and success of the Commonwealth's economy, but Massachusetts currently has gaps and inequities in both access to and participation in CS. In Massachusetts in 2020-2021, 84.7% of high schoolers attended a school that offered CS, but only 5.8% of students were enrolled in a foundational CS course.[4] Furthermore, urban high schools—which tend to serve high proportions of minority and low-income students—were less likely to offer foundational CS courses than rural and suburban districts, and the majority of CS enrollees were white and male.[5] In fact, 29% of the state's urban high schools do not offer a single foundational computer science course.

Beyond this, according to CSforMA, an organization that offers programs to help schools expand CS exposure, Massachusetts is experiencing a shortage of qualified CS teachers, which hampers the ability of well-intentioned, motivated districts to hire instructors and offer the subject.

2020-21 SCHOOL YEAR

84.7% of MA high school students attend a school the **offers foundational computer science**.

Only **5.8%** of students are **enrolled in a computer science course**.

Urban schools were **less likely** to offer **computer science** than suburban and rural schools.

Only **28.4%** of students enrolled in a computer science course are **female**.

Source: Code.org

Massachusetts—which is currently taking a grassroots approach to CS expansion—is missing out on a key opportunity to prepare its future workforce and ensure the economic and personal success of every student. However, some progress has been made in recent months. An amendment to the 2022 economic development bill (Chapter 268 of the Acts of 2022) allocated $2.5 million for the recruitment and training of educators to teach computer science, and requires the Department of Elementary and Secondary Education to submit a report to the legislature on a strategy to ensure access in every high school, increase participation rates particularly among those traditionally underrepresented, and to evaluate whether a foundational computer science course should be a requirement to graduate high school. Additionally, a newly-filed legislative proposal would require all Massachusetts high schools to offer a foundational CS course by 2026. The course must include rigorous mathematical or scientific concepts and align with standards established by the Department of Elementary and Secondary Education.[C]

C Code.org defines a foundational computer science course "In addition to aligning with the definition of computer science, a course that teaches foundational computer science includes a minimum amount of time applying learned concepts through programming (at least 20 hours of programming/coding for grades 9-12)."

This report, published by the Massachusetts Business Alliance for Education, offers a roadmap to policymakers and CS stakeholders regarding how Massachusetts can ensure equal access to and greatly expand participation in CS education for all Massachusetts high schoolers. This report ultimately recommends a more ambitious approach than current legislative proposals, but takes a phased approach that would allow Massachusetts schools and stakeholders to adequately prepare.

This report answers two primary questions:

- What steps can Massachusetts take to expand access to and participation in CS at the high school level?
- What are the biggest barriers that Massachusetts is likely to face, and what might it do to address these barriers?

The report draws upon interviews with officials in five states (Arkansas, Connecticut, Maryland, Rhode Island and South Carolina) and two Massachusetts school districts (Burlington and Springfield) that have been leaders in efforts to expand CS instruction. From these interviews—and interviews with numerous other experts in the CS policy space—three potential policy strategies for Massachusetts emerged.

Each strategy has the potential to be impacted by challenges that have variously manifested themselves in other states. As such, we have reviewed them in depth so as to understand how they might, and likely, would apply in the Massachusetts context.

STRATEGY 1

Use legislation to require that all high schools offer CS, but do not implement a CS graduation requirement. [ex. Connecticut]

- Challenges: Access to CS does not guarantee participation and general negative pushback to state mandates

STRATEGY 2

Use legislation to require that every student take a computer science class to graduate from high school. [ex. Arkansas, South Carolina and Maryland][D]

- Challenges: Lack of available time in the school day and the potential for a requirement to be "watered-down"

STRATEGY 3

Take a grassroots approach—individual districts choose their own policies around offering CS and requiring it for graduation. [ex. Rhode Island][E]

- Challenge: Decentralization leading to patchwork approach and continued equity gaps

In addition to these unique challenges there are five challenges shared among all three strategies:

- Need for human capital
- Need for buy-in from administrators and school counselors
- Cost
- Need for a state-level CS champion with power to affect change, and
- The need to overcome negative stereotypes about CS and negative messaging affecting which students participate in CS.

Interviews with experts from Massachusetts and beyond provided information that contributed to a pro/con analysis of the three strategies in the Massachusetts context.

D As explored later, Maryland's technology graduation requirement extends beyond CS.

E While Rhode Island has historically taken a grassroots approach to CS expansion, a 2022 proposal would modify the state's high school graduation requirements to include CS.

THREE STARTEGIES IN THE MASSACHUSETTS CONTEXT	
Strategy	Pros/Cons Analysis
STRATEGY 1: Require that all high schools offer CS	Would expand CS access and provide greater legitimacy to the subject, but would require significant human capital and would not necessarily increase participation.
STRATEGY 2:[F] Use legislation to require that every student take a computer science class to graduate from high school	Would ensure equitable participation, but requires additional human capital, would be negatively viewed as mandate, and could be watered-down in the absence of state oversight and clarity around student outcomes.
STRATEGY 3: Continue with a grassroots approach—individual districts choose their own policies around offering CS and requiring it for graduation	Would maximize district autonomy and avoid a potentially unpopular mandate, but would require particularly strong state-level leadership to prevent continued inequity in CS expansion efforts (i.e. wealthy districts moving more quickly to expand).

Massachusetts' current grassroots approach has already led to inequities in CS access and participation, and continuing along this path would likely result in further disparity. Thus, Massachusetts should take a bolder approach and utilize mandates.

A graduation requirement is the best policy lever to expand access to and participation in CS, and Massachusetts should aspire to implement a graduation requirement in the future. However, to get to a point at which a graduation requirement is feasible, Massachusetts must take steps to build up CS capacity. Requiring that all high schools offer CS will move the state in the right direction and will require steps toward building capacity. Massachusetts must also implement numerous other policies that can help prepare the state to introduce a successful graduation requirement.

A promising pathway forward would consist of the following components:

HIGHLIGHTS		
PHASE 1 (BY 2023) Convening and Promoting	PHASE 2 (IN 2023) Legislating, Guiding and Collaborating	PHASE 3 (BY 2025) Listening and Planning for Further Action
• Create forums for stakeholder engagement around goals and strategies • Capture the attention of state-level leaders with capacity to affect change • Promote CS in communities and as a statewide imperative	• Legislate to require that all Massachusetts high schools offer CS by September 2025 • Allocate funding to support this effort • Build capacity through expanded professional development and alternative pathways to licensure	• Conduct listening tours to collect feedback on expansion efforts • Hold convenings to determine a date by which a CS graduation requirement could be implemented

This approach can help Massachusetts enhance CS capacity, access and participation, preparing the state to implement a graduation requirement that reaches all students. In addition, this approach can allow Massachusetts to identify best practices over the next few years before it moves to a more intensive graduation requirement strategy.

F As explored later, Maryland's technology graduation requirement extends beyond CS.

Introduction

K-12 schools are educating the workforce of tomorrow, and yet schools do not always align their coursework with the skills students need. CS is one such necessary course of study, and yet only 53% of American high schools offered CS in 2021.[6]

Across the United States, demand for computer and information technology professionals is growing at a rapid pace. According to the Bureau of Labor Statistics, "employment in computer and information technology occupations is projected to grow 13 percent from 2020 to 2030, faster than the average for all occupations."[7]

At the same time, monetary rewards for these jobs are skyrocketing. In May 2020, the median annual wage for computer and information technology jobs was $91,250 while the median annual wage for all other occupations was $41,950. Within the computer and information technology sector, certain occupations can earn even more. Computer and information research scientists (who "design innovative uses for new and existing computing technology") earn an annual national median wage of $126,830.[8]

Figure 1: The demand for computer and information and research scientists outpaces demand for other occupations

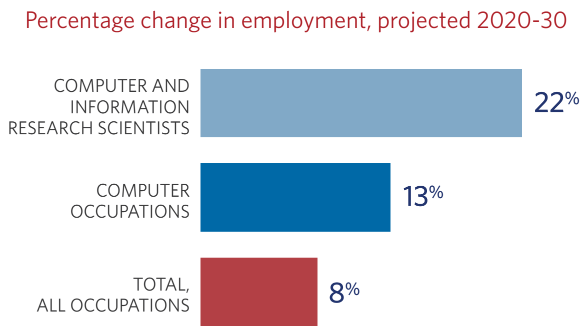
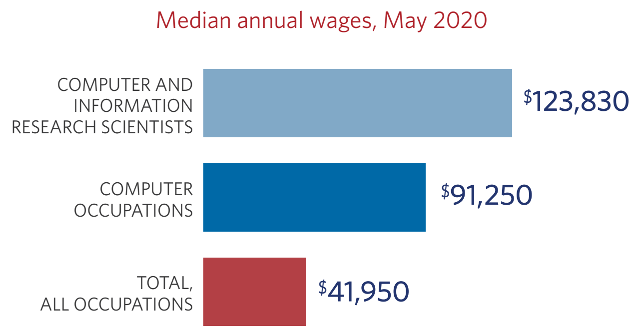


Figure 2: Computer and information research scientists earn a significant wage premium



Note: All occupations includes all occupations in the U.S. Economy.
Source: BLS Website

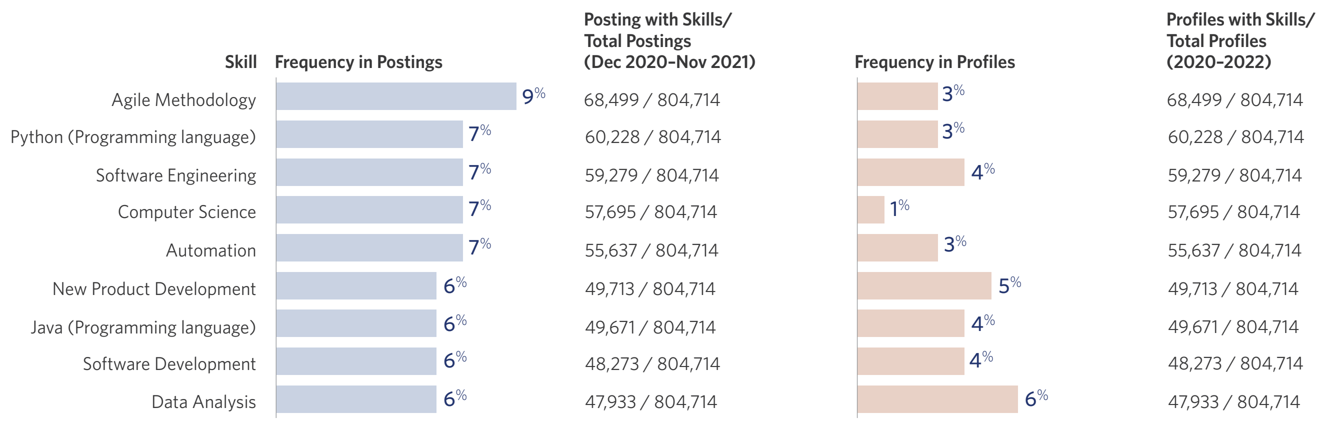
Massachusetts—home to a burgeoning technology and science sector—is experiencing rapid growth in jobs that demand advanced computer skills, but the demand for this labor has outpaced supply. As demonstrated by data compiled by the Massachusetts Technology Leadership Council (MassTLC), CS and related skills (including agile methodology, Python and software engineering) are the most in-demand tech skills in the Commonwealth. However, only a fraction of job candidates possesses these skills—limiting the ability of employers to fill computer occupations.[9] CS is also highly demanded across other sectors beyond technology. Jobs in science, media, security and other areas increasingly demand the study of CS.[10] (See figures 3 and 4).

Adjusting the K–12 education sector so that all students—regardless of race, gender, socioeconomic, English Language Learner (ELL) or disability status—receive training in the skills of the future is key to ensuring the ongoing success and growth of the Commonwealth's economy. But more importantly, providing students with the skills of the future will ensure the success and prosperity of students themselves.

CS has become a key area of study for students and will remain one for years to come. High-quality, accessible CS education in high school will give students choices for profitable future employment, regardless of the education pathway they decide to pursue. Indeed, while many employers have traditionally demanded a bachelor's or master's degree from candidates, employers are now beginning to think about expanding their hiring to students with associate's degrees—or even to students right out of high school.[11] High school CS exposure could set students on paths to well-paying employment.

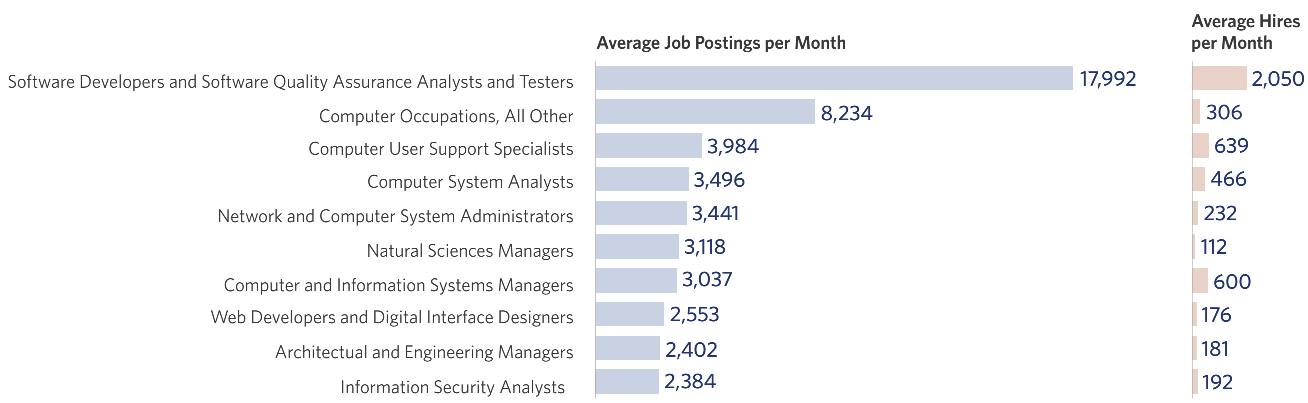
Figures 3 and 4: CS skills are in high demand, but employers are only hiring a fraction of the workers they seek

Top tech skills in-demand vs. workforce supply in MA (Job postings vs. profiles)



10 most in-demand tech job posting occupations vs. hires (Nov 2020-Oct 2021)

Average job postings may include multiple postings for un-filled position.



Source: MassTLC Website

Equitable access to high-quality CS in Massachusetts high schools could help ensure the financial future of students and reduce income inequality in the state and the U.S. more broadly. Furthermore, access to CS education would prepare students to be informed and active citizens of the digital age in any field they choose to pursue. But Massachusetts, while it has progressed in expanding high school access to and participation in CS, is still not reaching all students. In Massachusetts in 2020-2021, approximately 84.7% of high schoolers in the Commonwealth attended a school that offered CS, yet only 5.8% percent of students were enrolled in a "foundational CS course."[12 G] Massachusetts is missing an opportunity to prepare its future workforce and ensure the economic and personal success of every student.

G The data on CS access and participation in this report is from the 2020-2021 school year and comes directly from the Massachusetts Department for Elementary and Secondary Education. "Foundational CS" is defined in the next section.

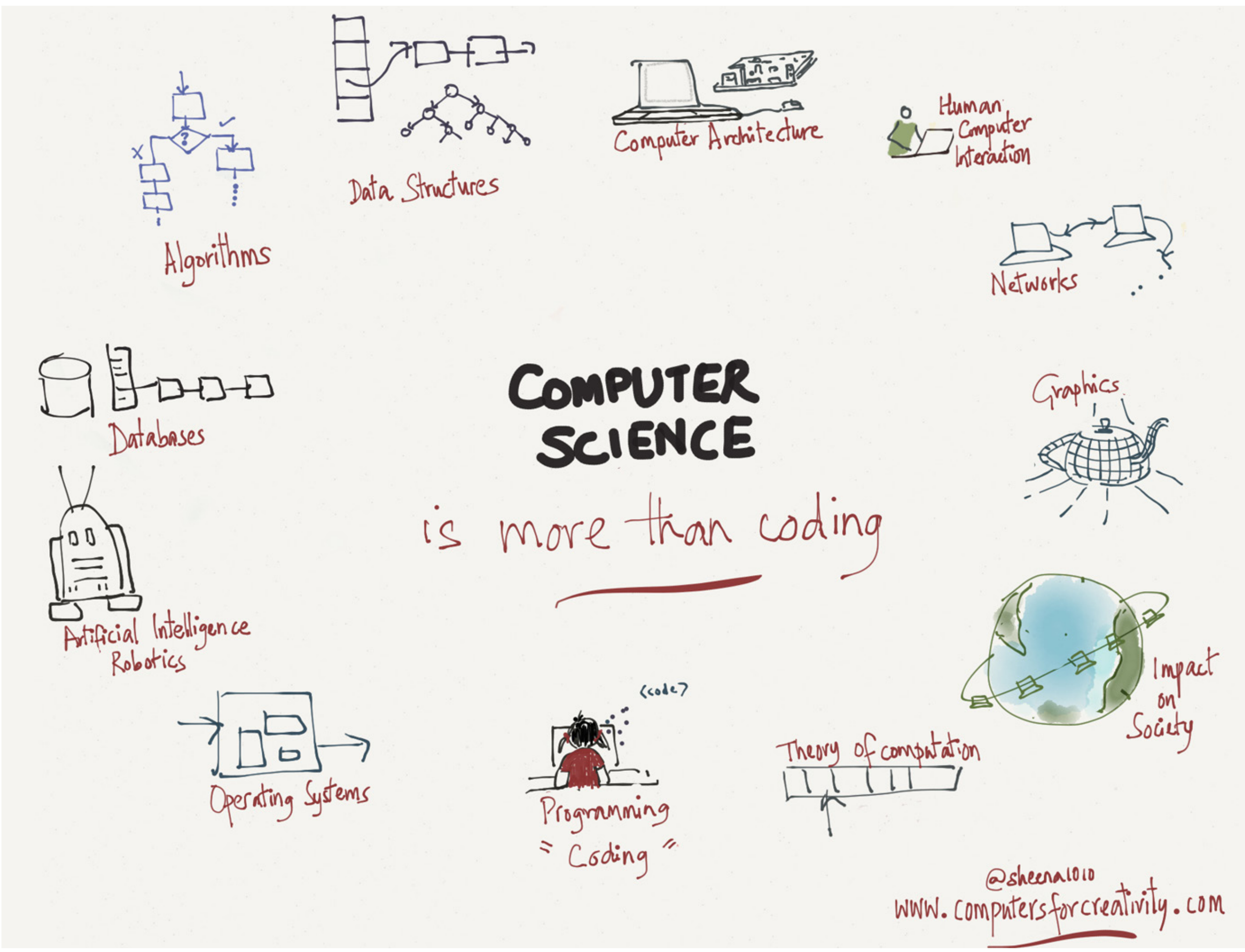
Definitions, Research Questions and Methodology

Definitions

What is computer science?

The term "computer science" (CS)—though seemingly quite simple—means many things to different people. Indeed, most people would associate CS with coding (in languages such as Java and Python), but CS is actually broader and more comprehensive.

Figure 5: CS skills extend beyond coding



Source: Computers for Creativity, Sheena Vaidyanathan

This report will take the following definition of CS as its working definition:

> "the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society."[13] [H]

H According to the Director of CSforMA, this definition was initially created by the Association for Computing Machinery and was later adopted by others.

Definitions matter for policymaking, and confusion over the definition of CS has proven to be a challenge in several states. In Massachusetts, defining CS is *especially* important because CS is often talked about in tandem with another subject: digital literacy.

What is digital literacy?

While digital literacy does sometimes overlap with CS, it is in fact a unique skillset, covering:

> "The ability to use digital technology, communication tools or networks to locate, evaluate, use, and create information.
>
> The ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers.
>
> A person's ability to perform tasks effectively in a digital environment. Literacy includes the ability to read and interpret media, reproduce data and images through digital manipulation, and evaluate and apply new knowledge gained from digital environments."[14]

Examples of digital literacy activities that do not constitute CS are entering data into Excel or creating a PowerPoint.

While this report focuses on the expansion of access to and participation in CS, it is important to understand that Massachusetts—unlike some other states—views CS as only one subset of the skills that are vital for students. As will be further explored below, Massachusetts combines digital literacy and computer science in its state standards—the Curriculum Framework for Digital Literacy and Computer Science (DLCS). In addition, oversight for all DL and CS activities come out of the same office at the Massachusetts Department of Elementary and Secondary Education (MA DESE).

Research Questions and Methodology

With the ultimate goal of contributing to a state-level policy strategy that ensures equal access to and greatly expands participation in CS education for Massachusetts high-schoolers, this report aims to answer two primary questions:

- What steps can Massachusetts take to expand access to and participation in CS at the high school level?
- What are the biggest barriers that Massachusetts is likely to face, and what might it do to address these barriers?

This report reveals that the most effective lever for expanding equitable access to and participation in CS is a high school graduation requirement. Massachusetts should pursue this approach, but must first take initial steps to build capacity, leadership and understanding.

This report primarily draws upon:

1. Data on access to and participation in "foundational CS courses," collected by the Massachusetts Department of Elementary and Secondary Education and analyzed and published by three CS organizations (Code.org, The Expanding Computing Pathways (ECEP) Alliance and the Computer Science Teachers Association). In order to be classified as a foundational CS course in Code.org's data set, a course must be:

> "based on the definition of computer science by the Computer Science Teachers Association and the K–12 Computer Science Framework: Computer science is the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society. High school courses must be offered during the school day and include at least 20 hours of programming to count as foundational computer science."[15]

Notably, Massachusetts' DLCS standards employ a very similar definition of CS:

> "the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society."[16]

More information on data can be found in Appendix 1.

2. Interviews with education officials in several other states that have taken significant steps to expand access to and participation in CS: Arkansas, South Carolina, Connecticut, Rhode Island and Maryland. These states were chosen in consult with members of Code.org's government affairs team and other leaders in the CS space. Notably, these states provide information on the merits and disadvantages of three policy approaches:
    - A high school graduation requirement: Arkansas, South Carolina and Maryland
    - A mandate that all high schools offer CS: Connecticut
    - A grassroots approach to CS expansion: Rhode Island
3. Interviews with a state education official at the Massachusetts Department of Elementary and Secondary Education, in addition to interviews with education officials in select Massachusetts school districts that demonstrate leadership in CS education—Burlington Public Schools and Springfield Public Schools.
4. Interviews with other experts in the CS space, including Code.Org, CSforMA, Bootstrap, Microsoft and The Expanding Computing Pathways (ECEP) Alliance.
5. The wealth of knowledge that exists in the literature on CS education.

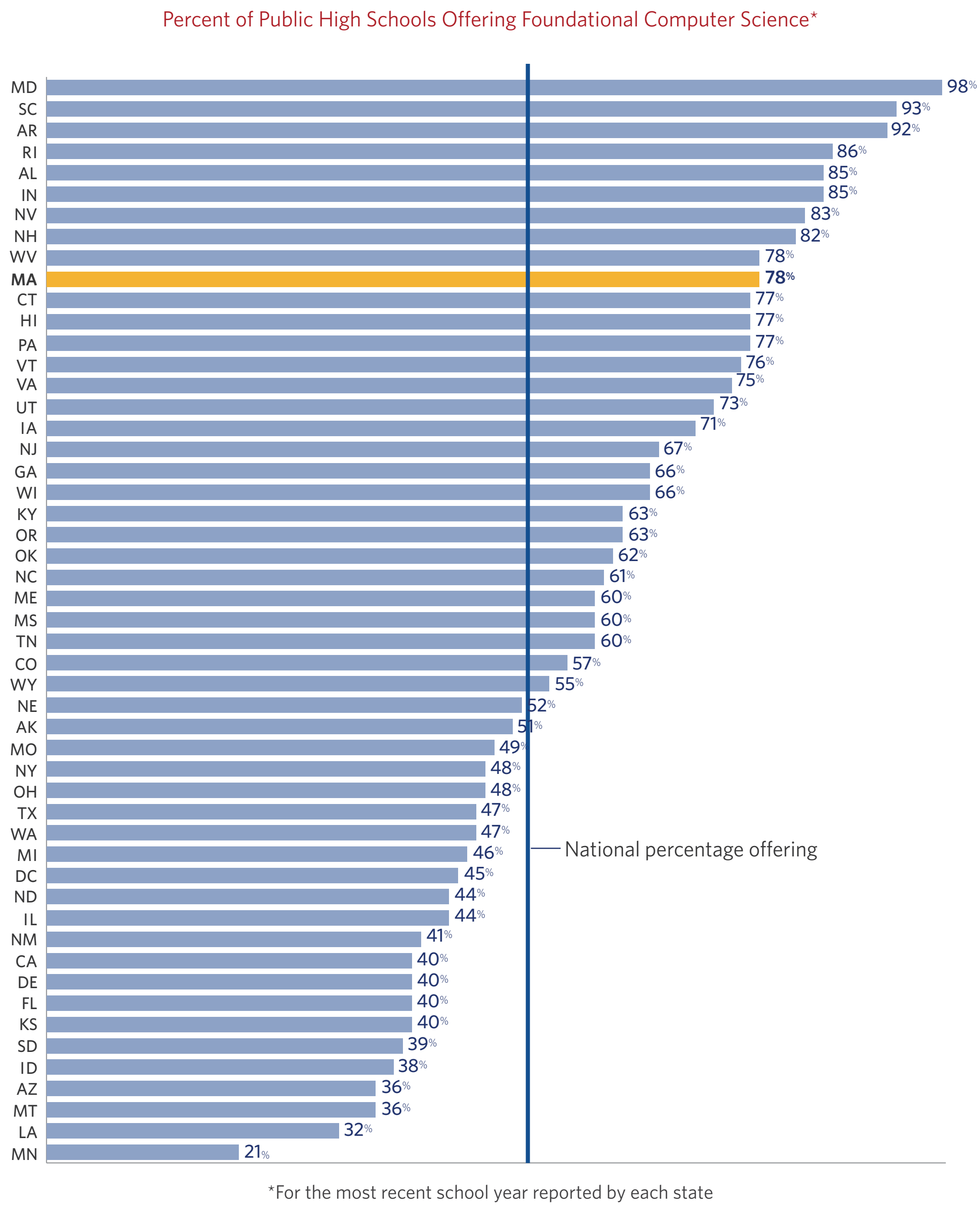
This report suggests and recommends elements that can be used to develop an ambitious and comprehensive state-level policy approach to expanding CS education. Developing that state-wide strategy is a step that must be taken today to set the Commonwealth and its students on a path to success.

The Current CS Landscape in Massachusetts

Data on CS Access and Participation in Massachusetts

Code.org/CSTA/ECEP's 2022 report, (which draws on Massachusetts' 2020-2021 DLCS participation data) reveals key information about where Massachusetts stands on policy, access, and participation. When compared to other states, Massachusetts looks to be ahead of the curve on both policy and access. However, as revealed below, Massachusetts still experiences inequities in CS access and participation.

Figure 6: 78% of Massachusetts high schools offer CS



(Source: Code.org 2022 State of CS Report, p.120)

Code.org's 2022 report highlights 9 target policies that all states should implement to enhance access to and participation in CS. More information on Code.org and these policies can be found in Appendix 2.

Massachusetts has already implemented 8 of the 9 Code.org target policies—the exception being a requirement that all high schools offer CS. But even without this requirement, Massachusetts ranks 8th in the country in terms of percent of public high schools offering foundational CS, sitting behind Maryland, South Carolina, Arkansas, Rhode Island, Alabama, Indiana, Nevada, and New Hampshire.[17]

Zooming in on the Northeast, Massachusetts has made more progress implementing Code.org policies than most other states. (Note: Maryland, which is examined in this paper, has implemented all 9 Code.org policies).

Massachusetts has not, however, funded teacher professional development (PD) to the same degree as its neighbor to the South, New York. Additionally, the number for Massachusetts PD reported by Code.org ($3.14 million) is an aggregate number that includes several years' worth of CS funding in Massachusetts. It is thereby a significant overestimate of PD funding.[18]

Fortunately, an amendment filed by Senator Barry Finegold to the 2022 economic development bill (Chapter 268 of the Acts of 2022) signed into law by Governor Charlie Baker in November allocates $2.5 million for the recruitment and training of educators to teacher computer science This is an important step that MBAE advocated for, but more will be needed to significantly ramp up capacity. Importantly, the bill also calls for the Department of Elementary and Secondary Education to submit a report by no later than February 1, 2023 to the Joint Committee on Education and the House and Senate Committees on Ways and Means on "(a) a strategy for ensuring that computer science instruction is offered in each of the commonwealth's high schools by September 1, 2025; (b) a strategy to increase participation rates in computer science courses, particularly for female students, students of color, English language learners and students from economically disadvantaged backgrounds; (iii) a recommendation on whether a foundational computer science course should be a requirement to graduate high school in the commonwealth; and (iv) a proposed timeline for said requirement to be implemented if recommended; and provided further, that funds in this item shall be prioritized for schools and districts that the department identifies as having inadequate computer science instruction."

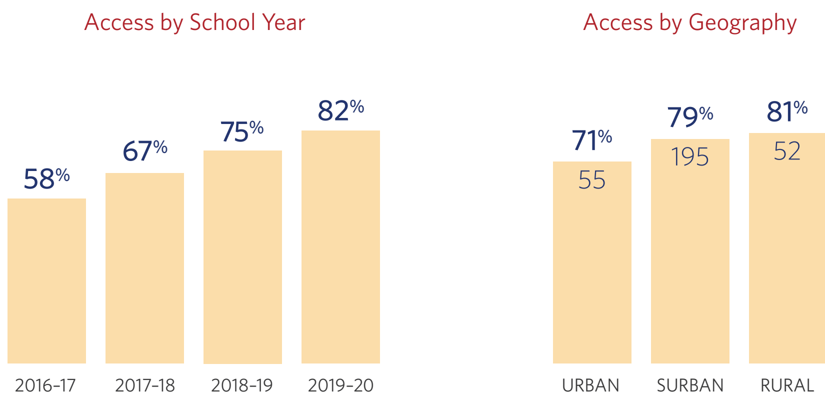
Figure 7: Compared to other Northeastern states, Massachusetts has made more progress on implementing Code.org policies

POLICY	MA	CT	ME	NH	NY	RI	VT
State CS Plan	✓	✓	✓	✓		✓	
K–12 CS Standards	✓	✓		✓	✓	✓	
Funding for Teacher PD	$3.14M		$100K		$24M	$840K	
Teacher Certification	✓	✓		✓	✓	✓	✓
Preservice Programs	✓	✓		✓	✓		✓
State CS Supervisor	✓	✓	✓	✓		✓	
All High Schools Offer		✓		✓		Other	
Graduation Credit	✓	✓	✓	✓	✓	✓	✓
Higher Ed Admission	✓						

Source: Code.org Massachusetts State Handout, p. 3

Code.org's number regarding CS access in Massachusetts still masks some inequities across the state. As demonstrated by the figure below, only 71% of MA's urban high schools offer CS, as compared to 79% of suburban schools, and 81% of rural schools.[20] Given that urban schools are those that tend to serve Massachusetts' students of color,[21] these students are missing out on a valuable opportunity to learn CS.

Figure 8: CS access varies by geography

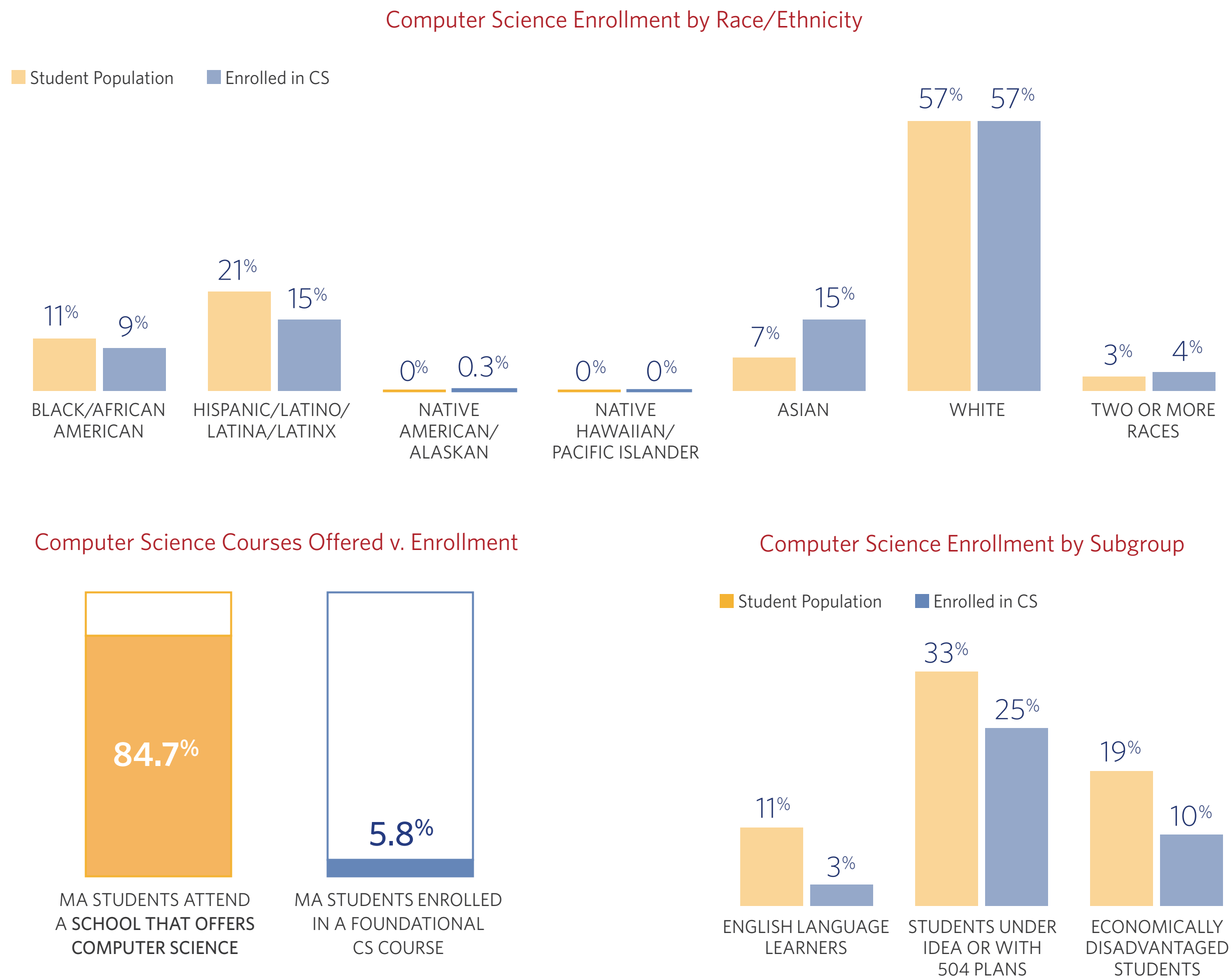


Source: Code.org Massachusetts State Handout, p. 2

Ultimately, the most striking issue for Massachusetts is not necessarily access to CS, but inequitable participation. In 2021, 84.7% of Massachusetts high schoolers attended a school that offered CS, but only 5.8% of students overall were enrolled.[22] [I] There were also striking differences in participation by demographic, as demonstrated on following page.[23]

I Code.org does not analyze participation by district.

Figure 9: In Massachusetts, participation in CS is unequal across race, gender and other characteristics



Source: Code.org Massachusetts State Handout, p. 2

The CS Policy Arena in Massachusetts

While Massachusetts certainly has room to grow on CS access and participation, the state *has* in fact put increasing emphasis on CS over the past several years. That said, some efforts have fallen short due to funding challenges, and notably, due to the dissolution of a key advocate for CS education—the Massachusetts Computing Attainment Network (MassCAN).

In 2013, MassCAN was founded as a "public-private coalition of education, industry, nonprofit, and academic partners who share a common interest in transforming computer science (CS) education in Massachusetts."[24] MassCAN was working to achieve two "high-level" outcomes:

"(1) preparing our youth for 21st century success by inspiring them and developing their technology and problem-solving skills and analytic abilities, which can be applied in any capacity and to any field, and (2) expanding the Massachusetts workforce to increase success across all information-based sectors of our economy."[25]

To do this, the group set four goals:

"1. Expand opportunities for all Massachusetts K–12 students to learn CS

2. Promote opportunities for all students, especially many more females and underrepresented minorities, to pursue CS careers

3. Inform and inspire educators, administrators, parents, and students about the extraordinary employment opportunities available in technology fields across all industries and nonprofits—locally, nationally, and globally

4. Mobilize, organize, and collaborate with partners across Massachusetts in industry, education, nonprofits, and the public sector to achieve the above goals."[26]

MassCAN received formal recognition from the state, and was responsible for raising $1 in matching funds for every $1 of state expenditure on CS. But in August 2018, MassCAN struggled to fund its programs and ultimately suspended its operations.[27]

Between 2015 and 2018, however, MassCAN did make significant progress on its 3-year strategic vision. In 2016, the state adopted the Massachusetts Curriculum Framework for Digital Literacy and Computer Science (DLCS), which built and expanded upon the state's prior Instructional Technology and Technological Literacy standards from 2008. These DLCS standards were the result of collaboration between DESE officials and educators, industry partners, families, and others—including MassCAN. As expressed by Mitchell D. Chester, Commissioner of Elementary and Secondary Education at the time of the DLCS standard publication, these standards (still in place today):

- Address core concepts in four key domains: Computing and Society, Digital Tools and Collaboration, Computing Systems, and Computational Thinking.
- Integrate practices necessary to successfully act in a technological world.
- Present coherent progressions of core concepts and practices from grades K to 12.
- Complement other Massachusetts Curriculum Frameworks."[28]

As is clear from their title, these standards cover concepts and goals that reach beyond CS, factoring in concepts related to digital literacy. This choice to incorporate *both* CS and DL is noteworthy because other states adjacent and near to Massachusetts chose to create CS-only standards. For example, Connecticut intentionally designed CS-only standards to prevent any potential confusion around what courses and curricula count as CS, versus other related subjects.[29] Similarly, while Rhode Island's standards incorporate DL as a theme (due to the influence of Massachusetts), the state made the decision to focus its standards on CS.[30] Maryland, too, has CS-only standards.[31] While this report focuses on CS, it is crucial that readers understand and recognize that MA's standards cover both topics, and oversight for all DL and CS activities come out of the same office at MA DESE.

Beyond establishing DLCS standards, Massachusetts established a DLCS teacher license in 2017. The license (for grades 5-12) was originally granted based on "competency review," but a full MTEL (Massachusetts Test for Educator Licensure) was implemented in 2021 and now serves as the basis for licensure.[32] In the 2022 school year, 498 educators in Massachusetts (across 400 school districts) were teaching with the DLCS license.[33]

In 2018, advocacy by CS stakeholders, including MBAE, led Massachusetts to amend MassCore, "a state-recommended program of study intended to align high school coursework with college and workforce expectations."[34] MassCore originally included "the successful completion of four units of English, four units of mathematics, three units of a lab-based science, three units of history, two units of the same foreign language, one unit of the arts, and five additional "core" courses."[35] But in 2018, MassCore was amended so that "[a] computer science course that includes rigorous mathematical or scientific concepts and aligns with the 2016 Digital Literacy and Computer Science Framework can substitute for either a mathematics course or a laboratory science course."[36] CS is still not a recommended course under MassCore.[37]

Subsequently, the Massachusetts legislature moved forward with funding for CS and established the Digital Literacy Now grant in 2019.[38] This competitive grant program was funded at $590,000 for FY20-FY22 and was intended to "establish and promote digital literacy and computer science education in public schools for grades kindergarten through grade 12."[39] The state chose to focus initially on DLCS implementation in grades 6-8,[40] with grant money being used to "[support] the creation of new programs and/or expanding existing programs to serve more students most underserved (including but not limited to students designated as economically disadvantaged, English language learners, special education, underrepresented minorities, and living in rural areas)."[41]

2019 also marked the beginning of a new grassroots effort around CS. Stakeholders came together to move forward on a CS agenda, drawing on the important (and still highly relevant) original vision of MassCAN. This grassroots engagement led to the creation of CSforMA in March 2020.[42] Given that CSforMA was founded at the start of COVID-19, the organization chose to focus initially on providing professional development. Between 2020 and 2022, CSforMA facilitated 45 workshops and engaged 846 unique educators. CSforMA is funded in part by MA DESE.[43]

Also, in 2020, Massachusetts published a DLCS Curriculum Guide, which provides an overview of DLCS curricula that schools may choose to use and an analysis of how those curricula align with state DLCS standards.[44] The guide was updated in April 2022.

In 2022, Governor Baker signed into law an economic development bill (Chapter 268 of the Acts of 2022) that continues to move the ball forward. It allocates $2.5 million for the recruitment and training of educators to teach computer science and calls for the Department of Elementary and Secondary Education to submit a report by no later than February 1, 2023 to the Joint Committee on Education and the House and Senate Committees on Ways and Means on "(a) a strategy for ensuring that computer science instruction is offered in each of the commonwealth's high schools by September 1, 2025; (b) a strategy to increase participation rates in computer science courses, particularly for female students, students of color, English language learners and students from economically disadvantaged backgrounds; (iii) a recommendation on whether a foundational computer science course should be a requirement to graduate high school in the commonwealth; and (iv) a proposed timeline for said requirement to be implemented if recommended; and provided further, that funds in this item shall be prioritized for schools and districts that the department identifies as having inadequate computer science instruction." As of February 15, 2023, the DESE report was not yet available. In addition, legislation filed in 2023 would require all Massachusetts high schools to offer a foundational CS course by 2026.

While Massachusetts has not neglected CS education, it has also not yet made CS a top priority. This report will explore potential policies that would set Massachusetts—a state with a burgeoning tech industry and a deep need for CS-educated citizens—on the path to becoming a true U.S. leader in the CS arena.

Insights from Literature on Computer Science

An analysis of existing literature on CS guides the thinking in this report. Specifically, literature in 5 areas provides key insights.

1. The benefits of learning CS

- Countries with more workers with information, computer and technology skills will experience higher economic growth, and workers with these skills will receive high returns in income. This can help reduce economic inequality.[45]
- CS classes provide students with a greater understanding of digital tools, which are essential in the 21st century.[46]
- CS classes that teach students fundamental problem-solving skills can help students excel in reasoning, creative thinking, mathematical skills and metacognition.[47]

KEY TAKEAWAY: CS, while it may not be the discipline that all students ultimately choose to pursue, can still have significant benefits for all students and their communities.

2. Public opinion on CS

- Parents, guardians and K-12 teachers view CS as increasingly important for students.[48]
- School administrators report that CS is now a top priority (although teachers disagree that this is the case).[49]
- Students themselves are not convinced of the merits of learning CS.[50]

KEY TAKEAWAY: Interrogating whether/how administrators prioritize CS will be essential in a statewide expansion of the subject. Furthermore, showing students the merits of CS will be key to enhancing participation.

3. Student perceptions of CS and connections to differential participation

- Negative stereotypes around CS (i.e. that boys are better than girls at programming) are engrained in children at a young age.[51]
- Gender disparities in CS persist due to 2 core factors: perceptions of CS as a "masculine" discipline and limited pre-college opportunities for exposure.[52]
- Female students are less likely to participate in CS due to a negative school environment (ex. curriculum with limited connections to real-life and pedagogy that discourages collaboration).[53]
- For racial minorities, limited CS participation stems more from a lack of access than a lack of interest.[54]

KEY TAKEAWAY: To increase participation in CS by women, CS exposure must occur early and classroom environments must be welcoming. To increase participation among racial minorities, increasing access to CS is key.

4. Promising solutions to limited participation among women

- There are several proven strategies to reduce differential CS participation across gender: for example, exposing girls to CS early on and engaging girls in projects with real-life connections.[55]
- School counselors (who act as course "gatekeepers") have also proven effective in guiding students to CS courses.[56]
- At the university level, efforts such as organizing students by CS level and exposing women to CS networking/job opportunities have boosted female CS participation.[57]

KEY TAKEAWAY: Female participation in CS can be boosted through early exposure to the subject and efforts to connect women to CS courses, career pathways and female CS peers.

5. A policy framework regarding the expansion of CS

- While enhancing participation in CS is often the goal for policymakers, capacity to provide CS and access to CS must exist before participation can grow.[58]

KEY TAKEAWAY: States seeking to expand CS participation must not neglect efforts to expand capacity for CS delivery (in human capital, leadership, etc.) and increase access to CS.

Findings: Three State Policy Strategies and Their Barriers

This report seeks to answer two main questions:

- What steps can Massachusetts take to expand access to and participation in CS at the high school level?
- What are the biggest barriers that Massachusetts is likely to face, and what might it do to address these barriers?

Overview of Findings Section

To identify potential policy levers for Massachusetts, it is useful to look to other states that have made significant progress in expanding access to and participation in CS. The selection of these states—Arkansas, Connecticut, Maryland, Rhode Island and South Carolina—was mainly guided by Code.org's Government Affairs team, but this selection was also confirmed by other experts who saw these states' approaches as potential models for Massachusetts. Each of these states have approached CS expansion differently, and their decisions have been guided by several factors. These include strength of leadership on CS expansion and existing levels of CS human capital.

Looking at these five states is instructive in determining potential pathways forward for Massachusetts. It is of course worth recognizing that given a small sample size, these options do not reflect the full scope of policy approaches that could be (or have been) considered across the U.S. These options nonetheless represent three high impact pathways forward for Massachusetts. Additionally, the states interviewed are lauded for their CS efforts, and thus in choosing a CS expansion strategy, Massachusetts would be wise to choose among this universe of options.

It is also worth noting that the three strategies considered are only core policies, and Massachusetts has many other strategies at its disposal. These include (among others), building human capital through expanded professional development offerings, efforts to foster awareness around the importance of CS, and the identification and engagement of future CS champions.

This section digs deeper into the several challenges associated with the three core policy options utilized by the five states studied—revealed by state officials in original interviews. Interviews with two Massachusetts school districts—Burlington and Springfield Public Schools—were also critical in identifying not only how districts have approached CS expansion (and the barriers to doing so), but also how each potential state policy strategy could affect administrators, teachers and students.

Five States and Their Policy Approaches

This report draws on interviews with officials from five states that have expanded CS access and participation using different strategies. Below is a brief overview of the five states.

Connecticut: All High Schools Offer CS

- In 2019, Connecticut required that all high schools offer CS. However, the state has not dedicated funding to support the effort.

Arkansas: High School Graduation Requirement

- In 2015, Arkansas became the first state in the nation to require that all high schools offer CS and student participation increased dramatically under this strategy. In 2021, the state made CS a graduation requirement (starting with all ninth graders entering in 2022-2023).

Maryland: High School Graduation Requirement

- Maryland requires that all students take a course in engineering, technology, or CS to graduate. In 2018, the state went further on CS, requiring that all high schools offer it.

South Carolina: High School Graduation Requirement

- South Carolina's CS graduation requirement has existed since the 1980s, but that requirement originally included subjects like keyboarding. In 2018, the state updated its requirement to be a "pure" CS requirement.

Rhode Island: Grassroots Approach

- CS4RI launched in 2016, and this organization is a collaborative effort across numerous stakeholder groups. CS4RI has taken a more grassroots approach to CS, setting a goal that all high schools offer the subject by 2017, though this goal has not been met. A 2022 proposal to revise RI's high school graduation requirements would, if implemented, require that all students take a CS course to graduate from high school.

More details on the states and districts studied can be found in Appendix 3. High-level takeaways from state interviews can be found in Appendix 4.

The states analyzed can be grouped into 3 policy approaches.

STRATEGY 1: Require that all high schools offer CS	STRATEGY 2: Implement a high school CS graduation requirement	STRATEGY 3: Take a grassroots approach without mandates around CS expansion
Connecticut	Arkansas Maryland South Carolina	Rhode Island

Currently, Massachusetts can be classified as taking a grassroots approach, but as evidenced by low participation rates and disparities, this is not an adequate strategy. Mandates will be necessary to expand access to and participation in CS.

Challenges to Each Policy Approach

Challenges Common to All Three Strategies

Throughout the interview process, five challenges common to the three policy strategies emerged. These include: need for human capital, need for buy-in from administrators and school counselors, cost, need for state-level champions with power to affect change, and continued negative messaging and stereotyping around CS.

Need for Human Capital (Teachers and CS-Dedicated Staff)

TEACHERS

Across the country, there is a clear shortage of CS teachers. This issue largely stems from the fact that most students graduating with BS and BA degrees in CS do not intend to become teachers. Furthermore, CS graduates can obtain higher salaries in the private sector.[59] As a result of the CS teacher shortage, many states that have found themselves strapped on human capital have built up capacity by recruiting in-service teachers (teachers licensed in other subjects) to learn and teach CS while also encouraging these teachers to become licensed so they can teach more CS sections.

Interviewees noted that for teachers who are brand new to CS, this can be overwhelming and difficult, and the process requires strong professional development with follow-up.[60] However, numerous interviewees noted that in-service teachers from all different subjects are highly motivated to teach CS because they are seeking new challenges.[61] Several interviewees noted that almost anyone can learn to teach CS, so long as they have access to strong training and support.[62]

Related to human capital is the issue of licensure. While many states do allow teachers to teach a certain number of CS courses without a CS license, states encourage teachers to obtain these licenses if they exist. Still, licenses can pose a barrier to teachers. The exam that leads to licensure may not be applicable to the skills a teacher needs at their given level of teaching.

In the case of South Carolina, there is one standard CS exam that covers elementary-level CS skills up through more advanced high school CS skills. This license is thus not fully applicable to all teachers, especially those teaching students in lower grades. As a result, South Carolina is experimenting with an alternative certification model, piloting a program of "microcredentials" with approximately 50 teachers.[63] Microcredentials are an alternative method of licensure by which teachers can demonstrate their skills in more applied and hands-on ways, and then gain stacked credentials for each demonstrated competency.

Beyond experimenting with microcredentials, states including Arkansas, South Carolina, Rhode Island and Maryland have also experimented with direct incentives in the form of bonus payments.[64] Officials in these states noted that these incentives are contributing to increases in licensure,[65] but incentives have also proven less effective during the COVID-19 pandemic.[66]

In 2017, Massachusetts put in place its DLCS Teacher License for grades 5-12. This license requires that teachers have knowledge of DLCS standards two grades below and two grades above what they actually teach. Advanced Placement CS teachers must also be authorized through the College Board.[67] In the 2022 school year, 498 MA teachers (across 400 districts) were teaching with this license.[68] This number, though small, is not necessarily surprising given that the DLCS license is still quite new. This number may also reflect two other parts of MA's licensure structure that may limit fast action on licensure. First, even though the DLCS license is in place, MA DESE does offer a "hardship waiver" for schools that are struggling to hire a licensed teacher.[J] Also, if teachers are teaching CS as less than 20% of their normal course load, they are not required to submit a "hardship waiver." Because of DESE's efforts, many teachers in this situation are becoming DLCS licensed, (and MA DESE expects that more teachers will pursue this license in the future) but there is still progress to be made.[69]

Massachusetts is no exception to the issue of limited human capital. The state lacks CS teachers across the board. Even in districts making great strides in CS it is difficult to recruit and retain teachers—particularly at the middle and high school level. And, given COVID stress, teachers are currently less likely to sign up for additional professional development. Relatively slow uptake of the Massachusetts DLCS license may simply reflect the fact that the license is new, but may also indicate that Massachusetts should experiment with licensure incentives or alternative pathways to licensure, such as microcredentials. Finally, Massachusetts' small DLCS staff in DESE would benefit from larger internal capacity and expanded partnerships with external entities who have additional capacity to deliver professional development and other services.

J This waiver is intended to be temporary.

CS-DEDICATED STAFF

A major challenge of expanding CS is the sheer intensity of work for those in charge of implementation. Across states that have expanded CS, officials have noted that this work is time-intensive and challenging and requires strong collaboration across entities.[70]

States can approach their staffing in many ways, housing their efforts fully in a state department of education or contracting out/working across entities. Arkansas' CS team (comprised of over 10 dedicated CS specialists) sits in the state Department of Education, but is largely programmatically independent.[71] This group delivers Professional Development and generally runs CS efforts. Connecticut houses its CS efforts in its Department of Education,[72] as does Rhode Island (although Rhode Island's CS efforts began in the Governor's Office of Innovation).[73] Maryland houses its efforts in the Maryland Center for Computing Education, an entity that works closely with the Maryland Department of Education through a Memorandum of Understanding.[74] In Massachusetts, DLCS efforts are housed in DESE and support for PD is provided by CSforMA and other entities. Regardless of how a state structures and houses their CS efforts, a CS team must have the capacity to cover numerous efforts (PD, outreach to districts, collaboration across departments, etc.) and must be properly compensated for this work.

Need for buy-in from administrators and school counselors

Numerous interviewees emphasized that "buy-in" from administrators and school counselors is key to ensuring successful CS expansion. Within Massachusetts, districts have attributed their success to strong administrative support. For example, in the Burlington Public Schools, the leadership of the Superintendent has been influential in driving CS offerings within the district. With this support, the district has been able to fund programs and teachers have been able to take more time for PD than what is offered in many other districts.[75]

Research has also pointed to school counselors as CS "gatekeepers" for course-taking, meaning they can be highly influential in encouraging students to participate in CS.[76] Some states immediately named lack of engagement with counselors as a barrier to CS expansion—namely, Rhode Island, which is very intentional about engaging with counselors to make sure they can assist with enrolling diverse students in CS classes.

In Massachusetts, DESE generally provides guidance to counselors regarding regulations and strategies for expanding access to CS instruction. Even still, it is difficult, for a number of reasons, for counselors to fully engage with students on class choices.[77]

> While some Massachusetts districts have fully embraced CS, others have not yet moved in this direction. Superintendents may be concerned about several issues, likely including a lack of qualified CS teachers, or even more fundamentally, lack of time in the day.

Cost

Expanding CS can be expensive, and costs can manifest themselves in unexpected ways. Thus, states may underestimate the cost of ensuring that schools are fully equipped to teach CS.

The cost of human capital is likely to be the biggest expenditure for any district. New CS hires are expensive, but schools may be able to utilize CS teachers for multiple functions—which could reduce spending. The Burlington Public School District employs CS teachers that also serve as tech coordinators, meaning they teach 2/3 of the time and deal with logistics 1/3 of the time.[78] CS licensure can also present a cost, especially if a state is providing monetary incentives for teachers to attain a license. The cost of recruiting and maintaining a strong team of professionals to guide state CS efforts is also not insignificant.

Aside from human capital, there is a cost associated with devices, with which some districts may be very well equipped and others less so. Some districts, such as Springfield, have gone 1:1 with devices (meaning one device per child),[79] but this is not the case for all districts in the Commonwealth. For districts that are not as advanced, simply equipping schools or individual students with appropriate technology for CS, and sustaining it, would require significant investment. This investment would vary depending on past technology investments made by districts and the development of a coherent technology strategy.

Curriculum can also be costly. While some CS curricula are free, others are not. For example, Project Lead the Way (PLTW) has a relatively steep price tag because it is a ready-to-implement curriculum that requires iPads. PLTW is one curriculum option in Massachusetts' CS Curriculum Guide, and the state has provided districts with funding to support PLTW implementation.[80]

One "hidden" cost for districts is the hardware that goes along with curriculum. For example, Burlington Public Schools uses "Sphero" to teach coding, a program that requires physical robots. Burlington must pay to acquire the Sphero robots, and over time, must pay to repair them due to normal wear and tear. For districts that receive funding for CS through grants rather than more sustained sources, upkeep can present a barrier.[81]

Massachusetts is not currently funding DLCS at a level that would be appropriate or sustainable for long-term expansion, and given that Massachusetts still has a long way to go to build up its capacity (namely in human capital), the cost barrier could be significant. That said, given the future returns to Massachusetts and its students that expanded CS education could provide, the case for funding CS at a high level is clear.

Currently, Massachusetts has helped fund CS at the district level through "Digital Literacy Now" (DLN), but this funding has expired. Going forward, it is difficult to predict what the overall cost of a state-wide high school CS expansion will be as districts are starting their expansion efforts from a variety of different programmatic levels. Nonetheless, the cost will be significantly higher than DLN's previous appropriation of $590,000.

Need for state-level-champions with power to affect change

Related to the issue of "buy-in" on CS, interviewees repeatedly noted that a CS expansion requires strong leadership by a CS champion—ideally a champion with power to affect change. This champion can be a governor, a legislator or even the business community, but state-level champions are key to advancing CS.

Arkansas Governor Asa Hutchinson was a state-level CS champion who was able to garner political support for his efforts.[82] Hutchinson was deeply committed to Arkansas' CS growth for many years and advocated for CS outside of his own state. As President of the National Governor's Association, Hutchinson made the expansion of CS the focus of his 2021-2022 Presidential initiative.[83] Similarly, former Governor Gina Raimondo of Rhode Island initially led the charge to expand CS in her state, and direct communication between the Governor and state education agencies allowed for faster implementation.[84] This leadership was key given that Rhode Island took a grassroots approach to CS expansion—a strategy that requires *particularly* strong leadership and coordination.

Leadership has been similarly crucial in Connecticut. According to Jennifer Michalek of the Connecticut State Department of Education:[85]

> "Leadership is critical in advancing CS. CSDE leadership works with leadership from other agencies, including the Office of the Governor, to align efforts and ensure that any potential dedicated funding has the most impact possible."

In Massachusetts, former Governor Charlie Baker hosted governors from across the U.S. for a discussion around CS expansion.[86] He also signed onto the National Governor's Association compact to commit to an expansion of CS in Massachusetts. To maintain momentum and accelerate progress, it's important that the state's new governor provide leadership on this issue. It is also likely that other champions—such as the Massachusetts business community and organizations like CSforMA—will need to come together as a strong voice in favor of CS education.

The Need to Overcome Negative Stereotypes about CS

Interviewees pointed to negative stereotypes about CS as a major barrier for getting students—particularly high school girls—to participate in the subject. Officials in Rhode Island spoke directly to the issue of stereotypes, noting that perceptions from students and some educators about "who" CS is for and who should take CS courses continues to limit participation by some student populations. Notably, the perception is that CS is for white males, or "math people."[87] Burlington Public Schools has found it difficult to keep girls engaged in CS after middle school once CS is no longer required. In the district, one obstacle could be that CS teachers in the district are mainly men. Interestingly, however, the district has found that hiring female CS faculty at the middle school level has helped increase female participation in CS at the high school level.[88]

> Strong state-level leadership on CS is a prerequisite to successful CS expansion. Leaders (or groups of leaders) must classify CS education among their top priorities, and must engage with CS stakeholders early and often.

In Massachusetts, approximately 60% of K-8 schools are teaching at least one DLCS course.[89] While starting students early is certainly one way to capture student interest, female enrollment in high school CS is still extremely low.[90] This would suggest that there is something else about CS that makes women unlikely to want to participate—perhaps stereotypes about the types of people who are computer scientists, perhaps a lack of female role models, or perhaps something about the environment that is fostered within CS courses.

> Given the depth of the stereotypes around CS, these stereotypes are likely to be a very strong barrier to expansion of CS participation in Massachusetts. If Massachusetts is to increase CS participation in high school, it must devote ample time and resources to tackling this issue head-on. Ideally, this would mean engaging students in CS in elementary and middle school before stereotypes set in and harden.

Challenge Common to Strategies 1 and 2

Strategy 1 (require that all high schools offer CS) and strategy 2 (a graduation requirement) would both require mandates for implementation. Given that Massachusetts districts value their autonomy, pushback to these mandates is likely.

General Pushback to Mandates

A primary barrier to CS expansion through mandates/legislation is pushback to those mandates. District superintendents, principals and teachers can oppose state-level mandates due to concerns that states are adding to schools' existing levels of responsibility and doing so without recognizing constraints in time and capacity.[91]

Potential pushback on mandates has discouraged some states—including Connecticut and Rhode Island—from pursuing more aggressive policies such as graduation requirements.[92] Even Arkansas, which did successfully pursue a graduation requirement, experienced systemic pushback at the outset of its CS expansion effort. However, pushback was mitigated by the fact that the state put significant funding behind its CS expansion, which demonstrated the state's commitment to the subject.[93]

In Massachusetts, even with support for the idea of students learning CS, legislators can almost certainly anticipate pushback from superintendents, principals, and teachers. For teachers, a core concern is feeling unprepared as the state adds responsibilities.[94]

Challenges Unique to Strategy 2

The following challenges apply uniquely to a graduation requirement. Notably, these challenges apply regardless of what type of graduation requirement is implemented—a pure CS requirement (Arkansas, South Carolina), or a broader, multi-subject requirement (Maryland).

Lack of time in the school day

High school schedules are already packed. This begs the question: if CS becomes a graduation requirement, must another subject be taken away? From the perspective of MA DESE, the issue of "time in the day" is likely one that prevents districts from taking up CS.[95] Furthermore, according to Dr. Emmanuel Schanzer of Bootstrap, a popular CS curriculum provider,

> "Required CS courses at least give you equitable access, but they need a larger, well-qualified teaching staff to get the capacity to reach every child. But recruiting, training and staffing is just the tip of the iceberg: required courses also need time in the master schedule and room in the building to teach them. And it's not like there's empty rooms and empty hours in the most schools, so what do we cut?"

> In Massachusetts, districts value their independence and may react poorly to a CS mandate. However, if Massachusetts were to provide ample funding for CS and invest in professional development (among other strategies to build human capital), this barrier's impact could be mitigated.

In states where CS is a graduation requirement, these states have made a conscious decision to add CS to student schedules, without eliminating other courses.[96] Arkansas' graduation requirement is intentionally flexible, and can be satisfied by a long list of courses. This ideally allows students to feel that their CS elective is an engaging and enjoyable course. In South Carolina, the CS graduation requirement is similarly flexible. Students have a wide range of courses to choose from and course instructors are encouraged to work together across subjects to create projects that engage students.[97] Maryland's graduation requirement provides flexibility in another way. The state does not have a "pure" CS requirement, meaning that students can take CS, engineering or technology. That said, all courses that fall into these categories expose students to CS concepts.[98]

> Even though a CS requirement would add to already packed schedules, Massachusetts could aim for increased flexibility to mitigate this issue. Indeed, MA could aim to ensure that numerous types of courses satisfy the requirement.

Potential for a requirement to be "watered-down"

Another risk associated with a graduation requirement is that while a requirement may exist on the books, it may not be implemented with fidelity—especially if well-qualified teachers are lacking. Dr. Emmanuel Schanzer makes an important related point on the general risk of watering down CS:[99]

> "Teaching any subject requires high-level skills that go far beyond reading the subject's textbook to kids! So, without people who actually know how to teach CS, school must pick their poison: water down the content to the point where students aren't really learning CS at all, or rely on bad pedagogy that sacrifices equity by having students fend for themselves. Tragically, schools wind up having to choose both."

Implementation fidelity also requires ample state oversight (that is clear on desired student outcomes).[100]

If Massachusetts were to move to a graduation requirement, the risk of that requirement being "watered-down" would not be zero—especially given that Massachusetts is still in the process of developing its human capital for CS. However, with ample state oversight, it is likely that the state could mitigate some of the potential issues associated with implementation fidelity.

A Challenge Unique to Strategy 3

Strategy 3, take a grassroots approach without mandates around CS expansion, has its own challenges.

Local Control

Massachusetts, unlike many states of similar size, takes an approach of "local control" in the education sphere. Massachusetts consists of 400 school districts, so there is great variation in district capacity, resources, expertise, and motivation to implement an expansion of CS—which can lead to inequities in access to programming across districts.

If Massachusetts were to continue its grassroots approach to expanding CS (without implementing any sort of mandate), local control would likely present a massive barrier. Wealthy districts with vocal parents would be most likely to take-up CS expansion, while lower socioeconomic status districts would lag behind.[101]

An Overarching Challenge

Beyond the challenges highlighted above, Massachusetts must develop greater clarity of the size of the challenge at hand. As Jim Stanton of EDC (formerly of MassCAN) noted:[102]

> "I'm very concerned that we're making so little progress on the equity front and honestly feel that there is a lack of understanding of the magnitude of the challenge, just not enough dialogue going on with districts to say: 'Talk to us. Tell us the challenges that you really face, tell us about the cultural issues that make any kind of innovation and change a real challenge, and what do non-school players need to be knowing and doing to kind of connect the dots?' I mean, it certainly can't be the case that we just need to be setting higher aspirations for superintendents and schools and teachers. But I think there is a desire to feel that there ought to be a quicker, simpler solution to getting real results without understanding the territory at a very deep level."

> Massachusetts must emphasize equity in its CS expansion and local control is likely to present a very strong barrier to achieving this goal.

As Massachusetts moves forward on CS, dialogue between school players and non-school players to "understand the territory" will be essential in ensuring alignment of interests and coherent agreement on strategy and implementation.[103]

A Pathway Forward for Massachusetts

In the face of the barriers that each policy option presents, how can Massachusetts move forward on the expansion of access to and participation in CS education?

Recommendations

Massachusetts' current grassroots approach has already led to inequities in CS access across the state and continuing along this path would likely result in further disparity. Thus, Massachusetts should take bolder steps to ensure equitable access to and participation in CS.

A graduation requirement is the best policy lever to achieve that end, and Massachusetts should move towards the implementation of one in the future. However, to get to a point at which a graduation requirement is feasible, Massachusetts must take steps to build up CS capacity. To build this capacity, Massachusetts should require that all high schools offer CS (in addition to implementing numerous other policies that can help prepare the state to implement a successful graduation requirement).

This section maps out a pathway forward for Massachusetts, focusing on recommendations that span three phases. These phases intentionally allow for some time flexibility, giving stakeholders agency to decide exactly when to implement certain activities.

PHASE 1 (by 2023)	PHASE 2 (by 2023)	PHASE 3 (by 2025)
Convening and Promoting	Legislating, Guiding and Collaborating	Listening and Planning for further action

PHASE 1 (by 2023)
Convening and Promoting

1. Identify and connect with CS champions

To truly push forward the other recommendations outlined here, Massachusetts needs strong state-level CS champions with power to affect change (i.e. a Governor, Commissioner of Education, etc). Ideally, Massachusetts' new Governor will follow up on the work of Governor Baker and the efforts of the Department of Elementary and Secondary Education by embracing CS education as a priority. Other champions could come from within the legislature or the business community, but as is evidenced by other states such as Arkansas and Rhode Island, gubernatorial leadership is likely to be a critical element.

To engage the next Governor's administration, CS stakeholders must:

- Have a coordinated and realistic strategy: one that a Governor can easily take and implement,
- Be vocal about their goal: expanding CS access and participation to all students,
- Disseminate strong evidence regarding the benefits of CS education for the state and students: economic benefits and cognitive benefits,
- Develop a solid argument for why the Governor should prioritize CS education over other policy priorities: likely using an economic argument, and
- Point to success in other states: particularly states like Arkansas where Governors have been influential in expanding CS

education.

Stakeholders must also recognize, however, that Massachusetts' new Governor is not guaranteed to take up CS education as a top priority. If this does not occur, stakeholders must consider whether key legislators (perhaps those with strong voting records on education innovations) might be solicited as champions, or whether a segment of the business community could coordinate to advance CS as a priority.

2. Foster public awareness of CS offerings and the benefits of learning CS

While many stakeholders agree that CS education is important, Massachusetts is not reaching enough students and must spend time building awareness around CS and its benefits to students and the state.

Here, Massachusetts can look to Rhode Island for inspiration. Rhode Island has taken a grassroots approach to expanding CS education and has focused immensely on building awareness around CS. The state has invited thousands of students and over 100 companies to a CS event that showcases student work and allows students and their families to understand what CS really is, and what future jobs might entail. A similar type of event could be powerful in Massachusetts, and could motivate families, teachers, counselors and superintendents to advocate for CS. This type of event could also motivate students to try CS, even if they have never had prior interest.[104]

Massachusetts could also leverage its existing CS success stories. Districts including Springfield and Burlington have made major strides in expanding CS education to diverse groups of students, so the state would be wise to showcase best-practices from these districts and others, along with examples of how students have responded to CS courses and what they have gone on to do after receiving CS exposure. Massachusetts can also showcase positive examples of CS expansion through the Digital Literacy Now (DLN) program, as middle school expansion can still inform expansion at the high school level.

PHASE 2 (in 2023/2024)
Legislating, Guiding and Collaborating

1. Require that all high schools offer CS

The Massachusetts legislature should mandate that all high schools offer CS education by 2025. While unlikely to lead to fully equitable participation, this policy would:

- expand CS access to students for whom the course has never been available, thereby moving the needle on equity and hopefully piquing student interest,
- require districts to focus on their CS human capital, thereby preparing them for more intensive CS expansions in the future, and
- signal the state's commitment to CS.

If legislation is passed in the 2023-2024 legislative session, high schools should have sufficient time to offer CS by 2025 as access is already high across the state. Still, this mandate should provide for some initial flexibilities as human capital takes time to develop. Arkansas can serve as an example, as it also needed time to develop human capital in schools. Similar to Arkansas, Massachusetts should allow schools to apply for short-term waivers if they are struggling to find a CS teacher and Massachusetts should utilize its existing virtual school platform to offer CS courses for students who do not yet have an in-person CS teacher.[105]

2. Allocate funding for CS

To accompany its mandate, the state must allocate ample line-item funding to help districts cover the costs of CS education outlined earlier in this report. As a sustainable source of funding for all high schools, line-item funding would allow districts to invest in CS without fear of financial struggle. Furthermore, a fully state-funded CS expansion (as opposed to Massachusetts' prior approach of a business match) would signal a strong state commitment to helping districts. This approach could also attract more business support as it would signal that the state is equally committed to the effort and is not leaving business to fill in the gaps. Massachusetts has made some progress with the 2022 economic development bill (Chapter 268 of the Acts of 2022) allocating $2.5 million in funding for the recruitment and training of CS educators.

In addition to creating dedicated line-item funding for supporting the expansion of CS in high schools, Massachusetts should renew its funding for the DLN program, which helps a small number of districts expand their CS programs at the middle school level. This program's funding has expired, and simply letting the funding disappear without recognition of continued need will likely kill momentum on CS at the middle school level.[106] Massachusetts should continue its commitment to DLN, thereby continuing to create positive models for CS expansion at the middle school level. Additionally, in the future, Massachusetts would be wise to ensure that all students receive CS on a continuum from K-12, so working to expand middle school CS now can help set Massachusetts on a strong path in this direction.

3. Build up state infrastructure for CS service delivery and oversight

Massachusetts currently has several entities involved in overseeing CS activities and delivering services (including professional development). That said, a statewide expansion of CS access and participation will require significant efforts to continue building this infrastructure and solidifying state oversight. While some states center their CS oversight and service delivery in their state department of education, others house CS efforts in external entities that partner with the state (ex. entities like Code.org or other professional development providers).

MA DESE would benefit from expanded in-house capacity and resources so it can guide CS expansion across the state. Additionally, because MA DESE already has many responsibilities in terms of CS oversight, contracting with external partners that currently have additional capacity to provide professional development and other workshops could be a beneficial way to advance CS efforts in the state.[107]

In choosing partners, DESE should look for entities that share its vision so that service delivery is relatively standard across the state. State officials in Arkansas and South Carolina spoke to the importance of this "vision-definition" in ensuring that CS services are delivered in a high quality, clear way.

DESE should also designate districts with strong CS infrastructure as regional partners that assist DESE in collecting and sharing best practices among districts. These partners could then share this information with DESE (and its partners) to use in training sessions. Districts could also be influential in bolstering efforts around curriculum identification and implementation. Currently, MA DESE publishes curricula for teachers to consult in a system called CURATE.[108] Districts could help identify new curricular materials (that may not be in the existing state DLCS curriculum guide) and could provide the state with valuable feedback on the accessibility of its CURATE platform.

4. Build human capital: modify teacher licensure

Perhaps most importantly, Massachusetts must implement efforts to build human capital: specifically focusing on teachers and school counselors.

Given that many CS teachers in Massachusetts are teachers that also teach other subjects, DESE must enhance professional development offerings through partnerships with external providers. PD should not just cover CS skills, but should also provide information on how teachers can create inclusive environments in their CS classrooms.

For both in-service and pre-service teachers, Massachusetts has already made progress on licensure by developing a DLCS license for grades 5-12. To maximize the number of teachers with DLCS licensure (which would allow teachers to teach more than just a few sections of CS), DESE should design alternative pathways to obtain a DLCS license. In collaboration with state universities, the state should build a system of DLCS microcredentials. Teachers should be able to demonstrate competency in individual aspects of DLCS curriculum and pedagogy and earn stackable microcredentials from a state university (recognized by Massachusetts in the form of licensure). The inherent flexibility of this process would likely encourage more teachers to get licensed in DLCS and would have the added benefit of giving teachers concrete skills to employ in their classrooms. Massachusetts should also experiment with monetary incentives to attract teachers to licensure (either the traditional DLCS license, or microcredentials).

The Commonwealth should also grow its overall pre-service pipeline into DLCS teaching. One option would be to expand the number of DLCS teacher preparation programs. Currently, there are only 4 DLCS teacher prep programs for grades 5-12 and 2 Instructional Technology Specialist prep programs—one potential reason being that schools do not necessarily want to invest in a DLCS teacher preparation program if there is no guarantee of financial return.[109] Massachusetts could use some of its CS line-item funding to incentivize institutions of higher education (IHEs) to develop new pre-service programs. Funding could be distributed through a competitive grant program run through DESE, which would allow DESE to retain some oversight over how the programs are run. A competitive grant would ideally prioritize funding for IHE's that make efforts to recruit diverse cohorts of DLCS professionals who reflect the diversity of Massachusetts' students, and can serve as positive role models for students who may wish to pursue careers in CS.

5. Build human capital: connect with school counselors

DESE and partners should greatly expand outreach to high school counselors who help students plan their schedules. Workshops should train counselors on the importance of CS for digital citizenship, cognitive development and future job opportunities. Workshops must also focus on breaking down stereotypes around which types of students should take CS. DESE should actively encourage school counselors to recommend CS to all students, not just those who show competency in math or a pre-existing interest in computers.

6. Build opportunities for industry involvement and dialogue with schools

Massachusetts' burgeoning tech industry has immense resources to offer to CS expansion and should participate in several ways, including:

- Volunteering directly in schools to teach CS courses and train CS teachers (through programs like Microsoft TEALS that pair industry professionals with classroom teachers),
- Offering professional development workshops in-person and online,
- Offering internships and mentoring opportunities to high school students during the semester or over the summer,
- Funding programs in schools,
- Communicating the importance of CS.

Industry representatives should convene with districts to understand the barriers that districts face and develop strategies for assisting districts without overwhelming them.

7. Build opportunities for collaboration with institutions of higher education

Massachusetts is home to numerous institutions of higher education (four-year and two-year institutions) whose resources could be leveraged in the expansion of CS. University CS professors could be enlisted to provide CS training to aspiring high school CS teachers (along with consistent follow-up and mentoring), and CS university students could mentor high-schoolers and provide tutoring.

High-schoolers may also be able to enroll in CS courses at institutions of higher education either in-person or online. While all high schools in Massachusetts will ideally provide CS directly, schools could use partnerships with higher education institutions to provide expanded offerings to students—particularly in districts that are struggling to hire teachers (which could be the case in some rural districts, for example). Schools with existing Early College programs (programs that allow high school students to enroll in college classes and earn college credit) could serve as a model for partnerships between high schools and higher education institutions.

Finally, institutions of higher education could be quite influential in a move towards a CS graduation requirement once Massachusetts has built up more CS capacity. For example, Massachusetts' state universities could exert pressure for a graduation requirement by requiring CS courses for entry into college.[110] Higher education officials should be engaged in early stakeholder conversations around CS, as colleges and universities could be highly influential in this policy discussion.

8. Revisit MA's current state DLCS Standards

While Massachusetts already has comprehensive DLCS standards, these standards were created in 2016 and should be reviewed and potentially updated.

Massachusetts should reconvene the group of people who originally created the standards, and this group should focus on two things: first, reviewing the standards to ensure that they are still up-to-date given technological changes over the past several years, and second, taking a critical look at whether DL and CS should perhaps be separated into different sets of standards.

Several states have intentionally created standalone CS standards to avoid confusion among districts and other stakeholders regarding what types of courses and lessons count as CS. Massachusetts would be wise to work with stakeholders to understand whether the standards (in their 6 years of practice) have perhaps led to confusion in the state, and whether they should be updated to separate DL and CS.[K]

9. Develop a research strategy around CS expansion

If Massachusetts expands CS to all high schools, this would be an ideal opportunity for the state to gather information about this expansion. DESE should collaborate with researchers from across the state to develop a research strategy around CS expansion.

Among other topics, Massachusetts would be wise to investigate (within the context of MA specifically):

- When all schools offer CS, who enrolls?
- What is keeping students from enrolling in CS in MA schools (even if classes are offered)?
- What interventions by administrators and counselors are most effective at increasing participation?
- What courses do students enjoy the most?
- What are the outcomes of diverse students who participate in different types of CS courses?

K According to CSforMA's Director, coursetaking is higher in DL than CS. Revising the standards could be one way to encourage schools to teach more CS.

PHASE 3 (by 2025)

Listening and Planning for further action

1. Conduct listening tours to collect feedback on expansion efforts

By 2025, all Massachusetts high schools should offer CS. As this expansion occurs, DESE and other stakeholders must conduct listening tours to collect feedback on expansion efforts, and particularly the challenges districts and schools are facing. This information—along with any initial data collected through research—will be critical as the state thinks ahead to how it can ensure CS participation for all high-schoolers.

2. Hold convenings to determine a date by which a CS graduation requirement could be implemented (and establish next steps)

Using the information collected on listening tours, stakeholders should come together to discuss next steps—specifically, a date by which a CS graduation requirement could be implemented, and a plan for additional capacity-building measures. This timeline will need to be directly informed by district experiences, along with an assessment of current state leadership on CS.

These recommendations can help Massachusetts enhance CS capacity, access and participation, with the goal of ultimately implementing a graduation requirement that reaches all students—regardless of race, gender, socioeconomic, ELL or disability status. In addition, this approach can allow MA to identify best practices over the next few years before the state potentially moves to a more intensive graduation requirement strategy.

Conclusion

Expanding student access to and enrollment in computer science classes is both an economic development strategy and a student equity imperative.

Computer science has become a critical area of study that provides students with skills they need across numerous sectors and social contexts. It can open up a world of opportunity, leading to careers that provide job security and economic mobility. Yet, students who currently participate in CS, are mostly white and male.

National salaries for computer and information technology jobs are skyrocketing. Massachusetts is experiencing rapid growth in positions that demand advanced computer skills, but the demand for this labor has outpaced supply. At the same time, employers are deeply committed to increasing diversity in the tech workforce and addressing deep income and wealth gaps.

Now is the time to take bold steps to expand participation in computer science study and ensure we are providing equal access and opportunity. Requiring that all students take a foundational computer science class is the best way to enhance equitable access and participation, and Massachusetts should move toward that approach; one which will require significant coordination and leadership.

The recommendations in this report provide a phased approach to expanding CS access and participation that can help Massachusetts build its human capital and enhance its coordination across entities in ways that will be critical to its development and success as a national leader in CS.

APPENDIX 1

Data

Much of the data for this report is pulled from Code.org's comprehensive advocacy materials, developed in partnership with the Computer Science Teachers Association (CSTA) and the Expanding Pathways to Computing Education (ECEP) Alliance. Code.org solicits data from state educational agencies, so data may arrive in different formats depending on how the solicited state collects data on coursetaking. Once data is collected, Code.org determines whether any given course counts as "computer science." The Code.org definition of a "foundational computer science course" may differ slightly from that of any given state, but using this definition, Code.org is able to capture a standardized picture of CS offerings across the country.[111]

Code.org describes foundational CS as follows:

> "The Access Report describes the prevalence of foundational computer science, a subset of all computer science courses. The operating definition of "a course that teaches foundational computer science" is based on the definition of computer science by the Computer Science Teachers Association and the K–12 Computer Science Framework: Computer science is the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society. High school courses must be offered during the school day and include at least 20 hours of programming to count as foundational computer science."[112]

Notably, Massachusetts' DLCS standards employ a very similar definition of CS as that presented by Code.org and partners in their 2021 advocacy report:

> "the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society."[113]

That said, there may be some differences in how Massachusetts and Code.org classify courses based on hours of instruction. In addition, Massachusetts and Code.org differ slightly on how they define "high schools." According to Code.org:

> "For the school list, we use the 2019–20 NCES list of schools that enroll students in at least one high school grade (9–12) and remove schools that we know have since closed, do not offer academic courses, or serve transient populations (e.g., some specialized programs or some juvenile detention centers), and CTE centers that are co-located with a high school."

Using this definition, Code.org's analysis is based on 389 schools with high school grades. The state reports economically disadvantaged students rather than students who qualify for free and reduced-price meals. If students select "Hispanic or Latino" and a race category, they are counted as Hispanic or Latino, not 2 or more races. Students who select 2 or more races and not Hispanic or Latino are counted as 2 or more races. These students are not included in other categories. Participation data was masked at low counts.[L]

> It is, of course, important to note that Code.org only reports participation in CS for one-year periods (ex. One school year): In Massachusetts in 2020-2021, "84.7% of MA high school students attend a school that offers foundational computer science, but only 5.8% of students are enrolled in a computer science course." The 5.8% of students participating in the 2020-2021 may or may not participate in CS more than once during their high school careers.

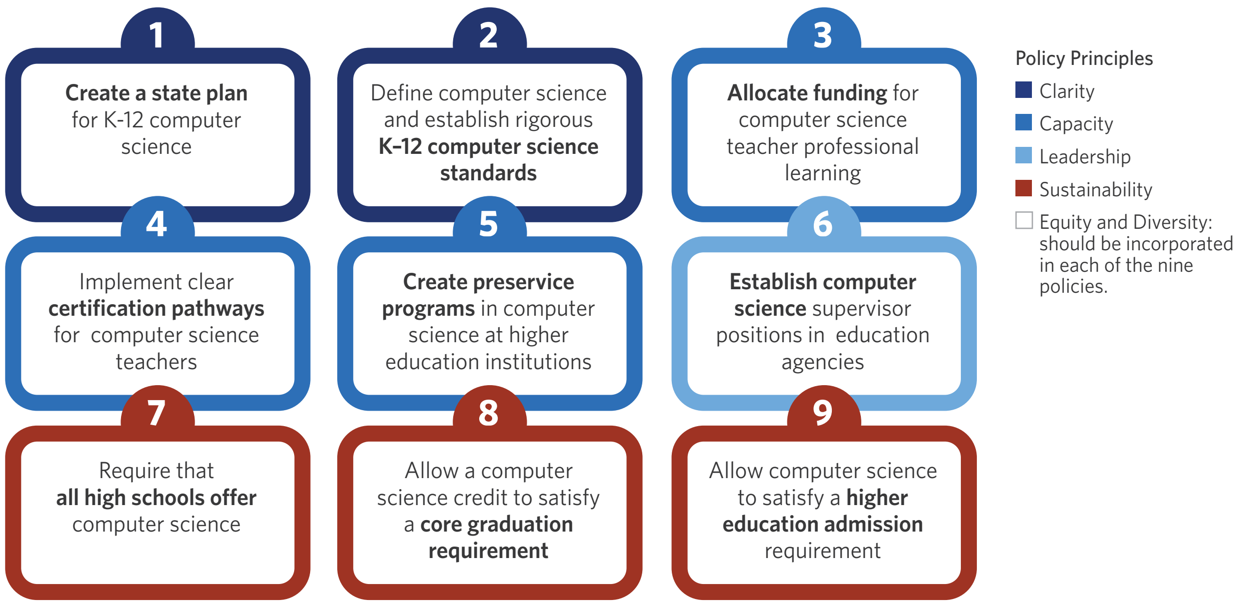
[L] MA DESE's DLCS Lead confirmed that Code.org's data provides a reliable picture of the state of CS in Massachusetts.

APPENDIX 2

Code.org and its Nine Policies

Code.org is a non-profit founded by Hadi and Ali Partovi, and it is "dedicated to expanding access to computer science in schools and increasing participation by young women and students from other underrepresented groups."[114] The organization has a vision that "every student in every school has the opportunity to learn computer science as part of their core K-12 education."[115] Code.org's advocacy coalition—a group of over 100 "industry, nonprofit, and advocacy organizations"[116]—drives this effort and advocates for 9 policies that every state should implement.[117]

Figure 6: Code.org's 9 policies demonstrate one recommended approach to expanding CS access and participation (Source: Code.org 2022 Massachusetts State Handout, p. 1)



Code.org's 9 policies are a (mostly) comprehensive set of policy options by which states can equitably expand their CS offerings. But, as explored in the report, Code.org's policies are not the only policy options available to states. And, depending on state contexts, some policies may be more palatable and feasible than others.

Additional information on Code.org's 9 policies can be found in the organization's 2022 State of CS Report.[118]

APPENDIX 3

Details on States and Districts

The information in this section is compiled from interviews (and state agency/organization websites to fill in details around licensure, etc).

	STATE POLICY APPROACH	HISTORY AND TIMELINE
ARKANSAS	High school graduation requirement	In 2015, Arkansas (AR) was the first state in the nation to require that all high schools offer CS. In 2021, the state passed a law to make CS a graduation requirement (starting with all ninth graders entering in 2022–2023.
CONNECTICUT	All high schools required to offer CS (but no CS graduation requirement)	In 2019, Connecticut passed legislation requiring all high schools to offer CS. The state does not currently have any dedicated funding for the subject. CT does not require that students take CS as a graduation requirement. Rather, CT's approach is to offer CS and encourage students to take it before they graduate.
MARYLAND	High school graduation requirement with CS as an option	Maryland has long had a high school technology graduation requirement in place, under which students must take a course in engineering, technology, or computer science. In 2018, the Maryland legislature went further by passing a law requiring all high schools to offer CS.
RHODE ISLAND	Grassroots approach—no mandate around offering CS/no current graduation requirement	Rhode Island has taken a grassroots approach to expanding access to and participation in CS, educating districts, students and families on the importance of offering CS and enrolling students. However, a 2022 proposal to revise RI's high school graduation requirements would include CS.
SOUTH CAROLINA	High school CS graduation requirement	South Carolina has had a CS graduation requirement in place since the 1980s, although this graduation requirement used to extend to courses such as keyboarding. This requirement was updated in 2018 and is now a "pure" CS requirement that can be satisfied by approximately 50 different courses.

ARKANSAS [119 120 121]	
State Policy Approach	All High Schools Required to Offer + High School Graduation Requirement
Original Champion of CS	Governor Asa Hutchinson
Structure of CS Oversight	Team situated in the AR State Department of Education (led by Anthony Owen, includes numerous CS specialists).
Structure of Graduation Requirement	Flexible requirement: students can take one of many courses to satisfy the requirement. • The state has designed numerous courses that span different topics such as Artificial Intelligence and Machine Learning, Mobile Application Development, and Robotics. • There are no prerequisites for courses, which limits barriers to entry.
Structure of Professional Development	Owen's team provides direct PD instead of contracting out.

Structure of State Licensure	AR has a CS certification and the state provides $2000 bonuses to high school teachers who obtain it.
Key Barriers to CS Education + Mitigation Strategies	*Pushback to mandates*: Mitigated by putting state funding behind the effort (which also attracted industry support and attention). *A need for human capital (teachers)*: Owen's team does extensive PD to train in-service teachers, and AR has implemented incentives for teachers to get certified. Additionally, when AR required schools to offer CS, schools offered few courses at the outset. Courses were also offered online to give schools time to adjust.
Additional Highlights	AR's graduation requirement is intentionally flexible—it is not a "one size fits all" approach.

CONNECTICUT[122]	
State Policy Approach	All High Schools Required to Offer + (Grassroots Approach)[J]
Original Champion of CS	Governor Ned Lamont and Lieutenant Governor Susan Bysiewicz
Structure of CS Oversight	Housed in Connecticut State Department of Education.
Structure of Professional Development	Numerous providers train in-service and pre-service teachers Example: Partnership with Sacred Heart University and Code.org
Structure of State Licensure	Teachers can earn a CS cross-endorsement (through coursework or Praxis)
Key Barriers to CS Education + Mitigation Strategies	*Figuring out how business can support CS*: Ongoing challenge *Fidelity of implementation regarding the requirement that schools offer CS: even though schools are required to offer CS, limited enrollment may cause a class not to run*: Ongoing challenge *Tensions between CS, math and science*: Students must take 9 credits of STEM, but can choose how to allocate these credits among subjects *Risk of additional asks: if CS were to become a graduation requirement, other groups could ask for additional requirements*: CT has not pursued a CS graduation requirement *CS curricula do not always mesh well with CT's strict data privacy laws*: Ongoing challenge
Additional Highlights	CT currently has no dedicated funding for CS. CT's approach is to offer CS and encourage students to take it before they graduate.

MARYLAND[123]	
State Policy Approach	All High Schools Required to Offer + (Grassroots Approach)[J]
Original Champion of CS	CS is an option within the state's technology graduation requirement + All High Schools Required to Offer.
Structure of CS Oversight	Numerous groups (a bipartisan effort)
Structure of Graduation Requirement	Students in MD are required to take a tech course to graduate—CS, tech education or engineering. CS is not technically required, but all three areas require significant computational thinking.

Structure of Professional Development	Maryland Center for Computing Education (MCCE) runs professional development.
Structure of State Licensure	Teachers generally need full degrees in an area to get licensed. Teachers can pass the Praxis or they need 15 credits of CS coursework and 15 credits of related coursework. • Teachers can teach 2 credits outside of their content area without being licensed. • MD has been working on alternative pathways (may change in the near future) and has been working to help teachers pass the Praxis. • MD has experimented with a $1000 stipend for teachers who pass the exam.
Key Barriers to CS Education + Mitigation Strategies	*Getting teachers fully licensed*: MD is trying to create more flexibly pathways to licensure and has helped teachers through the process of studying for the Praxis (offering stipends as well) *MD is in the process of changing its teacher preparation and licensure policies*: Ongoing challenge: MCCE must adapt when these changes are made *A need to build awareness among teachers who are new to CS*: Ongoing challenge: the state is building awareness through communication with districts (the state tries to share easy-to-use resources to make CS more accessible) *A need to build trust between districts and the state*: Mitigated by enhanced communication between the state and districts—an emphasis on the fact that the state is not punitive
Additional Highlights	MCCE works to improve access to CS for students with disabilities. • Example: A partnership with the Maryland School for the Blind. Sometimes teachers based in colleges will teach a few courses at high schools.

RHODE ISLAND[124]	
State Policy Approach	Currently grassroots—no mandates around CS education. 2022 proposed revisions to the Secondary Regulations currently under consideration would require all Rhode Island students to take a computer science course to graduate from high school.
Original Champion of CS	Governor Gina Raimondo
Structure of CS Oversight	CS4RI (comprised of mostly part-time employees) originated in the Governor's Office for Innovation, but now sits in the Department of Education.
Structure of Professional Development	Partners including Code.org, Project Lead the Way and Brown University are funded to train teachers (using curriculum that align with state standards).
Structure of State Licensure	RI now has a CS certificate in addition to a teacher endorsement, which can be added to another certification.
Key Barriers to CS Education + Mitigation Strategies	*Limited information among "gatekeepers" (administrators and school counselors) about CS*: CS4RI is intentional about outreach and conversations with these groups. *Issues with scheduling:* Ongoing challenge. *CS is labor intensive: it requires a large enough team (and it requires funding):* Ongoing challenge: CS4RI is a very small team. *Changes in leadership can cause state priorities to shift*: Ongoing challenge. *A need for sustainable funding*: Ongoing challenge.

Additional Highlights	RI initially took a grassroots approach because mandates can result in pushback. RI has scheduled numerous events to showcase student work in CS, industry careers in CS, and generally recruit students into CS courses. This has proven successful.

SOUTH CAROLINA[125]	
State Policy Approach	All High Schools Required to Offer + High School Graduation Requirement
Original Champion of CS	CSforSC
Structure of CS Oversight	Housed in SC Department of Education
Structure of Graduation Requirement	Flexible requirement: Districts can offer the requirement in middle school (a course divided up over several semesters).
Structure of Professional Development	SC uses grants with CSTA (Computer Science Teacher's Association) to fund PD.
Structure of State Licensure	SC has a CS license, but the license requires a Praxis exam that doesn't make sense for all teachers, as it tests CS knowledge appropriate for numerous grade levels. • SC is experimenting with microcredentials (50 teachers). • SC also utilizes a work-based licensure pathway (which allows industry professionals to become teachers). SC uses incentives for teachers—pays teachers to take Praxis test prep.
Key Barriers to CS Education + Mitigation Strategies	*Severe pushback from LEAs at the outset:* Over time, as teacher capacity has grown, pushback has become more limited. *Limited teacher capacity:* SC is currently in a major push to train teachers and it is experimenting.
Additional Highlights	Families are influential in CS expansion because they ask for CS education when they see it happening in other districts South Carolina has been very intentional about building trust and ensuring communication with districts Curriculum choice is left to districts, but the state determines if curricula aligns with standards SC understands that not all students will major in CS, but believes it will be a part of students' daily lives

SPRINGFIELD PUBLIC SCHOOLS (MASSACHUSETTS)[126]	
District Policy Approach	Using numerous grants to expand CS education K-12 . American Rescue Plan money is being used to fund one CS teacher in every school in the district.
Key Barriers to CS Education + Mitigation Strategies	*Lack of time in the day*: Ongoing challenge. *Confusion around the definition of CS*: Ongoing challenge. *Fear about taking time away from MCAS preparation, since teacher jobs can be tied to student success on MCAS*: Ongoing challenge: a focus on test scores makes it challenging for teachers to feel like they have time to innovate and try something new. *Difficulty recruiting licensed teachers at the middle and high school levels*: Ongoing challenge. *Lack of time for professional development*: Springfield allows teachers to take more PD than the average school (8 days) but this is still not enough. *If a student takes CS as opposed to another math or science course, this could hurt their chances of being accepted into a selective college that requires these courses*: Ongoing challenge.
Additional Highlights	MA districts with parent demand for CS are the ones offering CS courses (these are districts with more white students). Starting CS early in K-8 is key. Motivated teachers drive the effort in Springfield, so districts need to engage with teachers early and often. There is a lack of messaging around the importance of CS with alternative pathways to licensure

BURLINGTON PUBLIC SCHOOLS (MASSACHUSETTS)[127]	
District Policy Approach	PreK-12 districtwide CS initiative CS required in middle school
Key Barriers to CS Education + Mitigation Strategies	*Negative stereotypes around CS contribute to limited female participation after middle school:* Ongoing challenge however, hiring female teachers has helped. *Costs (initial costs are limited, but upkeep of devices can be costly):* In-district funding can be helpful, but the district is still working on finding sources ofsustainable funding—grants are also not sustainable, and a lot of funding currently comes through grants *School counselors lack knowledge around CS:* Ongoing challenge
Additional Highlights	A supportive superintendent is key to expanding CS education. Burlington is trying to make CS a course that bridges art, music and other subjects so students will get engaged. People are supportive of CS, but implementing it on a large scale is challenging. Teachers would push back on expansion if they had to teach something they were not prepared to teach.

APPENDIX 4

State Interviews—High-Level Takeaways

	STATE POLICY APPROACH	HIGH LEVEL TAKEAWAY
ARKANSAS[128]	High school graduation requirement	AR's experience of expanding CS demonstrates the importance of leadership in moving CS policy—and highlights the power of having a Governor on board. AR's process also highlights that while offering CS education can greatly increase participation, a graduation requirement is the best way to reach all students.
CONNECTICUT[129]	All high schools required to offer CS (but no CS graduation requirement)	Similar to AR, CT's experience highlights that leadership and collaboration across agencies is critical to advancing CS.
MARYLAND[130]	High school graduation requirement with CS as an option	MD provides an example of a CS requirement that is broader than what exists in other contexts—and yet still provides CS exposure to all students. MD is also an example of positive collaboration between entities that work together to advance CS. The Maryland Department of Education and the Maryland Center for Computing Education work together through a memorandum of understanding, and this collaboration allows for greater attention to CS and specialization around certain tasks.
RHODE ISLAND[131]	Grassroots approach—no mandate around offering CS/no current graduation requirement	RI is an example of a successful grassroots effort, but that effort was largely successful due to the leadership of the Governor. State-level leadership is crucial in states that choose to take a grassroots approach.
SOUTH CAROLINA[132]	High school CS graduation requirement	SC is an example of a state in which a graduation requirement has truly increased participation. SC also a positive example of alternative pathways to licensure (ex. microcredentials).

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