AN ANALYSIS OF SUPPORTS AND BARRIERS TO OFFERING COMPUTER SCIENCE IN GEORGIA PUBLIC HIGH SCHOOLS

A Dissertation
Presented to
The Academic Faculty

By

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In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Interactive Computing

Georgia Institute of Technology

December 2019

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To Susan Powell, for being my computer science teacher in high school

ACKNOWLEDGEMENTS

This dissertation, and the years in this doctoral program, is the result of the support of a myriad of people. Many mentors, colleagues, and friends were there as I grew throughout the program; they answered my questions, supported me when I doubted, and made me smile. I am grateful for every one of these people and feel incredibly fortunate to receive so much from so many.

My advisor, Mark Guzdial, has guided me through this process from Day 0. A true educator, Mark provided a scaffolded research project to start and, over the years, the projects slowly became more independent. Thank you, Mark, for helping me grok what it means to do research and for helping me see the forest when I was stuck worrying about the weeds. I am honored to be one of your students.

Thank you to my committee members for their interest in my work and advice over the last few years. Thank you, Betsy, for providing learning sciences insights and adopting me into the CAT lab. Beki, thank you for your advice and support throughout my time in the HCC program. Willie, I am so glad that I took Betsy's advice to take a course with you. Thank you for our conversations on education and diversity that give me new insight into my work. And Leigh Ann, thank you for letting mine be your first Ph.D. committee to serve on. Your precision and knowledge of the K-12 field has improved my research every step of the way.

Without the support of the Georgia Department of Education, particularly Bryan Cox and Caitlin Dooley, this dissertation would not have been possible. Thank you, Bryan and Caitlin, for your insightful answers to my never-ending questions and for providing the data that is the cornerstone of this research.

I extend my appreciation to all the school officials I contacted, worked with, and interviewed over the course of these studies. Your insights and perspectives will help CS Education understand the challenges you face.

Thank you to Mike Erlinger, Maria Klawe, Nick Faulkner, Colleen Lewis, Christine Alvarado for all helping me decide to come to Georgia Tech and work with Mark in the first place. I am incredibly grateful for your guidance then and your continued advice and mentorship over the years. Especially Christine, my first research advisor, and Colleen, who introduced me to CS Education as a subfield. Thank you, Christine, for inviting me to work with you after my freshman year and being determined to make me switch from Chemistry to Computer Science. Immense thanks are due to Colleen for teaching a CS Education course at Mudd, and encouraging me to publish my research from that course. I am so grateful to have you in my corner.

My research labmates over the years have been a continuous source of inspiration and entertainment. Briana, Katie, Kayla–thank you for always being there to discuss theories, vent, edit a paper, or goof off. In the broader College of Computing graduate community, I have been molded by the the friendship of many students that have come and gone through the years: Casey, Maia, Jess, Alex, Stevie, Michaelanne, Ari, Prateek, Ben, Sarah, and Sam. I could write a dissertation-length document of all the memories we've made together. And of course, thanks to Chad, for being the first student I met at GT, inviting me to lunches, and for continuing to bring his roommate to happy hours.

Thank you to the many people outside of GT that helped me learn to have a work-life balance, especially Stephanie and Bo. And thanks to my tutoring colleagues, Alexis and Lynn; I truly enjoy coming to work with you every day, even if it means talking about commas or geometric means.

My mom, Sherie' Parker, has given me constant support and cheerleading. I would not have gotten to this point if it was not for your perseverance in the face of countless challenges. Thank you for always just wanting your children to be happy.

Thank you to my corgi companion, Cassiopeia, for comforting me and reminding me to take breaks and play every now and then. You are one cute doggo.

And finally, thank you does not come close to describing my appreciation for my part-

ner, Matt. Your unwavering support and reality checks motivated me day in and day out. From making cookie dough while I wrote my first conference paper in graduate school to making dinner when I worked on this document for hours in a day, you have always been there to help me through this. Thank you, and here's to many more adventures wherever we land in the future.

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SUMMARY

There is an international movement to give every child access to high-quality computing education. However, expansion of formal computing education opportunities in primary and secondary schools has been slow. For all students to gain access to computer science (CS) courses, their schools have to offer it. For their schools to offer it, the principals and districts have to value it and they would need to find teachers who are qualified to teach CS. The process through which school officials make these decisions, and the supports and barriers they face in the process, is not well understood. But, once we understand these supports and barriers, we can better design and implement policy to provide CS for all.

In my thesis, I explore public high schools in the state of Georgia and the supports and barriers that affect offerings of CS courses. My work addresses the following research questions:

- RQ1: What are the quantitative factors that impact CS enrollment and offerings at public high schools in Georgia?
- RQ2: What do school officials perceive as barriers to and supports for offering CS at their school?

I quantitatively model school- and county-level factors and the impact they have on CS enrollment and offerings. The best regression models included prior CS enrollment or offerings, implying that CS is mostly sustainable once a class is offered. However, the regression models included a large unexplained variance. To help explain this variance, I visited four high schools and asked principals, counselors, and teachers about what helps, or hurts, their decisions to offer a CS course at their school. I build case studies around each school to explore the structural and people-oriented themes the participants discussed. One major topic explored was difficulty in hiring, and maintaining, qualified teachers in CS. The case studies are also framed using diffusion of innovations, which provides additional

insights into what attributes support a school deciding to offer a CS course.

This dissertation builds the evidence base for understanding schools' decision making process around CS courses. The qualitative themes gathered from the case studies, in addition to the quantitative factors used in the regression models, provide a theory of supports and barriers to CS courses in high schools. This can inform future educational policy decisions around CS education and provides a foundation for future work on schools and CS access.

CHAPTER 1
INTRODUCTION AND MOTIVATION

In 2008, *Stuck in the Shallow End: Education, Race, and Computing* was published, which revealed racial and economic disparities in access to computers and computing in three Los Angeles public schools [1]. Margolis et al. talked with students, teachers, counselors, and administrators to reveal systemic barriers that were beyond the students' control. Schools may have wanted to offer a computer science (CS) course in response to student interest, but administrators did not perceive that interest nor did they have the resources (technology, time, or curriculum) to offer a computing course.

In the years since *Stuck in the Shallow End* was published, K-12 CS has grown [2, 3]. There is an international movement towards making computing education more available than ever before [4]. Within America, states are creating CS standards and mandating CS for their schools and students [5]. However, access to CS is still as inequitable as it was in *Stuck in the Shallow End* in 2008 [6, 7]. Lower-income and Black students still have less access to CS learning opportunities in school than their peers [8].

Educational policy at the state-level plays a critical role in increasing access to CS in an equitable way. These policies could include counting CS towards high school graduation requirements, approving CS standards, or the creation of a CS specialist in the state Department of Education. While schools make the individual decision to adopt computer science and how they teach their courses, state government has a broader role because of the policy maker's ability to set funding and computing standards for the classroom.

Access is not only about students or teachers or schools or state policy. All of those pieces are needed to increase access to and support for students in CS courses. This work focuses on the the part of the school, and how that might also be impacted by state-level policy decisions. This dissertation explores questions around why public high schools in

Georgia choose to start teaching computer science, and why they might not.

This work is comprised of two studies, each providing insight into schools' role in access to CS. The first study seeks to answer these questions quantitatively by using public data sets. School- and county-level variables are added to correlation and regression models to explain the relationship between the factors and CS in a school. The second study explores the unexplained variance in the quantitative models through qualitative methods. Four public high schools in Georgia were visited and principals, counselors, and teachers were interviewed about decisions around CS at their school. These studies together develop a theory of what factors are barriers to or supports for offering CS in public high schools in Georgia.

1.1 Motivation

Within computer science, classroom- or student-level policy analysis is a critical piece to understanding student access. However, school- and state-level research is also needed to understand how to lower barriers to entering computer science for classrooms and students. There are calls from multiple stakeholder groups to create "Computer Science for All," in an effort to support more students learning computer science. Yet, implementing change blindly or poorly can have dangerous side effects that perpetuate the inequity present in computer science today.

We know that wealthier students are more likely to have access to computing [9, 10]. We know that white students are more likely to have access to computers and computer science [11]. We know men are more likely to pursue, and be encouraged to pursue, computing [11, 12, 13]. However, these are all pieces of knowledge that are not fully explored in broader contexts with consideration of confounding variables. In order to create "Computer Science for All," we need to know what works and what does not for other groups: schools that are characterized by high levels of free and reduced lunch, minority students, and under-achieving students.

Table 1.1: Situating my work amongst prior, similar work

	Stuck in the Shallow End [1]	BASICS [14]	My Dissertation
Case Size	Students	Districts	States
CS Scope	All courses	ECS curriculum	All Courses
Contributions	Awareness of lack access to CS; led to creation of ECS	List of supports and barriers for different participants	Theory of supports and barriers for offering CS across Georgia

This dissertation builds on two cornerstone pieces of work around supports and barriers to CS. In Table 1.1, I outline the similarities and difference between these research projects and my work. My dissertation builds upon the work done previously by widening the case size to a state-level, rather than a student- or district-level. These projects and my similarity to them are further discussed in Chapter 3.2.

My research interest in this topic arose after conducting a meta-analysis of Science, Technology, Engineering, and Math (STEM) education research [15]. I investigated the discussion of privilege in the research, comparing STEM education to CS education, in order to better understand what can be gained from the existing, neighboring research. From that research I developed an interest in issues of socioeconomic status and how that affects CS education opportunities, access, and achievement.

I began to design and conduct an experiment to understand the variables associated with achievement in CS. My experiment focused specifically on socioeconomic status, access to computing, and spatial reasoning. Simultaneously, I was conducting research on how students and teachers use a CS eBook. This eBook is an in-browser learning material for the coding portions of AP Computer Science Principles. In both experiments, I was finding a dearth of low socioeconomic students. Because of this, I was unable to create correlations between socioeconomic status and CS, since there was no variability in socioeconomic status in my data sets. We began to ask the question, “Where are the low-socioeconomic status students?” This dissertation arises from the core of that question, which seeks to find the variables that are connected to what we cannot see or find in our data.

Rather than taking a student-centric approach to this question, I wanted to go up a level and explore the schools and the decisions they make. This interest in policy- and school-focused analysis stems from my contributions to the K-12 Computer Science Framework [16]. This framework is the first to offer guidance to standard and curriculum writers as to what CS concepts to teach in what grade level, and what practices to use to tie those concepts together. The document is accompanied by chapters that codify what CS is at the K-12 level, what research is needed to further support the framework, and what equity means in CS education. Through my work on this project, I gained insight into the policy levers that determine access to computing and what could be done to move those levers.

This dissertation combines my prior experience in CS education to contribute a theory of supports and barriers to public high schools offering CS courses in the state of Georgia. This theory is constructed from my quantitative and qualitative analysis of CS offerings and enrollment. While this theory cannot be generalized to other states, it provides a testbed for future research into access to computing.

1.2 Thesis Statement

Schools have a choice as to whether or not to offer computer science and how they offer it. I theorize factors that support, or are barriers to, offering CS in schools can be modeled through regression analyses. The unexplained variance in these models can be explored by talking with school officials about CS at their school. These findings can be combined into a theory of barriers and supports to offering CS in high school, which can provide actionable recommendations to educational decision makers.

1.3 Dissertation Overview

The remainder of this dissertation details the two research questions and accompanying studies that are outlined in Table 1.2. The rest of this introductory chapter states the definition of CS used in this dissertation and provides a look at the landscape of CS education in public high schools in Georgia. Chapter 2 provides definitions of education terminology and descriptions of relevant CS policies. Chapter 3 includes a review of related literature and theoretical frameworks used later in the dissertation. Chapter 4 presents a study to investigate the factors that impact CS offerings and enrollment, using publicly available data and statistical analyses. Chapter 5 details a study to explore the barriers and supports to offering computer science in public high schools in Georgia through four case studies. Chapter 6 reviews the contributions and limitations of this work, including recommendations for future work for researchers, teachers, and policy makers.

1.4 Defining Computer Science

In a 2016 Google-Gallup survey, 78% of principals in the U.S. said their school offers a CS class [17]. However, what administrators might classify as a CS class might be a computer applications course with little computing. Additionally, offering a CS class could mean different things to different principals. To one it could mean the ability to provide a teacher, space, and time to a class of students interested in the course. To another it could mean there exists infrastructure such that a CS class that could be offered, even though it doesn't have any students enrolled in a given year. These two views of "offering" a course are very different. In the state of Georgia, infrastructure exists for computing courses such that all high schools could offer one, or more, of those courses. However, not every school delivers a CS course to a student.

There is an obvious ambiguity in what qualifies as "computer science" at the K-12 level. Part of this is due to CS being classified into different departments in different states [6]. In Georgia, CS is within the Career Technical and Agricultural Education (CTAE) department, which provides nine different Information Technology (IT) pathways and 18 different courses the make up those pathways. The pathways are themed progressions each consisting of three computing related courses. Themes include CS, IT, Cybersecurity, Web Design and Development, and Game Design. Nine of the classes that make up these

Table 1.2: Research questions, methods, analysis, and contributions

Research questions	Methods	Analysis	Contributions
RQ1: What are the quantitative factors that impact CS enrollment and offerings at public high schools in Georgia?	Compilation of publicly available data on the school and county levels, focusing on factors previously reported in landscape surveys	Correlation to assess relationship between factors Simple linear, multiple, and hierarchical multiple regressions to model factors that affect CS enrollment Binary logistic regressions to model factors that affect if a school had CS	Evidence of what factors can impact CS offerings and enrollment in public high schools in Georgia
RQ2: What do school officials perceive as barriers to and supports for offering CS at their school?	Case study of four high schools in Georgia across different characteristics of income, enrollment, and CS enrollment Interviews with principals, counselors, and/or teachers about past, present, and future decisions around CS	Thematic analysis of interviews within-case to identify supports and barriers discussed with participants Cross-case analysis to compare supports and barriers across schools	A theory of barriers and supports school officials consider when deciding to offer a CS course

pathways count towards a fourth science or math course for graduation; four years of math and four years of science are required in order to graduate high school in Georgia. These courses are:

- Computer Science Principles
- AP Computer Science Principles
- AP Computer Science A
- Programming, Games, Apps, and Society
- Web Development
- Embedded Computing
- Game Design: Animation and Simulation
- IB Computer Science Year 1
- IB Computer Science Year 2

AP stands for Advanced Placement. IB stands for International Baccalaureate and is similar in rigor and standardization to the AP program. Both of these programs are discussed further in Section 3.1.1.

While certainly all courses in all the IT pathways touch on computing in some way, I *limited the definition of a CS course to the courses that count for graduation requirements*. These courses focus more heavily on computer science, rather than computer literacy, educational technology, digital citizenship, or information technology, which are the other areas of K-12 computing outlined in the K-12 CS Framework [16]. This eliminates considering courses such as Introduction to Digital Technology, the first course in each of the nine IT pathways, which focuses on building a basic set of vocabulary and skills to prepare students for any future computing course or career. Although all courses within the IT pathways are valuable, some courses are outside the scope of the policy-defined "computer science."

During the time frame of my analysis (school years 2012 through 2016), only six of these courses were offered as a state-funded course with an associated course code number. AP CSP, Web Development, and Embedded Computing were not released, i.e. funded and given a course code number, until the following years. Additionally, those six courses were not available during the entire time frame because the Georgia Department of Education updated the CS courses offerings in the 2013-2014 school year. In 2012 and 2013, only AP CS A and an Information Technology course were on the official Georgia computing course list, and only AP CS A counted towards graduation requirements.

When I refer to CS in Georgia throughout the remainder of the dissertation, I am referring to the six courses that were available and counted for graduation requirements. This restricts CS to a binary and ignores the instances where CS is integrated into other curricula or into after school organizations. Restricting the definition in this way assists with data analysis to reduce debates of how much time in a CS learning experience "counts" as taking a CS course. Additionally, I use the term "computing courses" to refer to the courses that are in the CTAE IT pathway but do not count for graduation requirements.

1.5 Visualizing the Landscape of Computer Science in Georgia

Map-based visualizations are presented here in order to convey the change in computing and CS courses from 2012 to 2016. These visualizations show a map of Georgia in each year. Overlaid on the map are dots representing high schools offering CS courses. The color of the dot corresponds to a CS course offered in Georgia. The size of the dot is representative of the percent of students enrolled in a school that took that course. These visualizations are important in order to develop understanding of the pattern of CS offerings over time. The computing and CS course enrollment visualizations are discussed below.

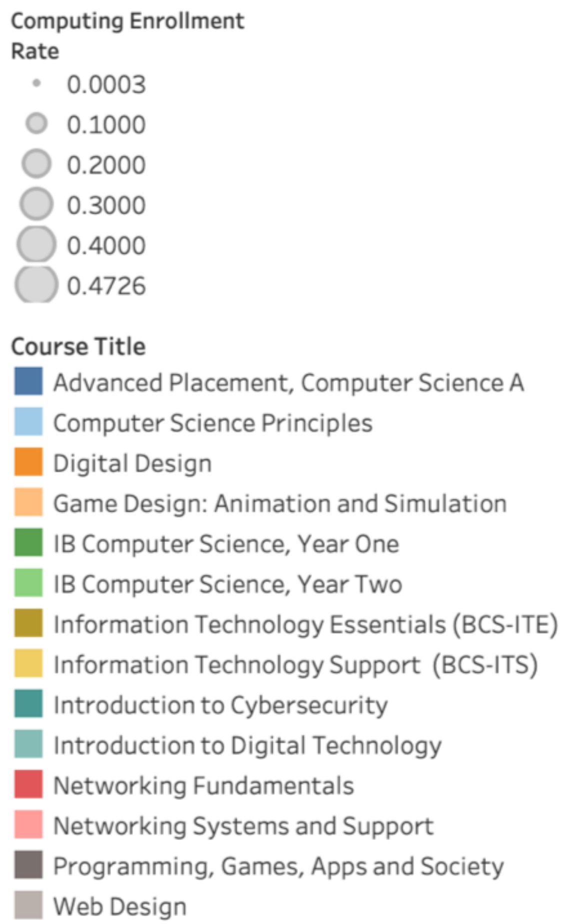


Figure 1.1: Legend for computing course enrollment visualizations

Computing Courses

Over the course of 2012 to 2016, the landscape of computing courses, including CS courses and all other courses in the Information Technology career cluster, has grown. The visualizations of computing course enrollments for 2012-2016 can be found in Figures 1.2 to 1.6, and the legend for each of these visualizations can be found in 1.1.

In 2012, only AP CS A and Information Technology courses were officially recognized and recorded by the GADOE. These courses were primarily situated around the Atlanta metropolitan area, with IT courses occurring around the Augusta and Savannah areas as well. However, there are some instances of more remote offerings of CS, in counties that are not connected to the major interstates that run across Georgia, or the major metropolitan

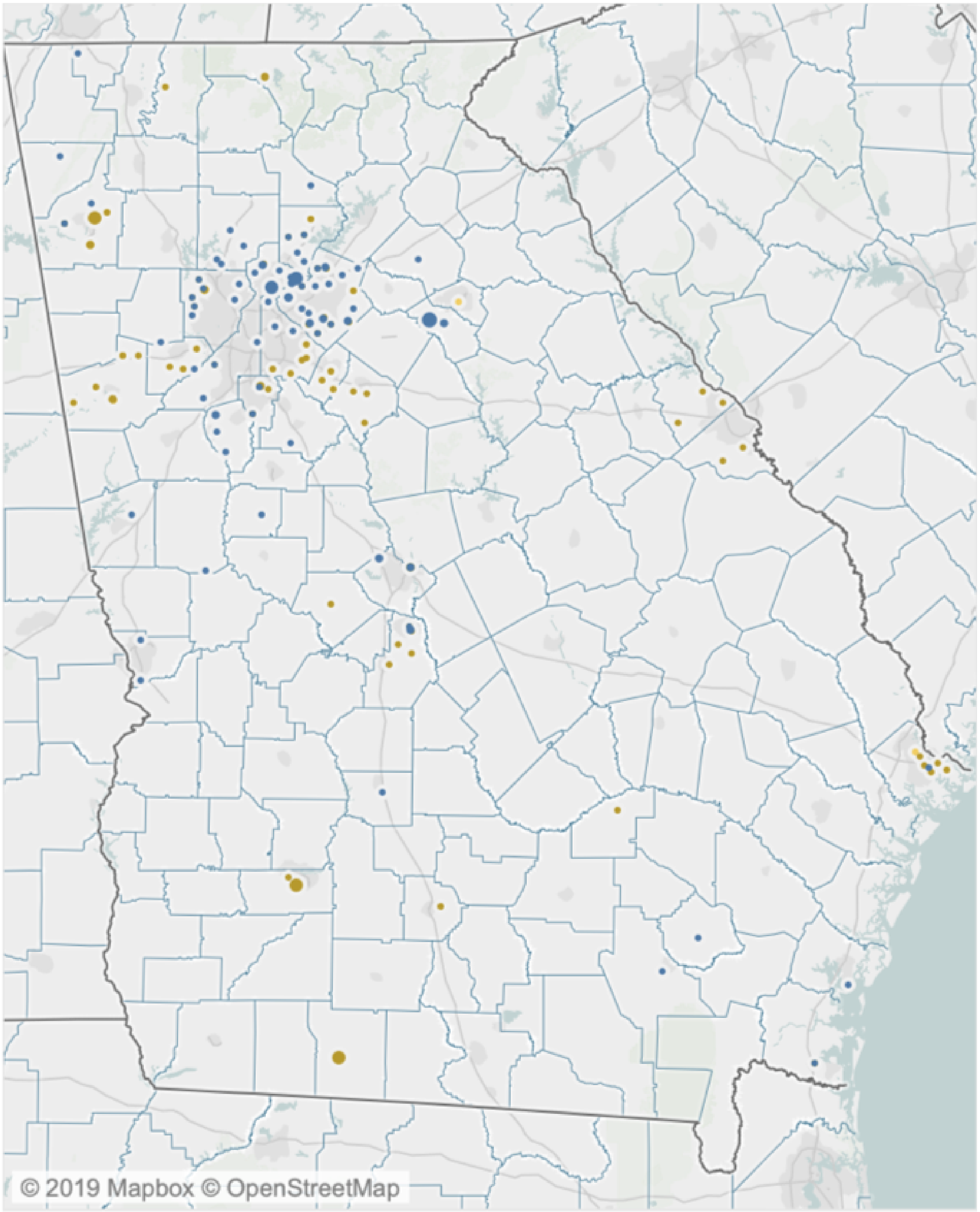


Figure 1.2: Computing course enrollment rate in Georgia, 2012

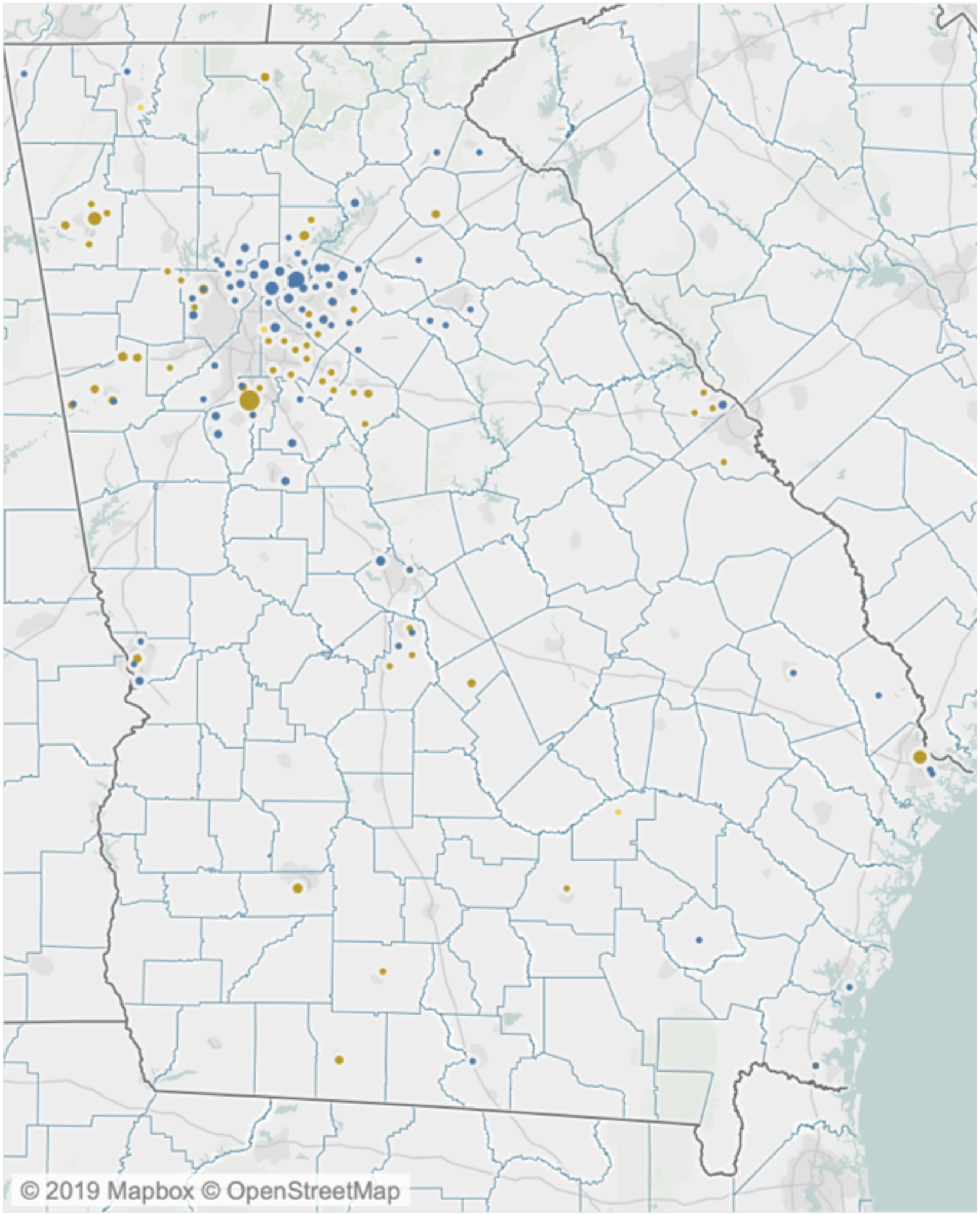


Figure 1.3: Computing course enrollment rate in Georgia, 2013

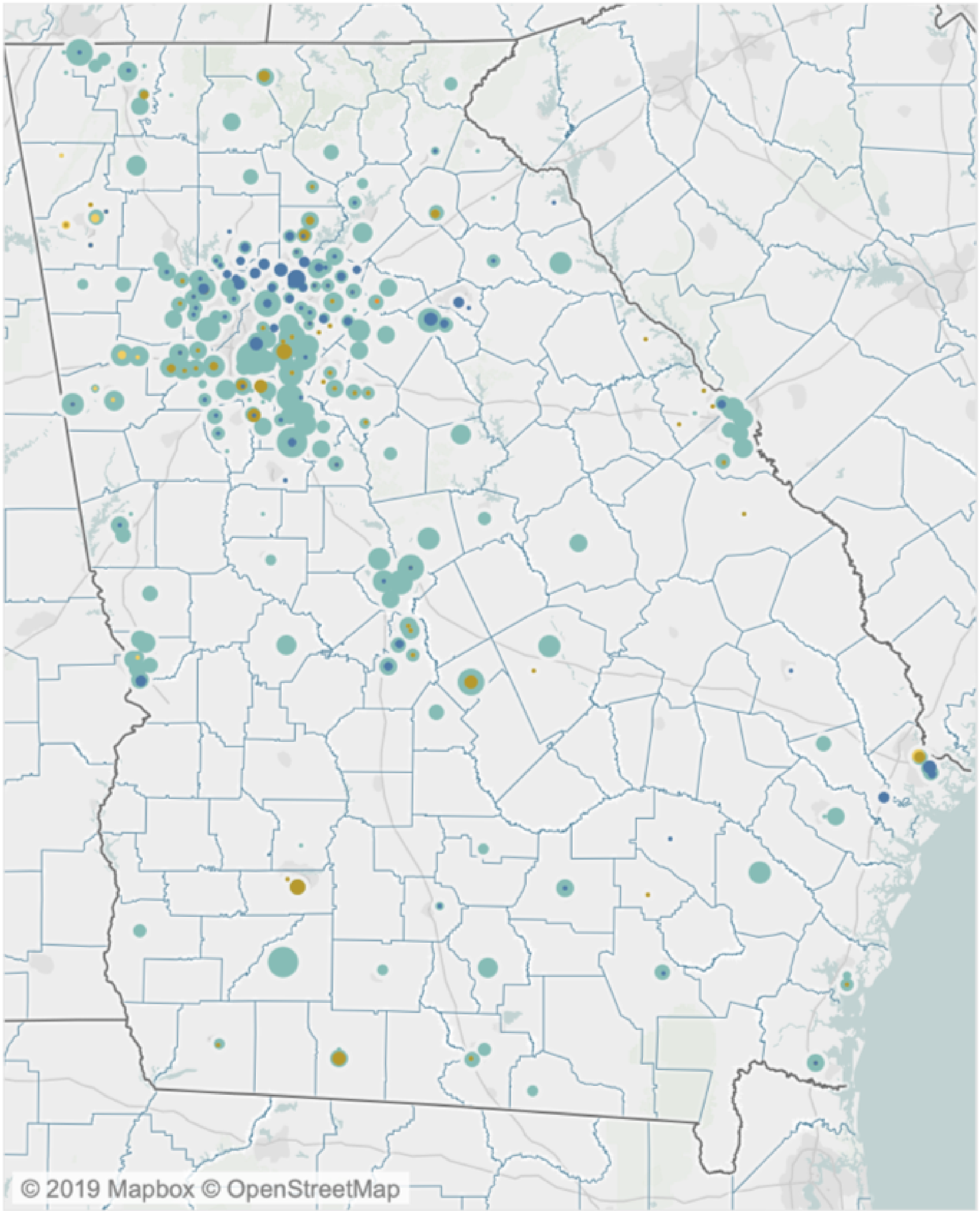


Figure 1.4: Computing course enrollment rate in Georgia, 2014

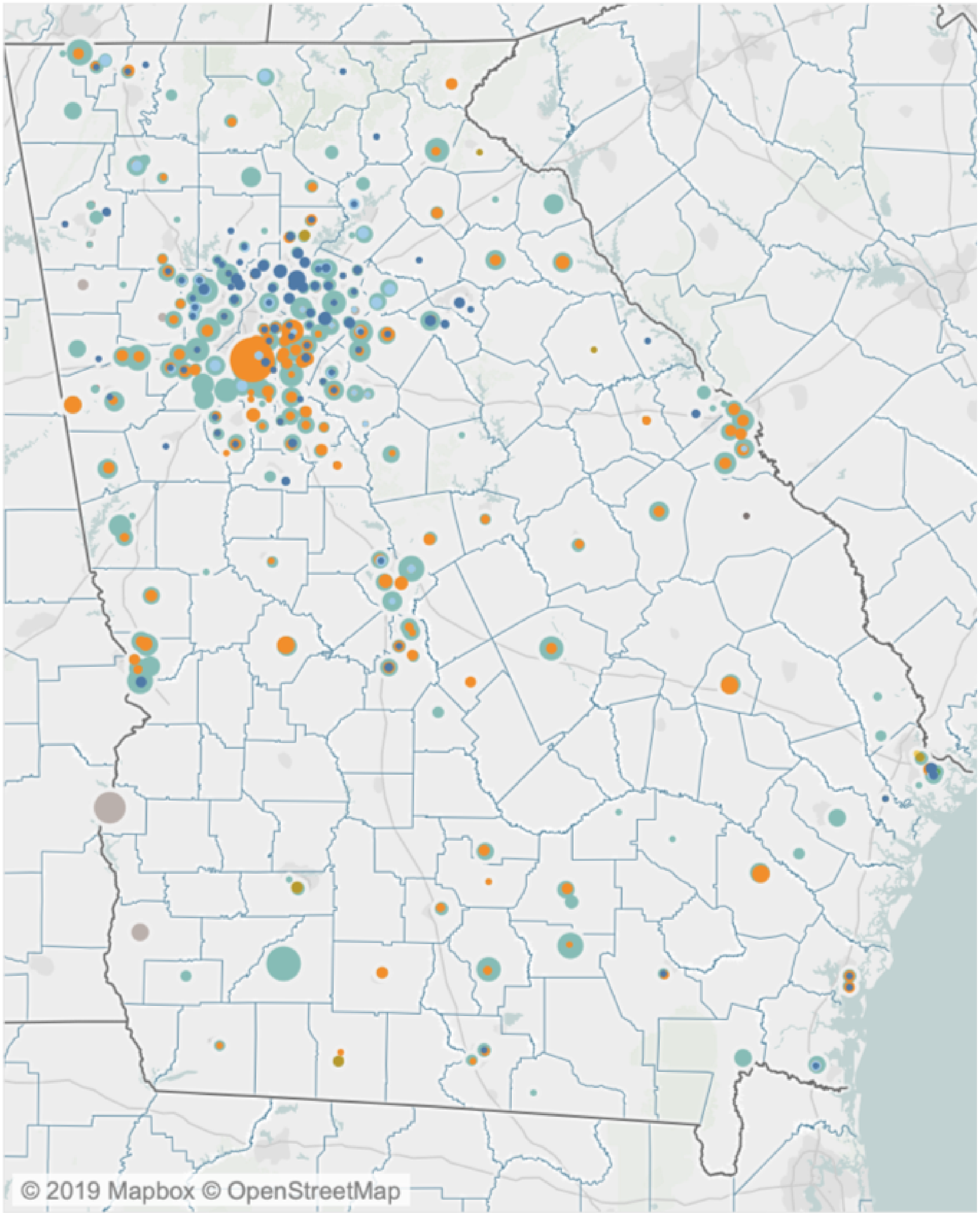


Figure 1.5: Computing course enrollment rate in Georgia, 2015

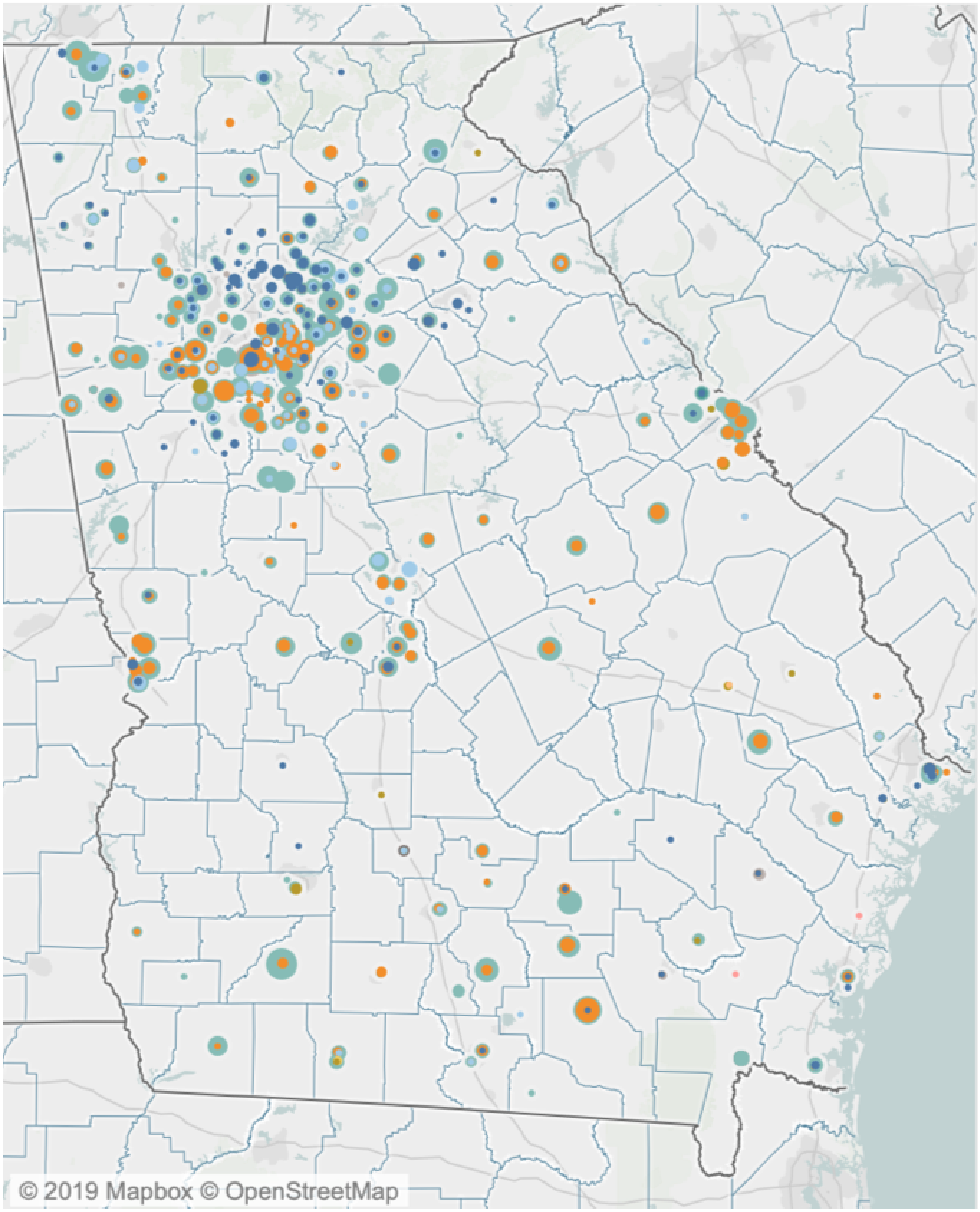


Figure 1.6: Computing course enrollment rate in Georgia, 2016

areas.

In 2013, some shifting in offerings in the rural areas can be seen. Some IT and AP CS A enrollments go away, while new ones emerge. There are fewer computing courses around Savannah than in 2012. There is a large growth of the IT Essentials course in just the southern portion of the Atlanta metropolitan area.

2014 was the first year of the IT career cluster and pathways. New courses were added, including an Introduction to Digital Technology which was widely adopted. Schools that have never had a computing course before now have sizable enrollments in Introduction to Digital Technology. This course is the start to every pathway in the IT career cluster, so the first year of every three-course pathway is spent taking Introduction to Digital Technology. Additionally, there continues to be shifts in the rural offerings of AP CS A and IT courses.

In 2015, there continues to be increased offerings outside of urban centers. The instances of Digital Design start to grow as Introduction to Digital Technology decreases. Digital Design is the second course (Year Two) in the Web and Digital Design pathway, so it makes sense that it was not very present during the first year of the pathway rollouts. There are also instances of Web Design, which is the third course in that pathway (Year Three), in the Southwest corner of Georgia. These are intriguing since one location did not have any computing courses the year prior, and the other one only had Introduction to Digital Technology, not any Digital Design. Furthermore, some instances of Introduction to Digital Technology are constant, with no new computing courses in those areas. These patterns indicate students may only be taking courses as an elective, rather than aiming to complete a whole pathway.

2016 shows a minor shift in computing courses in the South Georgia region. More instances of Computer Science Principles can be seen across the state. The Web Design courses in the Southwest corner of Goergia have disappeared, along with any other computing course. Otherwise, the enrollment rates and type of courses appear fairly constant.

CS Courses

Similar to the computing courses, the landscape of CS courses, or courses defined as computer science in Section 1.4, has changed between 2012 to 2016. The visualizations of computer science course enrollments for 2012-2016 can be found in Figures 1.7 to 1.11.

In 2012, the only CS course available was AP CS A. Since AP CS A was one of three computing courses during that time, making up over half of the course enrollments during this time, the pattern of CS courses is similar to the pattern of computing courses. Most of the instances of CS was focused around metropolitan areas, namely Atlanta and Savannah. However, there is also a CS presence around Columbus, as well as in more rural counties in the Southeast and North regions.

In 2013, CS courses became more localized to the Northeast Atlanta area. There were new, small instances of CS across the state. However, at the same time, some rural instances of CS disappeared.

In 2014, with the addition of new CS courses to the GADOE registry, it appears that more schools are offering a CS course. Although there are still a lot of courses around Northeast Atlanta, offerings also increased in more rural areas. The Savannah instance of CS has grown, though some instances around Columbus appear to have ended.

The change between 2014 and 2015 is distinct, with enrollment in CS courses increasing. This primarily happens at schools with pre-existing CS courses, but there are new occurrences as well. However, some of the more rural instances have gone away.

2016 has the most offerings CS across the state. Part of this is due to CS enrollments at schools rising from the year before, and part of this is due to schools offering a CS course for the first time. As noticed in the Computing course visual analysis, this could be from CS Principles being offered more.

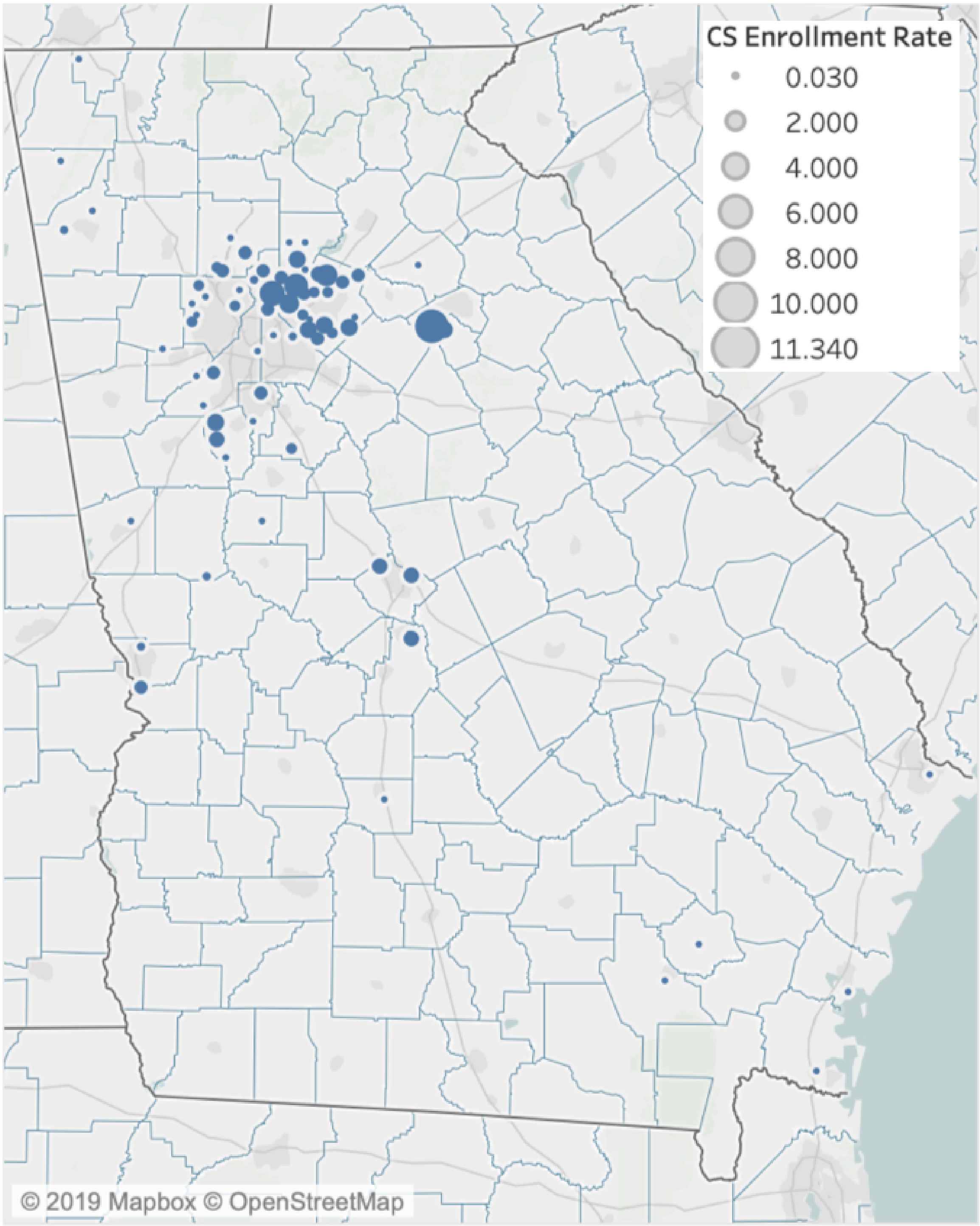


Figure 1.7: CS course enrollment rate in Georgia, 2012

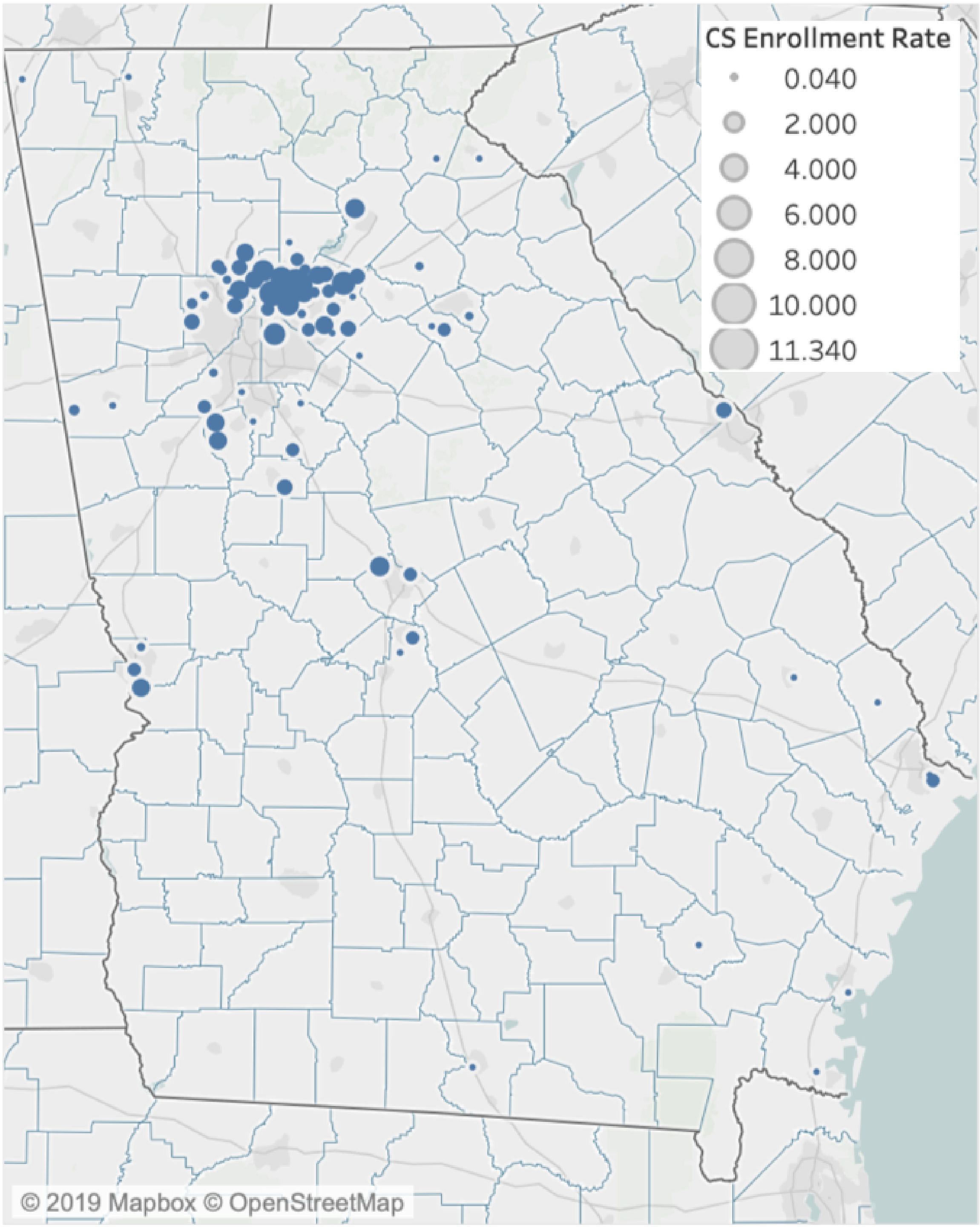


Figure 1.8: CS course enrollment rate in Georgia, 2013

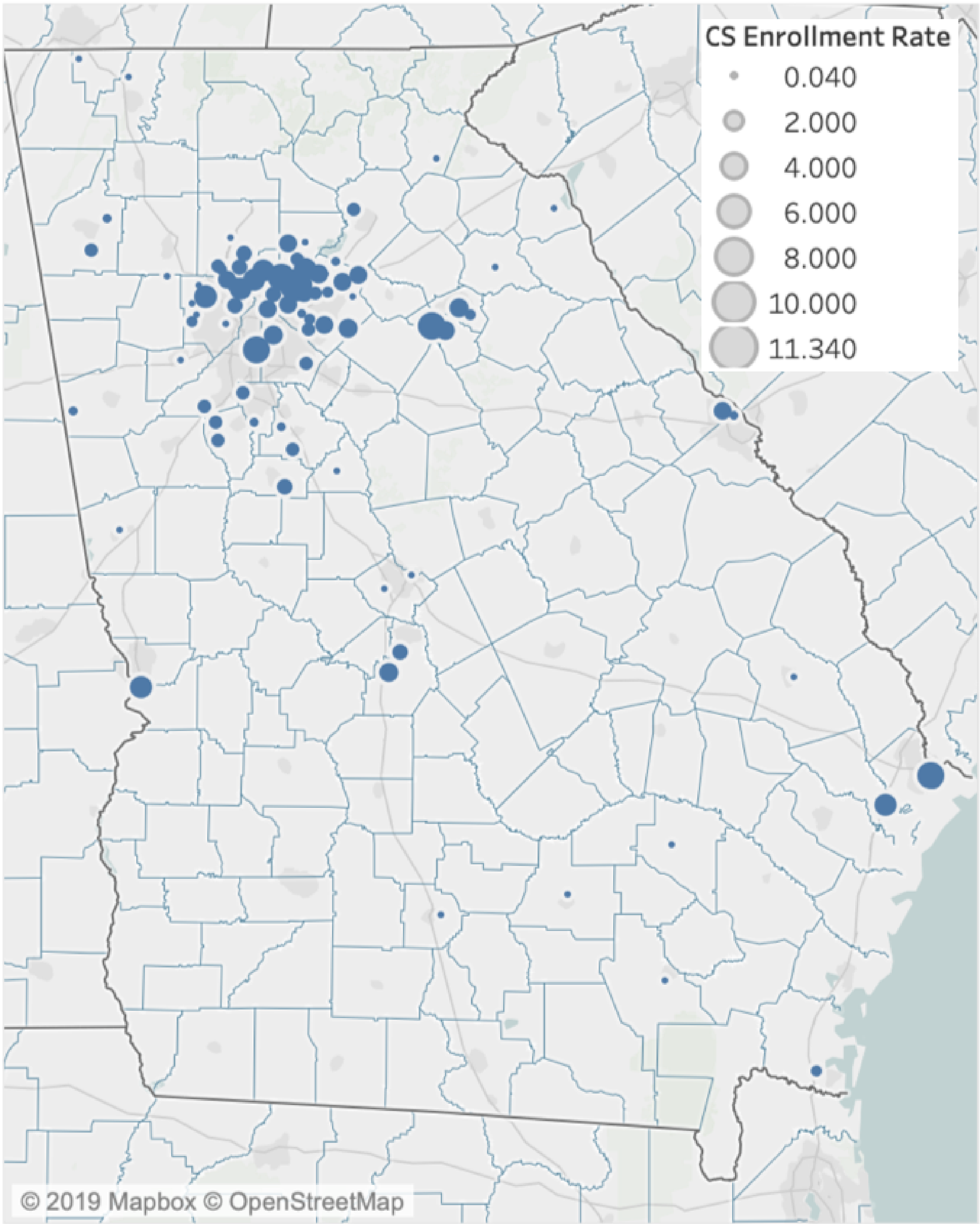


Figure 1.9: CS course enrollment rate in Georgia, 2014

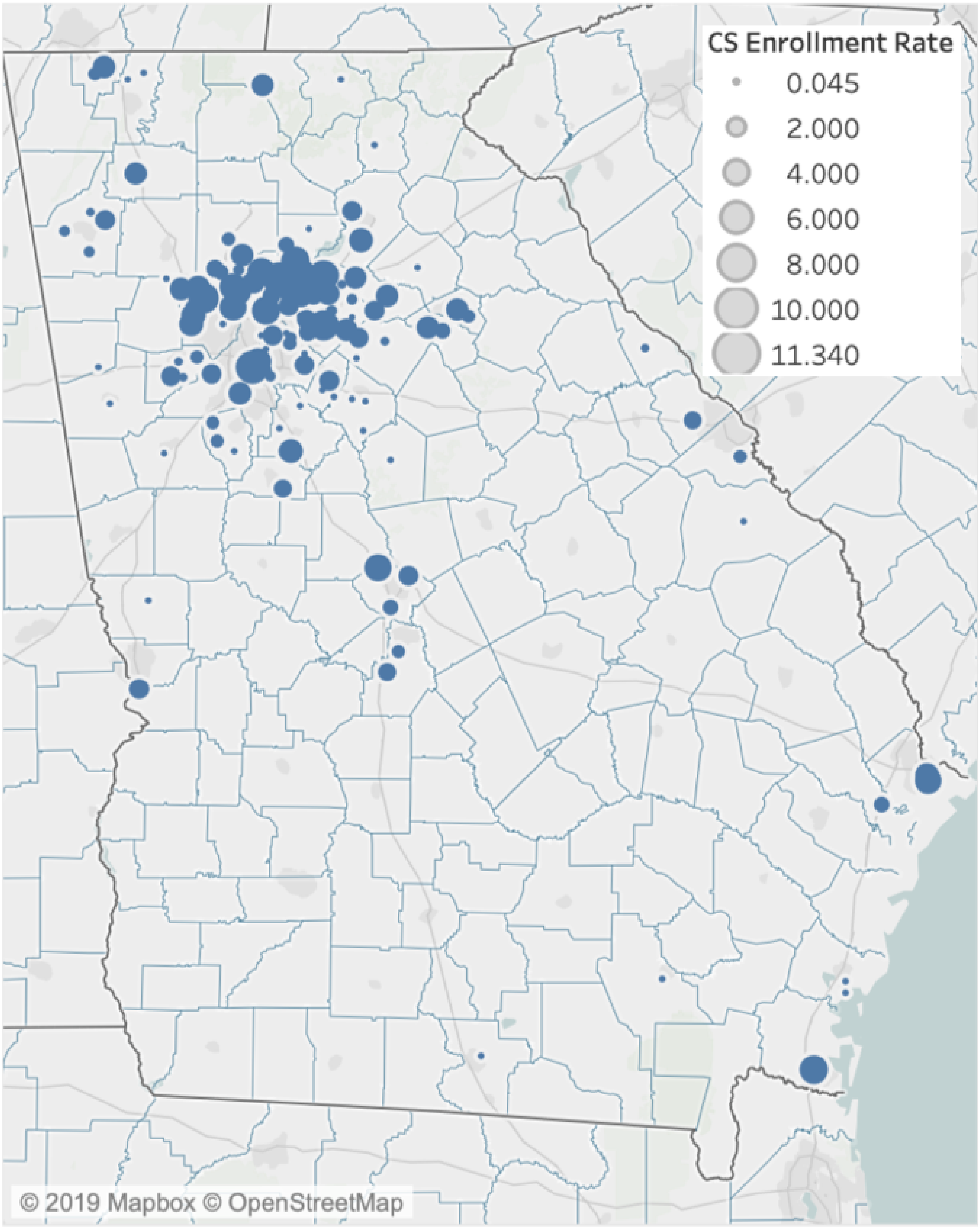


Figure 1.10: CS course enrollment rate in Georgia, 2015

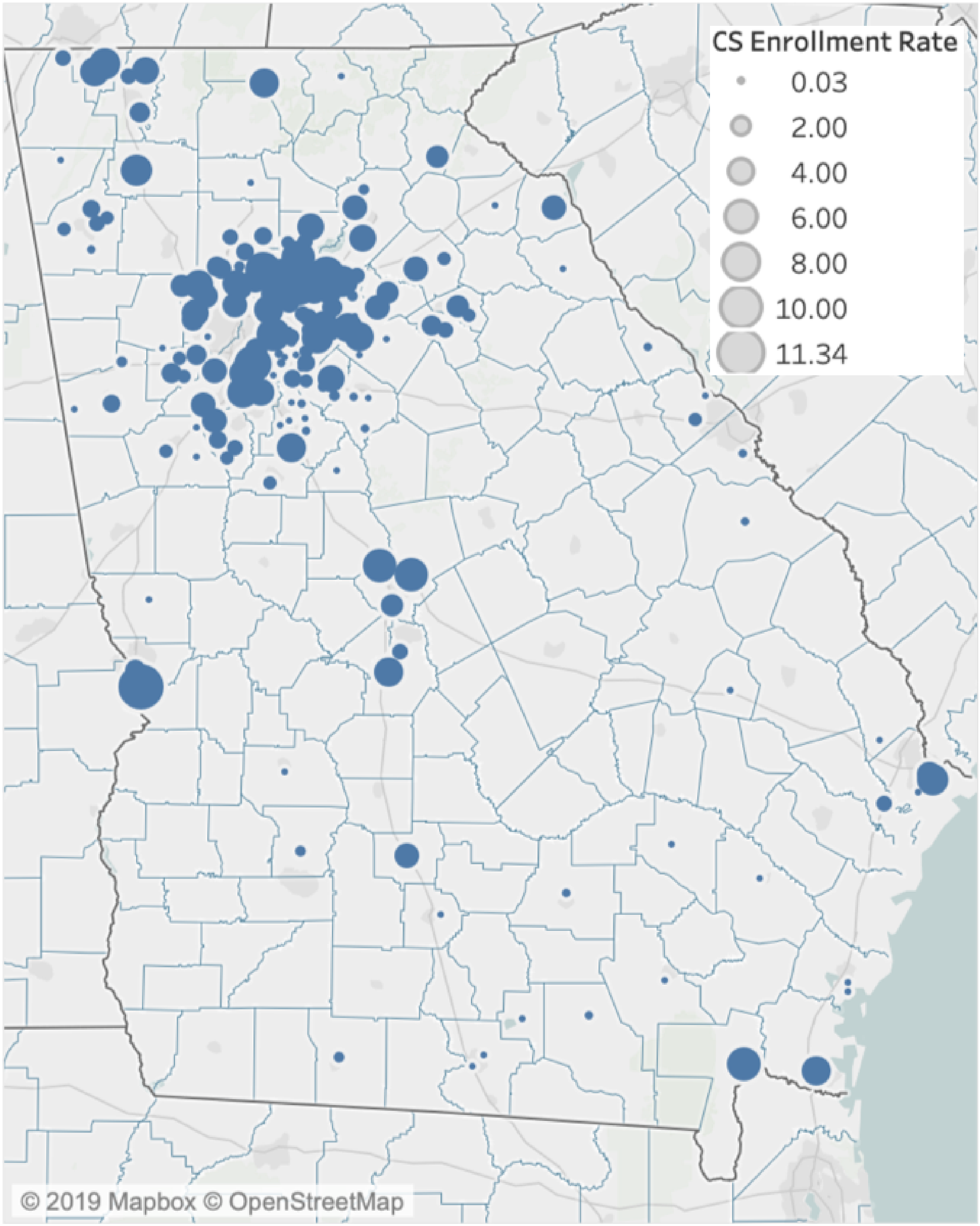


Figure 1.11: CS course enrollment rate in Georgia, 2016

CHAPTER 2

TERMINOLOGY AND RELEVANT POLICIES

This dissertation references national and state-level policies, as well as terminology related to K-12 education. This chapter expands on the policies referenced throughout this document, providing a timeline of when these policies came into effect. School terminology is also included in this chapter.

2.1 CS for All

Computers and their applications are becoming ubiquitous in today's world. The average American teen consumes approximately 6 hours of screen media daily, not including for school or homework, with only 3% of that time used for content creation [18]. Computing occupations make up two-thirds of all projected new jobs in STEM fields, whereas only 8% of STEM graduates study Computer Science [19]. Approximately one-fourth of schools in the country offer computing courses with programming components [19]. Women make up 18% of CS Bachelor degree earners and 25.5% of the CS workforce. Black or Hispanic individuals also make up 18% of CS Bachelor degree earners, but only 14.7% of the workforce [20].

A demonstrated need for more technology professionals exists. Local, state, and federal organizations are launching efforts to promote computer science at K-12 levels and fill the jobs of the future. To help meet this need, President Obama announced a Computer Science for All initiative in January 2016, hoping to make computer science available to every student in America. The reasons given for this movement are:

- To promote producers over consumers of technology in this growing digital age
- To address the need for more computer scientists in the workforce

- To provide more rigorous computer science in schools
- To expand access to CS to a more diverse population than is currently represented in the field

The call for more computing education is being addressed from policy and curricula fronts. There now exists a framework for K-12 computer science to outline what students should know and be able to do after certain grade levels; this document exists to support the creation of standards and curriculum for all grades in K-12. There are numerous efforts to promote and expand computer science across the country. The largest of these is the CS for All initiative, proposed by the White House and discussed above. CS for All is an effort to allow every student in the country a chance to learn computer science, as well as to diversify the computer science field. There have also been efforts on the state and district levels to expand computer science opportunities. According to code.org policy tracking, 35 states have computer science as a core graduation requirement (oftentimes as elective credit, rather than for math or science credit) [21].

Amidst the expansion of computing education, there is a dearth of discussion of what it means for CS for All to succeed. It could be said that CS for All stands to provide every student an opportunity to learn. This would mean that a CS learning experience has been offered to a student who chooses to participate or not, be it an hour of code or an elective course. On the other hand, there is a perspective that CS for All stands for every student to have access to computing. This would mean that there is a dedicated CS teacher(s) in every school with one or more CS courses taught, or that there is a system to integrate CS into other subjects to reach all students.

2.2 School Terminology

The United States and Georgia education system has many nuances and specialized vocabulary. These influence the analysis of barriers to CS in public high schools in Georgia.

Here I define relevant phrases and acronyms, as well as outline Georgia-specific policies.

2.2.1 United States Education Terms

Block scheduling Block scheduling refers to a school schedule where a set "block" of courses are alternated each day, with typically four classes each day.

Seven period day Seven period days refer to a school schedule where students have the same schedule each day with seven different classes. Also, each class is shorter than a class on a block schedule.

Free and Reduced Lunch The Free and Reduced Lunch program (FRL) provides low-income students with free or reduced-price meals at school. The number of students that receive FRL is an imperfect measure of the relative poverty rate of the students who attend the school.

Title 1 Title 1 is a designation given to a school that has a "large" percentage of low-income students. This designation means a school receives federal funds to assist in meeting those students' goals. The number of low-income students is determined by the number of students enrolled in the Free and Reduced Lunch program.

PSAT The Preliminary SAT (PSAT) is a precursor to the Scholastic Aptitude Test (SAT), which is used in college admission applications. The PSAT is taken by sophomores and juniors in high school, typically during school time, and is used to identify students for merit-based scholarships.

AP Advanced Placement (AP) is a program in the U.S. and Canada to take college-level courses in high school. AP courses range across all fields of study. There are two AP CS courses: AP CS A and AP CS Principles.

Table 2.1: Georgia high school graduation requirements

Areas of Study	Units Required
English/Language Arts	4 units
Mathematics	4 units
Science	4 units
Social Studies	3 units
CTAE and/or Modern Language/Latin and/or Fine Arts	3 units
Health and Physical Education	1 unit
Electives	4 units

Dual Enrollment Dual enrollment is when a high school student is also enrolled at a local college or university to take a course or courses for both high school and college credit.

Core Courses Core courses refer to courses that every student has to take at all levels, including English, math, social studies, and science.

STEM STEM refers to the subject areas of Science, Technology, Engineering, and Math.

K-12 K-12, or sometimes PreK-12, refers to the range of primary and secondary education in the U.S., which ranges from kindergarten (or pre-kindergarten) to 12th grade.

2.2.2 Georgia Education Terms and Policies

Georgia Graduation Requirements Georgia requires students to earn a minimum of 23 units (where a unit is equivalent to a course) to graduate high school. A breakdown of these credits can be found in Table 2.1. These graduation requirements have been in place since the 2008-2009 school year.

Fourth science or math High school students in Georgia have to take one course in Biology, one course in Physical Science or Physics, and one course in Chemistry, Earth Systems, or Environmental Science. That means the fourth required science unit is not a mandated course. Similarly, students in Georgia need one course in Algebra, one course in

Geometry, and one course in Advanced Algebra (Algebra II). The fourth required math unit can be decided by the student. Several approved courses can satisfy these fourth science or math requirements, including nine "Information Technology" courses listed below.

- Computer Science Principles (CSP)
- AP Computer Science Principles (AP CSP)
- AP Computer Science A (AP CS A)
- Programming, Games, Apps, and Society
- Web Development
- Embedded Computing
- Game Design: Animation and Simulation
- IB Computer Science Year 1
- IB Computer Science Year 2

Teacher certification policies Teacher certification policies change from state to state. In Georgia, certification requirements vary according to the CS course. A Computer Science Certification or endorsement, or an Engineering Certification are required for a teacher to teach AP CS A or AP CS Principles. Before June 30, 2019, however, a teacher with a Math, Science, or Business certification could be considered qualified for teaching a CS course. The CS certificate has been available since 2015. The CS endorsement is for teachers currently certified in another area that needs training in CS content and pedagogical content knowledge. The CS endorsement has been available since 2008.

Pathways Pathways consist of three courses (also referred to as units) that form a sequence and prepare students in a specific area. Pathway areas include **Career, Technical,**

and Agricultural Education (CTAE), Advanced Academics, Fine Arts, and World Language. This chapter focuses on CTAE pathways, which align content with industry-related standards to prepare students for college and career. In CTAE, there are 130 pathways across 17 Career Clusters. One Career Cluster is Information Technology, wherein there are 8 pathways. Students who take every course in a pathway are considered pathway completers. Every CTAE pathway also has End of Pathway Assessments (EOPAs). Because pathways consist of three courses, traditionally one per year, students typically only start a pathway in their 9th or 10th grade year. As such, recruitment for pathways is focused on 8th and 9th grade students. The CTAE pathways were introduced in the 2013-2014 school year. The word "program" is used interchangeably with "pathway" or a set of pathways.

CCRPI College and Career Ready Performance Index (CCRPI) is a tool used to measure a school's performance and indicate school quality. The overall CCRPI score is ranged from 0 to 100. Many aspects of the school factor into this score, including graduation rates, performance on Georgia's standardized end of course assessments, achievement improvements among economically disadvantaged students, English learners, and students with a disability, enrollment in AP, Dual Enrollment, or IB courses, and pathway completion. CCRPI can be used to designate a school as a "low-performing school" if the score is at or below the 25th percentile among other high schools. Similarly, schools can be recognized by the state if certain aspects of their CCRPI score is in the 93rd percentile or above. The CCRPI scores for the schools I visited can be found in Table 5.1.

HOPE The Helping Outstanding Pupils Educationally (HOPE) scholarship is a merit-based scholarship that provides financial assistance for eligible students towards the cost of tuition at eligible Georgia colleges and universities. To be eligible for the HOPE scholarship, students must have a 3.0 HOPE GPA and earn four rigor course credits. The HOPE GPA is calculated based on grades from core courses and foreign languages. Rigor courses include advanced math, advanced science, foreign language, or AP, IB, and Dual Enrollment courses.

Georgia Virtual School Georgia Virtual School (GAVS) is a system to offer courses online. These courses would be akin to Massive Open Online Courses (MOOCs). These courses count for credit for the student and count towards the course enrollment counts for the school in which the student is enrolled. All courses are led by a Georgia-certified teacher. Seven of the seventeen courses in the Information Technology CTAE Career Cluster can be taken on GAVS, including AP CS A, AP CS Principles, and CS Principles.

CEISMC The Center for Education Integrating Science, Math, and Computing (CEISMC) is a unit at Georgia Tech that works to enhance PreK-12 and post-secondary STEM education across the state of Georgia. CEISMC offers professional development opportunities, creates in-school STEM experiences for K-12 students, and conducts research on STEM education.

2.3 Georgia Schools and Policies

State policies on school organization matter for CS education since it is defined at the state (as opposed to the district or school) level in Georgia. This section describes the characteristics of Georgia that affect CS offerings and enrollments in public high schools. National movements, such as code.org, and funding shifts are also explored in this section, as they likely had an impact on Georgia.

2.3.1 Georgia School Structure: County-based

In Georgia, schools are organized into districts that are either county- or city-based. Georgia has 159 counties, and thus 159 county-based school districts, as well as 21 city-based school districts. The distinction between county and district becomes especially relevant when considering data, as some information is available at the county level that is not normally reported at the district level. While graduation requirements and course codes are decisions made at the state-level, decisions on budgets, course schedules, and teacher assignments are made at the district level.

2.3.2 Policy Changes for Georgia High Schools 2012-2016

Over the timespan this research explores, various state policy changes touched on CS education. These policies are listed below in chronological order. All of these policies are listed by the fall semester of the school year in which they became effective.

- 2009: Georgia counts AP CS A as fourth science. [22]. AP CS A counted towards graduation requirements before this time, but the course lost its status and was renewed in 2009 [23, 24].
- 2013: The Career Cluster and Pathway system for CTAE courses, described in Section 1.4, started in the 2013-2014 school year.
- 2014: Students can take a sequence of two CS courses to count for a foreign language credit [25].
- 2015: The current certification for CS teachers became available.
- 2015: CS courses were first accepted by the Georgia Department of Education as a fourth math course

This is not an exhaustive list of policy changes that occurred during the study time frame, but rather the most relevant ones.

2.3.3 National Changes that Impacted Georgia

There has been a growth of national programs and initiatives that started or affected other initiatives, between 2012 through 2016.

- 2009:Computer Science Education Week (CSEdWeek) is first offered by the Computing in the Core coalition. It is a week dedicated every year to promote CS to K-12 students.
- 2012: This was the last year of the Georgia Computes! program, which ran from 2006 to 2012 to improve computing education across the state of Georgia.
- 2012: The Expanding Computing Education Pathways (ECEP) Alliance began with Georgia and Massachusetts, with a goal to grow and broaden participation in CS by students, especially in K-12.
- 2013: Code.org was founded and began organizing CSEdWeek. Hour of Code, an event co-timed with CSEdWeek to offer a scaffolded way for new teachers and students to engage with computer science, began this year.
- 2016: President Obama, in his State of the Union address, created a "Computer Science for All" initiative, calling for increased funding of K-12 CS to increase access to all students.

While not all of these efforts were focused on Georgia, the national movement toward increased CS education and opportunities has undoubtedly affected Georgia's policies, schools, and students.

CHAPTER 3
BACKGROUND AND RELATED WORK

My dissertation draws on existing literature from computing education, policy, and social sciences. In this chapter, I provide an overview of relevant concepts that frame and guide my work. I begin by related work on expanding CS education in K-12 schools and analyzing the landscape of CS education. I then discuss why not every student can take CS, discussing various barriers that prevent access to CS. Similar work on advanced courses in STEM is reviewed. Prior work that helped motivate this work is included, which explores the relationship between socioeconomic status and CS achievement. The state of the computing education field is then framed using a diffusion of innovation model, where computer science courses are the innovation.

3.1 Computer Science in Schools Today

My dissertation work focuses on the state of Georgia. However, similar work has been done in other states and cities across the United States and at an international level. This section discusses the research that has occurred in expanding CS education in primary and secondary schools. Also included is a summary of the existing landscape surveys, detailing the state of CS education in given states.

3.1.1 Growing Computer Science at the K-12 Level

Related work includes studies of progress made in offering more CS courses to more students. These studies typically investigate a specific intervention or curriculum that was administered at the state level.

The impact of Advanced Placement (AP) computing courses is often reported to assess nationwide access to and achievement in CS. There are currently two computing AP courses: AP CS A and AP CS Principles (CSP). The AP CS exams are the only national measure of CS learning in the U.S. that are standardized. Ericson et al. use AP CS A data to see who takes the exam and how they perform [7]. Wealth was indirectly influencing the number of students taking the exam, via making the course more available. Killen et al. explore Maryland schools before and after AP CSP was introduced as an AP course [26]. The introduction of AP CSP increased the number of CS courses offered by Maryland public high schools overall, but it did not appear to have a large impact on bringing CS into schools where it had not been taught previously.

There are other curricula outside of the AP program that are adopted by cities and states. Exploring Computer Science (ECS) is one such curriculum for introductory computer science [27, 28]. Chicago is one large champion of the ECS curriculum, reporting equitable learning gains for students [29, 30]. A statewide rollout of ECS in Wisconsin reported more of an impact on schools with an economic disadvantage, with these schools less likely to offer a CS course before the ECS intervention [31].

There are several interventions, separate from curriculum-based interventions, that have been studied at the city and state levels. New York City (NYC) has a city-wide initiative called CS for All (CS4All) to provide high-quality CS education to all NYC public school students [32]. In this setting, Fancsali et al. found high participation in CS teacher training opportunities, though CS was more likely to be in schools that served more White and Asian students than Black and Latino students [33]. At the state level, Georgia Computes! was a statewide initiative targeted at multiple stages of the computing education pipeline [34, 35, 36]. The number of schools offering and students taking CS courses increased during the time frame of this intervention, and the state policy changed during this time to allow AP CS A to count as a science credit towards high school graduation requirements. This effort also led to the creation of ECEP, the Expanding Computing Education Pathways alliance [37, 38]. This alliance joins together US states and territories to share best practices for computing education initiatives at the state level, including policy changes.

Previous work also includes comparing CS adoption and policies at an international level. Among the countries studied, Heintz et al. identified as a common struggle the pre-service and in-service training of teachers [39]. They also compared CS at the primary and secondary levels across the countries, identifying whether it was compulsory, elective, and in what form CS was offered. A 2015 ITiCSE working group studied more countries' growing access to CS education and explored terminology, goals, content, programming languages, assessments, and teacher education [40].

Our work differentiates itself from these valuable studies by exploring a given state as is, not assessing the impact of a particular intervention or curriculum. While our methods align with a number of these works, we take a step further with regression analyses to attempt to model the current landscape of CS in Georgia and what factors could influence schools when they consider offering a CS course.

3.1.2 Analyzing K-12 Computer Science Access

Landscape surveys are reports that are borne from the Expanding Computing Education Pathways (ECEP) alliance (see Section 3.1.1). The state and territory teams often publish reports of what K-12 computer science education looks like in their state. These landscape surveys vary in terms of focus. Some reports focus on the diverse representation of students across the state, the development of a technology workforce, or a broad-stroke approach to what is happening in K-12 CS education, regarding students and teachers, across the state. I reviewed the available landscape surveys to identify what variables I should explore in my study of CS in Georgia. The surveys I reviewed, and what variables they gathered, are briefly summarized below. The specific results of the surveys will not be reported here since many of these landscapes have changed since their reports were released. I also include a summary of a similarly styled report out of the United Kingdom.

Gender and race were the most commonly reported variables across the landscape surveys. Massachusetts released a report on the big picture of the technology workforce development [41]. Although there was only a minor mention of the K-12 CS pipeline, the survey did include higher education variables, breaking down degrees by type of institution (public or private). A landscape survey out of California exposed disparities in access to computing in California public high schools [42]. This report used course offerings, median income, English language learner status and free and reduced lunch status (the latter two are often used in the U.S. as a proxy for barriers students face). Texas reported on the pipeline of offering CS in schools and considered partnerships with industry, existing math certified teachers, university-based programs for PD, non-profit activity (such as code.org [43]) [44]. Maryland's report uniquely includes data on membership in the Computer Science Teachers Association in the state and teacher demographics [45]. South Carolina, Indiana, and New Hampshire also reported on teacher variables, such as certifications or endorsements or licensing (all of these are what allows a teacher to teach CS, which is called different things in different states in the U.S.) [46, 47, 48]. These states also considered the type of course being offered, and South Carolina and Indiana included geographical elements, such as the distribution of demographics across their state. Indiana also reported on AP CS A scores, preservice programs, course funding, and CS credit transfer opportunities [47]. Additionally, South Carolina explored Title 1 funding (indicating a school that primarily serves low-income families) and the urban/rural divide in their state [46].

The Roehampton report is a comprehensive report of CS in the United Kingdom (UK) primary and secondary schools [49]. The Roehampton report is similar to the U.S. state landscape surveys in terms of themes, variables studied, and problems identified. Researchers surveyed 341 primary school teachers and 604 secondary school teachers and ran eight small teacher meetings to collect all their data. The Roehampton report considers demographic, geographic, course, and funding variables, as well as the programming language used, perceptions of computing, single-sex schools versus mixed schools, and teacher variables, including confidence, qualifications, position before teaching CS, and other subjects taught. The Roehampton report informs our analysis, convinces us that the problem is larger than just the Georgia local context, and gives us hope that our analyses may be useful to other international contexts.

3.2 Barriers and Access to Computer Science

My dissertation aims to add to the literature on barriers and access to computer science, and thus it is necessary to understand what that literature is. Previously identified barriers can be categorized as structural, societal, or relating to demographics. What follows is a brief discussion of barriers within these categories. This is in no way an exhaustive review of the literature but provides an outline of where major research has been done in these areas.

As discussed in Chapter 1.1 and Table 1.1, my work situates itself as building on the work of the BASICS project and *Stuck in the Shallow End*. *Stuck in the Shallow End* explored barriers to student access to CS in three Los Angeles high schools [1]. Out of that work, the Exploring Computer Science (ECS) curriculum was created to broaden participation in computing [28]. The BASICS project researched the implementation of ECS at a school district level[14]. I build upon these works by also studying access and supports and barriers to CS. However, my dissertation work is at a state-level, analyzing public high schools across Georgia. Whereas BASICS analyzed schools that had CS because of a focus on ECS implementation, my studies include all schools, regardless of curriculum or any CS implementation. Furthermore, where *Stuck in the Shallow End* focused on students and their experiences, I focus on the experiences of school officials when considering offering a CS course. BASICS and *Stuck in the Shallow End* are cornerstones of this dissertation work, which builds on their findings around barriers and access to CS.

3.2.1 Structural Barriers

Structural barriers are issues beyond one individual's control and typically relate to the environment or context of the situation. In the case of computer science education, structural barriers typically center around schools, but can also include state and federal policies. Researchers at Google have worked with Gallup to survey students, parents, principals, and superintendents across the country with regards to their perceptions and access to computer science [50, 51, 11, 8]. Their findings have indicated that the main reason schools do not offer computer science is because of time, budget, and testing requirements [8]. While teachers, principals, and superintendents agreed that their school board believes computer science education is important to offer, fewer believed that computer science education was a top priority for their school district [50]. Additionally, the Barriers and Supports to Implementing Computer Science (BASICS) project from the Outlier Research and Evaluation group at the University of Chicago found similar structural barriers as the Google/Gallup group [14, 52]. BASICS explored many additional barriers relating to teachers, finding that teacher self-efficacy, experience, and time management create barriers to teaching introductory computer science [14].

3.2.2 Socioeconomic Status

Low-income students have less access to technologies [53]. Previous reports have seen that not only are higher-income households more likely to have computers in the home [54], but also how these computers are used varies by socioeconomic status (SES). Based on reports from the National Telecommunication and Information Administration [55], SES also impacts the speed of internet connection in the home, the number of computers per household, and the quality of those computers.

Outside of the home, school-level SES can impact how computers are used. For instance, lower-SES teachers often have less technical support for their computers in the classroom [56] so they use them less often. Additionally, because they often can't assume that students will have home access to computers, they spend a large portion of their time teaching basic computer skills and are hesitant to send children home with computer assignments [57]. There are even broader differences in how access is provided to students in different SES schools – for instance, low-SES schools are more likely to use computers for “remediation of skills” and review, while higher-SES schools are more likely to use computers for creative expression [58].

In addition to technical factors, SES can also impact various social factors that relate to access. For instance, having peers [1] and family members [59] who are sophisticated users of technology can impact your understanding of it. We know that SES can be a determining variable as to whether students’ perceptions of software are more affected by home computer or by in-classroom exposure [60], though how SES was measured in that case is unclear. One study found that SES (measured according to parents’ occupation(s)) does not predict computer ownership but does affect attitudes, use, and competencies [61]. We also have evidence that students without prior access, exposure, and opportunities to use technology fall behind in college due to simply not knowing how to use the technological tools that colleges depend on in this digital age [62].

SES and Achievement

Although issues of achievement in CS are outside the scope of this dissertation, it is an area with more research connected to SES than simply access. However, what exists of SES and CS achievement in the literature identifies different definitions of SES and differing definitions of CS. There is a commonly held belief that being richer, thereby likely coming from a higher SES, can make a person better at computer science [10, 9]. And in general academia, there is a strong, positive relationship between socioeconomic status (SES) and academic achievement [63, 64, 65]. Students from low-SES households are less likely to attain high scores on achievement tests and grade-point average (GPA) measures while being from a high-SES household tends to predict academic success. This finding has been replicated in STEM fields [66], and we have evidence that this holds for computer science achievement as well [1]. It is not the mere presence of money that produces the ability to achieve in computer science. SES leads to other benefits, such as living in a neighborhood with less crime and better schools, or potentially better availability of toys that develop spatial reasoning skills [67]. Those other factors are more likely to have an impact on academic achievement rather than just SES.

Existing work comparing SES and CS achievement study the effects of SES on attitudes towards and perceptions of computing and knowledge of computing. However, it's important to note that the literature consists of different ways of measuring SES and differing definitions of CS. We know that SES can be a determining variable as to whether students' perceptions of software are more affected by home computer or by in-classroom exposure [60], though how SES was measured in that case is unclear. One study found that SES (measured according to parents' occupation(s)) does not predict computer ownership but does affect attitudes, use, and competencies [61]. We also have evidence that students without prior access, exposure, and opportunities to use technology fall behind in college due to simply not knowing how to use the technological tools that colleges depend on in this digital age [62]. These studies operationalized different definitions of SES, and cover three different types of technology–software, computer ownership, and college technology use.

3.2.3 Demographics

Inequities in access to computing education have been identified as critical issues that serve as barriers to women and underrepresented minorities participating more fully in computing [68, 1]. Black and Native American students have less access to computer science compared to Asian and White students [69, 53]. This, in turn, contributes to the lower participation of these low-access groups [70]. A report by Google and Gallup discussed that Black students have lower access to CS at school, and learn CS outside of the classroom at higher rates than their peers [11]. They're also more confident they could learn CS, compared to their peers [11].]

Gender is a well-known factor in issues of access to and pursuit of computer science. The gender gap can start early, as middle school boys have been found more likely than girls to use computers and to have taken computer classes that promote using computers to solve problems [12]. High school students conceptualize and perceive computer science as a male field which makes women less likely to choose it as a career path [71, 72, 73, 13]. Furthermore, Goode et al. discuss that the challenges are not just to recruit underrepresented students in computer science, but also to engage them with meaningful assignments and consideration of student motivations [62].

3.2.4 Community

Barriers also exist within social interactions between students and the community around them. If students have a greater sense of belonging in computer science, they are more likely to indicate an interest in computer science [74]. Parents and their encouragement of participation in STEM play a role in students deciding to pursue and persist in STEM careers [75, 76]. Akin to parents, teachers and peers also play a role in influencing students, especially girls, in deciding to pursue computing [77].

3.3 Similar Work on Advanced Courses

Although only two of the CS courses that count for fourth science or math credits are AP courses, comparisons can be drawn between access to AP and access to CS. They both offer rigor to students and are extra choices, but not necessities, for a school to offer. Drawing from the literature on access to advance (AP and IB) courses can provide insight on access to CS courses.

In 2018, 4,923,072 students took AP exams[78]. Approximately half of those students identified as white (49.6%), 22.2% identified as Hispanic/Latino, 15% as Asian, and 6.3% as Black [78]. These numbers say nothing about the number of students enrolled in an AP course, as not everyone in a course has to take the exam and not everyone who takes an exam has to be in a course. However, these numbers are more equitable than Ndura et al reported as being enrolled in AP classes in a Western US city [79], but are still not representative of these subgroups at large. Iatarola et al. (2011) link the likelihood of schools offering advanced courses with 8th grade test scores, while not finding evidence to support a connection between the size of the school and these offerings [80]. The authors speculate that schools offer advanced courses to retain their high-achieving students, to dissuade them from transferring to other schools [80]. Monk and Haller did find that school size is related to course offerings in a high school, with different impacts on different areas of the curriculum [81]. They also found that SES played a role in predicting course offerings [81]. Similarly, Attewell and Domina find strong connections between SES and the students taking the courses, but this says nothing of whether schools are offering the courses [82]. Although it doesn't directly identify the causes for not having AP courses, in a report by the NGA Center for Best Practices, state strategies were identified to improve AP enrollment and success: expanding access via virtual opportunities and state graduation requirements, building teacher capacity, providing extra support for students, and offering incentives for schools [83]. This report also discussed the use of PSAT data to identify students that could obtain mastery level in an AP course [83].

3.4 Socioeconomic Status and Computer Science Achievement

As discussed in Section 3.2.2, socioeconomic status (SES) has a measurable impact on many educational outcomes and likely also influences computer science (CS) achievement. Before the work described in Chapters 4 and 5, I led a team in analyzing SES and CS achievement. We examined possible mediating variables between SES and CS achievement, including spatial ability and access to computing. We define access as comprised of measurements of prior learning opportunities for computing, perceptions of computer science, and encouragement to pursue computing. The factors (SES, spatial ability, access to computing, and CS achievement) were measured through surveys completed by 163 students in introductory computing courses at a college level.

Through the use of exploratory structural equation modeling, we found that these variables do impact each other, though not as we originally hypothesized. This section describes how, for our sample of students, we found spatial ability was a mediating variable for SES and CS achievement, while access to computing was not.

This study is outside the scope of the dissertation but still has implications for the motivations of including SES in analyses. This study also raises questions about the role access plays in computer science achievement. Meanwhile, this dissertation explores what impacts access within high school education. More details about this study can be found in [84].

3.4.1 Motivations

If we can define how SES impacts CS achievement, we might be able to mitigate the effect by designing interventions that would affect the intermediate variables. Socioeconomic status could affect access to computing hardware, broadband networks, community and family members with positive perceptions of computer science, encouragement to pursue computer science, availability of toys or trips to the museum that develop spatial reasoning skills, or other variables that might give a student a better chance at achieving in computer science [62, 67]. Giving every student enough wealth to boost their SES would likely be impossible. But some of those other intervening variables might be significant and be manipulable with reasonable resources. For example, we might be able to distribute low-cost hardware, if access to computing hardware turned out to be a significant intervening variable.

We wanted to begin to explore the *intervening variables* (also referred to as *mediating variables*) between SES and CS achievement. A better understanding of this could help inform interventions to help level the playing field for all students in CS. Our research question is: *What are the mediating variables X between socioeconomic status and computer science achievement such that socioeconomic status affects X and X affects CS achievement?*

We focus on two possible intervening variables: spatial ability and access to computing. Spatial ability, spatial reasoning, or spatial cognition deals with the locations of objects, their shapes, their relationship to each other, and the manipulation of them [85]. We refer to spatial reasoning as the assessment of spatial ability. Spatial ability is connected to SES [86, 87] and to CS achievement [67]. In this study, access to computing is defined by access to learning opportunities, as well as encouragement to pursue computing and perceptions of computing. Access to computing is also connected to SES [1] and CS achievement [54, 88]. We chose these variables because of their known connections to SES and CS achievement, but their unknown roles as intervening variables to describe the effect of SES on CS achievement.

We sought to build a novel model for computer science education to account for the observed connections between SES and CS achievement. To do this, we surveyed undergraduate students in their first college computer science course. We administered four surveys to assess SES, spatial ability, prior access to computing, and CS achievement. We created methods to score the surveys and then analyze the relationships between them. We began analyses with Pearson's correlations, which showed significant correlations between each of our four variables. We continued with exploratory structural equation modeling which resulted in a model of spatial ability as an intervening variable between SES and CS achievement, but access to computing was not found to be an intervening variable. We discuss the implications of our findings for the CS Education community.

3.4.2 Structural Equation Modeling

To determine the relationship between our four constructed variables (SES, access to computing, spatial ability, and CS achievement), structural equation modeling (SEM) was employed. SEM can be thought of as a combination of exploratory factor analysis and multiple regression [89]. This method creates a series of regression equations to represent the hypothesized relationships being studied and organizes those relations visually to create a clear conceptualization of the theory being explored [90]. SEM allows researchers to explore and test theory regarding how constructs are linked and the directionality of relationships [91]. SEM is the most appropriate method to answer our research question regarding mediating variables between SES and CS achievement.

SEM is confirmatory by nature, because of the emphasis on building models grounded in theory and literature [91]. SEM is not the same as Confirmatory Factor Analysis (CFA) modeling. CFA is a type of SEM, along with path analysis, structural regression models, and latent change models [92]. SEM can be exploratory when building structural regression models to test or disconfirm proposed theories involving explanatory relationships among various latent variables [92].

There are five steps to build any SEM: model specification, identification, estimation, evaluation, and modifications [92]. Model specification is the step of gathering existing theories to formally state the hypothesized relationships among the variables. Model identification involves applying data to the variables in the hypothesized model. Model estimation is using software to determine path coefficients between variables. In our study, we use the EQS software [93] to determine the impact of one variable on another. The scale of impact is described as a path coefficient, which is analogous to β in a regression equation [92]. These numbers are standardized and typically fall in the range of -1 to 1. Model evaluation is using model fit indexes to determine how well the data fit the model. While there are dozens of fit indexes, we focus on Chi-square difference tests, Root mean square error of approximation (RMSEA), Comparative Fit Index (CFI), and Bayes Information Criterion (BIC). The last step of building an SEM is a model modification, which involves adding or removing parameters to improve the fit. One of our models is a modified version of our original model, which lends itself to Chi-square difference tests to compare models. Another one of our models is not a modification of the original model, which necessitates the use of the BIC measure to compare the model fit.

A brief history of SEM and a primer for its role in education research and practice can

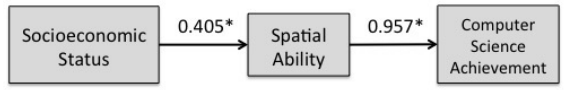


Figure 3.1: A model of socioeconomic status affecting spatial ability and spatial ability affecting CS achievement

be found in Khine's book on the topic [94].

3.4.3 Spatial Ability as a Mediating Variable

We created and tested three models. The first model stated that SES would have an impact on both access to computing and spatial ability, which in turn would each have an impact on CS achievement. The second model represented a hypothesis that access to computing did not play a role in affecting CS achievement. Rather, spatial ability is the only variable included to mediate the effect of SES on CS achievement. Thus, we removed all variables of access to computing, leaving a simplified model of SES having an impact on spatial ability, which in turn had an impact on CS achievement. The third model was another altered version of the first model. This model isolated access to computing, testing the impact that the components of access would have on CS achievement if spatial ability were not a factor. In contrast to the second model, we removed the spatial ability variable and allowed for each aspect of access to be a separate, observed variable with a path from SES and to CS achievement.

The second model, as seen in Figure 3.1, was the best model among the three tested, implicating spatial ability as a mediating variable between SES and CS achievement. Each path within the model is significant. SES has a medium effect on spatial ability, and spatial ability has a large effect on CS achievement. This finding extends the literature on SES, spatial ability, and CS achievement. It means there is a connection between these three variables, more so than access to computing. Spatial ability is a better mediating variable for SES and CS achievement than access, or in addition to access to computing. We can begin to answer our research question with the support that SES affects spatial ability and spatial ability affects CS achievement.

However, this model, as is true for the others, did not meet thresholds of individual fit indexes for a ”good” model. However, we were not using SEM to confirm a model by fitting it to data. Rather, we were trying to build a novel model for CS education, where there is a lack of theory to account for observed connections between SES and CS achievement. This model can serve as a foundation for continued study to understand how SES affects CS achievement.

3.4.4 Implications

We started this exploration with a hypothesis that socioeconomic status (SES) likely influenced CS achievement through the intervening variable of access. We thought that high-SES students likely had more positive access to computing education before they entered their first CS classes, and that's what led to higher achievement. However, our results do not support that hypothesis.

Instead, we find that spatial ability is a more powerful intervening variable than access. We had prior evidence from Cooper et al. that the impact of SES on CS achievement was mediated by spatial ability [67]. Our study specifically looked at that relationship, and our findings support it. Our results suggest that high-SES students tend to have higher spatial ability and that higher spatial ability, or the better ability to make use of spatial reasoning, thus predicts greater CS achievement. Students from low-SES backgrounds tend to have lower spatial ability or are less able to make use of spatial reasoning, which may be inhibiting their success in CS classes.

While surprising, the result is a positive one. Spatial ability can be taught [95]. David Uttal and his colleagues developed an approach to teaching spatial ability that measurably led to improved spatial ability that transferred outside the original testing context and was retained for months later [96]. Sheryl Sorby successfully taught spatial ability to Engineering students, which resulted in better performance in Engineering classes [97]. Spatial ability is an intervening variable that we can manipulate without changing students' SES.

We are not claiming that we have made an exhaustive search for intervening variables. We certainly should explore more. SES, spatial ability, and access do not explain all of a student's CS performance. The more we understand the relationship between SES and CS performance, the more we might be able to mitigate the effects of low-SES background in students.

While we have support for the model explaining SES impact on CS performance with mediation from spatial ability, we are not convinced that this model is complete and exhaustive. Because we gathered data only at the post-secondary school level, we are working from a biased sample. All of the students we studied already made it to post-secondary school. Any low-SES students in our sample already overcame odds to make it to this level. We do not know much about low-SES students who tried CS before the post-secondary level.

There may be different models at play between SES and CS performance at the elementary and secondary school levels. In particular, access may play a more critical role in primary or secondary school achievement. Access is likely an important variable in broadening participation in computing, but its impact may not be on CS achievement. For example, a lack of access may lead to higher attrition, so we do not even see the students without access in our sample populations.

Our current model gives us a lever. We now have an actionable explanation for why SES impacts CS performance. That is a useful contribution, both for understanding CS performance and for finding ways to mitigate low-SES conditions.

3.5 Diffusion of Innovation

Growing computer science in schools can be modeled as diffusion of innovation. Computer science courses can be thought of as the innovation, which is being diffused, or spread, throughout schools in America. I describe the literature of diffusion of innovation below, with ties to computer science education. To apply it to the situation at hand, it is important to understand its parts and how it relates to this issue.

3.5.1 Definitions

Diffusion is defined as the "process in which an *innovation* is *communicated* through certain channels *over time* among the members of a *social system*" [98]. Thus the four main parts of diffusion of innovations is the innovation itself, communication channels, time, and the social system.

Innovation

As defined by Rogers, "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" [98]. In my case, I'm considering computer science, as a course or a thing to learn, as the innovation. Innovations are defined by their perceived attributes, including relative advantage, compatibility, complexity, trialability, and observability.

Relative advantage is the comparison of the innovation to existing ideas. It can be measured in economic terms, social factors, convenience, and satisfaction. Computer science courses can be thought of in terms of their relative advantage to existing courses: math, science, English, and social studies. Do computer science courses cost more to provide than the existing staple courses? Do computer science courses offer more social status?

Compatibility is how much the innovation is perceived as fitting with existing ideas, experiences, and potential adopters. Incompatibility results in slower or lack of adoption of an innovation. For computer science courses, a question is often raised about integration into existing courses. On another level, the compatibility of computer science can be in terms of the school structure and schedule.

Complexity is how difficult an innovation is to understand and/or use. When new ideas are easier to understand, they will be adopted more rapidly than ideas that require the development of knowledge and skills. Computer science courses could be viewed as complex innovations, especially if teachers or school administrators haven't had previous training or education in computer science. However, complexity could decrease if there is a knowledgeable group of individuals who understand the concepts and what is required to develop that understanding.

Trialability is how much an innovation could be experimented with on a limited basis, such as trying out the innovation. If an innovation can be trialed it presents less uncertainty to an individual considering adopting it. Adding a new course to a school schedule for a year can be challenging, as it takes time from other courses that are involved in standardized testing. However, if a computer science course can be offered for a semester and not take from existing resources, its trialability would increase.

Lastly, observability is how much an innovation is visible to others. Visibility stimulates discussion of an innovation, prompting evaluation and referrals. If a neighboring school has a computer science course, a teacher or administrators in a school can observe that course or simply engage in discussions in the neighboring teachers and administrators. Being able to receive feedback on an innovation in this manner can provide comfort to schools considering offering computer science.

Communication

In terms of communication, Rogers says that "a communication channel is the means by which messages get from one individual to another" [98]. In other words, communication is when participants share information to reach a mutual understanding. In the context of this research, communication implies that it matters who the person that makes decisions in a school talks to. The communication can occur through channels, be it through mass media or interpersonal connections. For example, a teacher may learn about computer science courses through a friend's social media post or an email list to science teachers or from meeting someone at a professional development event. Regardless of the channel, it is important to note that communication makes the diffusion process social because it relies on relationships and connections.

Time

Time and its involvement in the diffusion process can be thought of in three ways. In one way, time is considered in terms of the time it takes for an individual to pass from first knowledge of an innovation to adopting or rejecting it. Another way is the early/lateness of an adopter compared with other members of a social system. The third way is the time it takes an innovation to be adopted in a system. Computer science courses as an innovation and their diffusion can be framed in terms of the time it takes for a school to decide to offer it, when the school decides and offers it compared to other schools, or the time it takes between deciding to offer a computer science course and when the first student enrolls in the course or steps into that classroom.

Social System

A social system "is defined as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal" [98]. Diffusion occurs in a social system. Thus, the social system can affect the diffusion of an innovation in many ways, such as through: the system's social structure, the norms of the social system can affect diffusion, the roles of opinion leaders and change agents, types of innovation-decisions, and the consequences of innovation. For example, computer science courses are being diffused across many social systems, including schools, districts, and states. Within the school level, it matters who the school is structured and what the norms are in terms of adopting an innovation such as CS. If a principal is accessible and open to discussions of innovation, then a teacher is more likely to approach the principal with the idea of adopting computer science (given the teacher knows about the innovation). Furthermore, the interactions between teachers and administrators can be altered by other opinion leaders and change agents, such as the school board or parents in the community.

3.5.2 History of Diffusion Research in Education

Innovations in public health (new drugs or treatments, family planning methods, HIV/AIDS prevention, etc.), agriculture (weed sprays, hybrid fertilization, etc.), communication (news events, telegram, telephone, etc.), and marketing (new products and brands) can all be explored through the lens of diffusion of innovations [98]. However, this proposal seeks to tie diffusion of innovation and education. According to Rogers, education diffusion research traditionally uses mailed questionnaires, survey interviews, and statistical analysis to create a model of understanding the diffusion [98].

Early educational diffusion studies were almost entirely conducted at Columbia University's Teachers College under the direction of Dr. Paul Mort in the 1950s. Rather than studying a specific innovation, Mort looked at innovativeness as a characteristic and explored whether it was related to local school control [99, 100]. Their studies were typically conducted through questionnaires sent to superintendents or principals of schools and used the school system as the unit of analysis. The researchers at Columbia University found that the innovativeness of a school could be predicted by how much money the school spent per student. In other words, wealthier schools were more innovative.

Other educational diffusion studies included investigating the adoption of kindergartens in U.S. schools (which took about 50 years) [101] and the adoption of driving training (18 years) [102] and modern math (five years) [103]. The latter two innovations were supported and promoted by change agencies, such as insurance companies and auto manufacturers for driver training and the National Science Foundation and the U.S. Department of Education for modern math.

CHAPTER 4
ANALYZING MODELS OF FACTORS THAT IMPACT COMPUTER SCIENCE ENROLLMENT AND OFFERINGS

In this chapter, I examine factors that might affect a decision for a school to teach CS. I pose the question, *What are the quantitative factors that impact CS enrollment and offerings at public high schools in Georgia?* This chapter describes my work to answer this question quantitatively. I perform correlation and regression analyses on publicly available data to understand what school- or district-level factors correlate with or explain a public high school offering a CS course and their ensuing CS enrollment. My findings indicate that median income correlates with and explains CS enrollment, but with only small amounts of variance explained. The most significant factor to impact CS enrollment and offerings is past CS enrollments and offerings. This suggests that, above all else, getting a CS course for the first time is a key to continue to offer CS. While this makes logical sense, I discuss additional implications regarding the low explanatory power of the other factors.

4.1 Data Collection and Processing

In this section, I describe the selection of factors in my models and the data sources. To know what data to obtain from public data sets, I first analyzed landscape surveys from different states. The content analysis of the landscape surveys guided what factors to include in the analysis. I also discuss the sources for my data, including the CS data and the school- and county- level factors.

This study uses the time frame of 2012 to 2016. School years are referenced by the by year of the spring semester. For example, the term "CS enrollment in 2016" refers to the school year that starts August 2015 and ends in May 2016. This time frame is due to the data available at the time of this study, but also provides a view into the impact policy can

Table 4.1: Variables reported on in existing landscape surveys

Variable(s)	State(s) Reporting
English language learner status Free and reduced lunch status	California
AP students and scores Pre-service programs Course funding Population density CS Credit transfer opportunity by institution	Indiana
Teacher demographics CSTA membership	Maryland
Title 1 funding Urban/rural Post-secondary offerings of CS (institution types)	South Carolina
Public/private partnerships Existing math certified teachers	Texas
Demographic Distributions	South Carolina, Maryland, Indiana
Teacher certifications, endorsement, or licensing	South Carolina, New Hampshire, Indiana
Type of course	South Carolina, New Hampshire, Maryland, Indiana
Median household income	California, Indiana
Professional Development opportunities (Non-profit and/or University-based)	Texas, Maryland, Indiana
Race	Massachusetts, California, Maryland, Indiana
Gender	Massachusetts, California, New Hampshire, Maryland, Indiana

have on CS enrollment and offerings. It provides a before and after view of the creation of the IT pathway, which added multiple new courses to the state-funded course list.

4.1.1 Landscape Survey Analysis

Landscape surveys were analyzed to select factors to focus on during the correlation and regression analyses. Landscape surveys are described at length in Chapter 3.1.2. I analyzed each landscape survey available at the time to gather information on what variables have been studied on a state level before, and thus what factors I should consider examining. I reviewed each survey report, taking notes on the focus of the report and what variables were reported on. After reviewing all the reports, the variables were aggregated to be considered for analysis. The list of variables that the landscape surveys report on can be found in Table 4.1. My study design focused on publicly available data and did not include plans to send out a survey to all schools or CS teachers as some of the landscape surveys did. As such, some variables that the landscape surveys used were unable to be included in my study because the corresponding data was not publicly available. I filtered out variables that were repetitive, out of scope (such as programming language taught, the gender of students, or curriculum used), or unrealistic to obtain (such as integration of CS at each school or what a teacher taught before CS). I considered the remaining variables as factors for my analysis and gathered data on them if it was publicly available.

4.1.2 Building the Data Set

Data were obtained for all factors identified from the landscape surveys which had publicly available data. CS enrollment data for the years 2012 to 2016 were obtained from the Georgia Department of Education (GADOE). School data, such as demographics, enrollment, and free and reduced lunch status (FRL, which is often used as a measure of socioeconomic status of the students [64]), were obtained from the National Center for Education Statistics (NCES) Elementary and Secondary Information System (ELSi). County-level data were obtained from the U.S. Census Bureau's American Community Survey 5-year data for 2016, such as median income and population. Each school resides within a school district which is primarily connected to the county. This made the county-level data, such as median income, useful since the information available at that level is not normally reported on at the school level. If the data were year-specific, data for 2016 were focused on, as that was the last year of available GADOE CS data.

Initially, 465 schools were included in the school-level data set. School data were then filtered based on data availability for all five school years. If a school changed status (such as being listed as a charter school for one year) during the time frame. Additionally, state schools (e.g. Department of Juvenile Justice schools) were removed, as well as alternative schools or special education institutions. If a school started at any grade level before 9th grade and did not have 12th grade as the highest grade offered, the school was removed from the data set. All of these filters were performed to standardize the comparison between high school populations. These filterings left **361 public high schools** in Georgia to compare. The CS data from GADOE was filtered to only include the 361 schools in the school-level data. As such, **25 schools** and **1,141 students** enrolled in CS were not included in the study.

CS data were categorized according to the operationalized definition of a CS course, as described in Section 1.4. The CS enrollment variable was transformed into a rate, which represented the percentage of students at the school enrolled in a CS course. This allowed for easier comparison among schools of different sizes. Consequently, ten students in CS at a school with two hundred students (5% of students) would be represented differently than ten students in CS at a school with two thousand students (0.5% of students).

Georgia has a virtual school (GAVS), which offers courses to Georgia students in middle and high school in a virtual (online) environment. The students enrolled in the virtual high school courses are counted as taking the course at the school. They are not counted any differently than a student who takes the course in a physical classroom with other students. This means that the enrollment numbers for CS at schools is slightly inflated and goes against the previously stated definition of what it means to offer a CS course at a school. There is no way to divorce the GAVS enrollment numbers from the in-school enrollment numbers and so the virtual students had to be included in this analysis as part of the in-school offerings.

The county- and school-level data sets are vast and contain various variables that could potentially correlate with or explain CS enrollment rates. However, only variables that had some level of theoretical connection to CS were used as factors in my analyses, to prevent misuse of p-values. Examples of rejected variables include the rate of religious adherents, voting patterns, and crime rates. Variables from the datasets used as factors in the analyses include median income and free and reduced lunch rates, which can be used to confirm the hypothesis that monetary resources are a significant factor in offering a CS course. School enrollment was also included as a factor, which can help explore if only larger schools have a CS course. Additionally, the rate of the demographics of White and Asian students at a school are included in the correlational and regression analyses. These demographics are known to be overrepresented in CS, compared to underrepresentation by Black and Hispanic students [11, 104]. Although women are also underrepresented in CS [11], that variable is not included in the analysis since schools in the U.S. are close to a 50% split in women and men at the school. This does not mean that the CS courses are a 50% split of women and men enrolled, but the demographics of students in the courses were not considered in this study. Rather, the focus was placed on the demographics of the school as a whole. Data on school demographics was not at a level to analyze the intersectionality of race and gender.

The data set I cultivated does not have all the possible variables that could factor into the model. Various elements could factor into a school's decision to offer a CS course on an individual level, such as professional development offerings [105, 106], student and parent interest [8, 17], and teacher self-efficacy [107]. These factors could not be analyzed in this study because there was no publicly available data on those factors.

4.2 Analysis

To answer my research question, correlation and regression analyses were conducted using the data set explained in Section 4.1. These correlations and regressions provided feedback about the model fit and shape. For example, if a regression did not explain enough variance, then that signaled that the model was not a good fit for the data. This would lead me to explore other models to determine a better fit. In this section, I describe the models I built to determine the impact various factors had on CS enrollment and offerings.

I hypothesized that median income would play a significant role in the models. I thought median income would vary with, and explain, the percentage of a school enrolled in a CS course. In this case, I expected to see a significant, strong correlation between median income and the percentage of a school enrolled in a CS course and that median income would explain a small to moderate ($0.2 < R^2 < 0.80$) amount of variance in a simple linear regression model.

Definitions and abbreviations for each factor used in the models can be found in Appendix A. All of the correlation and regression analyses were run in IBM SPSS Statistics 24.

4.2.1 Basic Analysis

In this section, I provide a high-level summary of the landscape of computing and CS in Georgia from 2012 to 2016. This information can help contextualize the amount of CS across the state and the shift in enrollment after the IT pathway was introduced. This section also includes the distinction between computing, courses in the IT pathway but don't count for the fourth-year science graduation requirement, and CS, courses that do count for that requirement.

A summary of computing and CS course enrollment numbers by year can be seen in Figure 4.1. The figure also shows the change in the computing landscape in Georgia between 2013 and 2014, when the IT career cluster started and new course codes were added to the course registry. In 2016, 457,671 students were enrolled at public high schools across Georgia. 5,893 (1.3%) of those were enrolled in a CS course, as seen in Figure 4.3. The CS enrollment numbers increased throughout the study by over 400%.

Out of the 361 public high schools in Georgia in the data set, 171 schools (47%) had a CS course in 2016. The change in this number over the years and as new courses were added to the state-funded course registry can be seen in Figure 4.2. The average CS enroll-

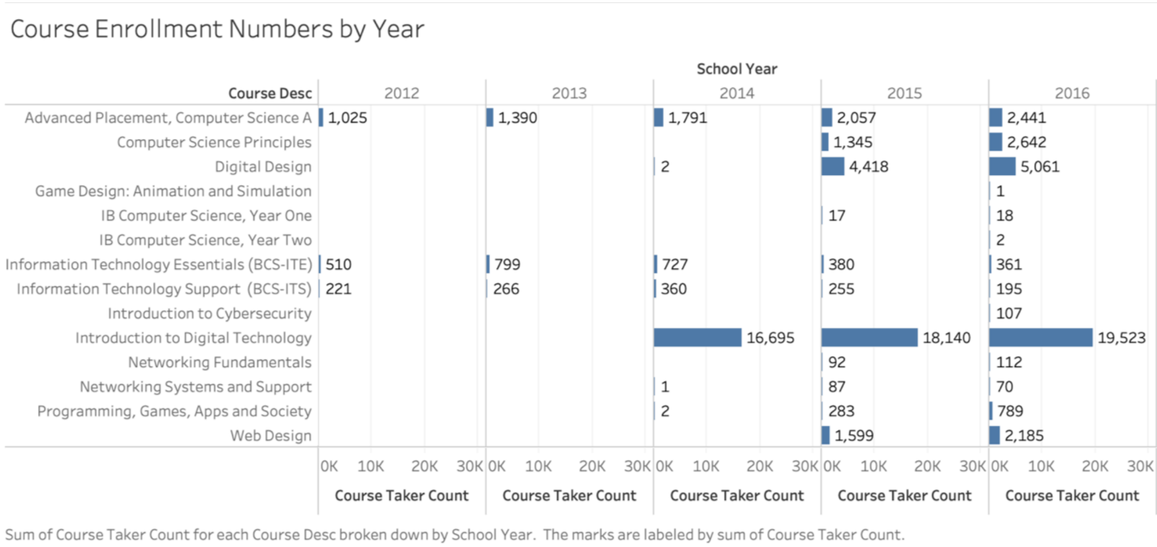


Figure 4.1: Enrollments in CS courses 2012-2016

ment at a school was 0.96%. That is, on average, less than 1% of students were enrolled in a CS course in each public high school in Georgia in 2016. The highest percentage of a school enrolled in a CS course was 11.3%, which was in 2016. In the entire time frame of 2011 to 2016, 157 schools never had a CS course. In other words, 43% of high schools in Georgia never had a student enrolled in a CS course in that time frame.

4.2.2 Correlation Analysis

To determine the relationship between CS enrollment rates and the selected factors, a Pearson's correlation was run. Correlations were also performed between each of the factors to assess if any factor was potentially redundant. The results of this analysis can be seen in Table 4.2.

There was a statistically significant, strong ($|r| > 0.5$) positive correlation between the percentage of a school enrolled in a CS course in 2016 and CS enrollment rates in 2015, 2014, and 2013. There was only a significant moderate ($0.3 < |r| < 0.5$) positive correlation between CS enrollment rates in 2016 and 2012. Significant, moderate ($0.3 < |r| < 0.5$) positive correlation was found between the percentage of a school enrolled in a CS course in 2016 and median income, which was true for the other years of CS

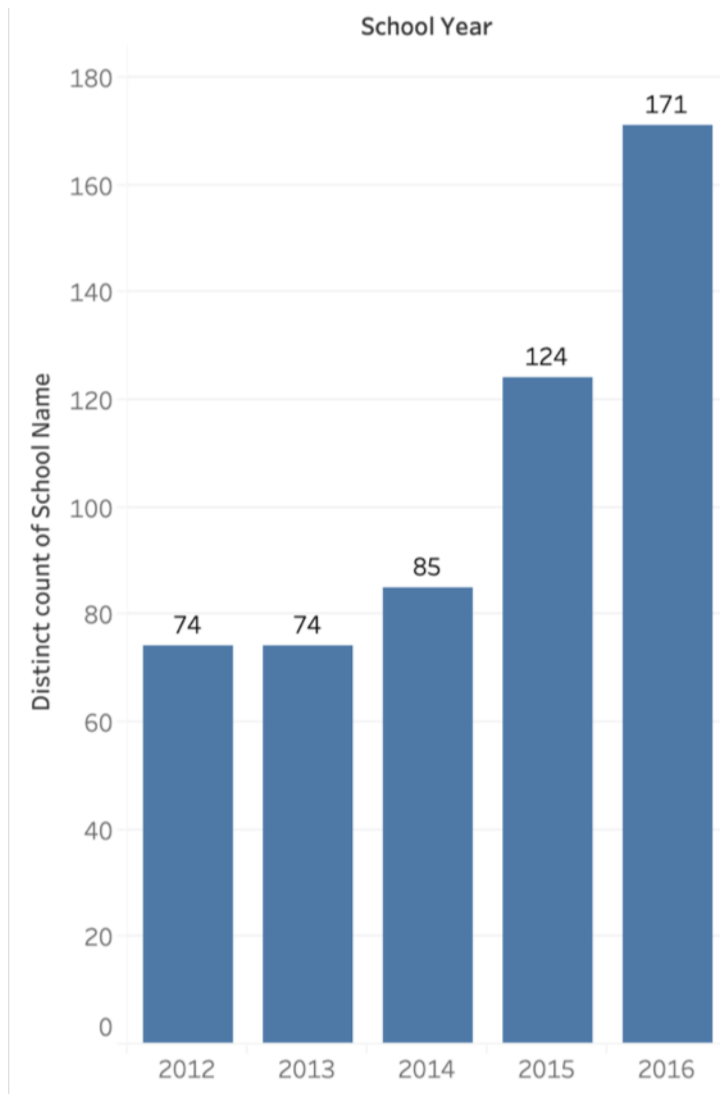


Figure 4.2: Number of schools with non-zero CS enrollments, 2012-2016

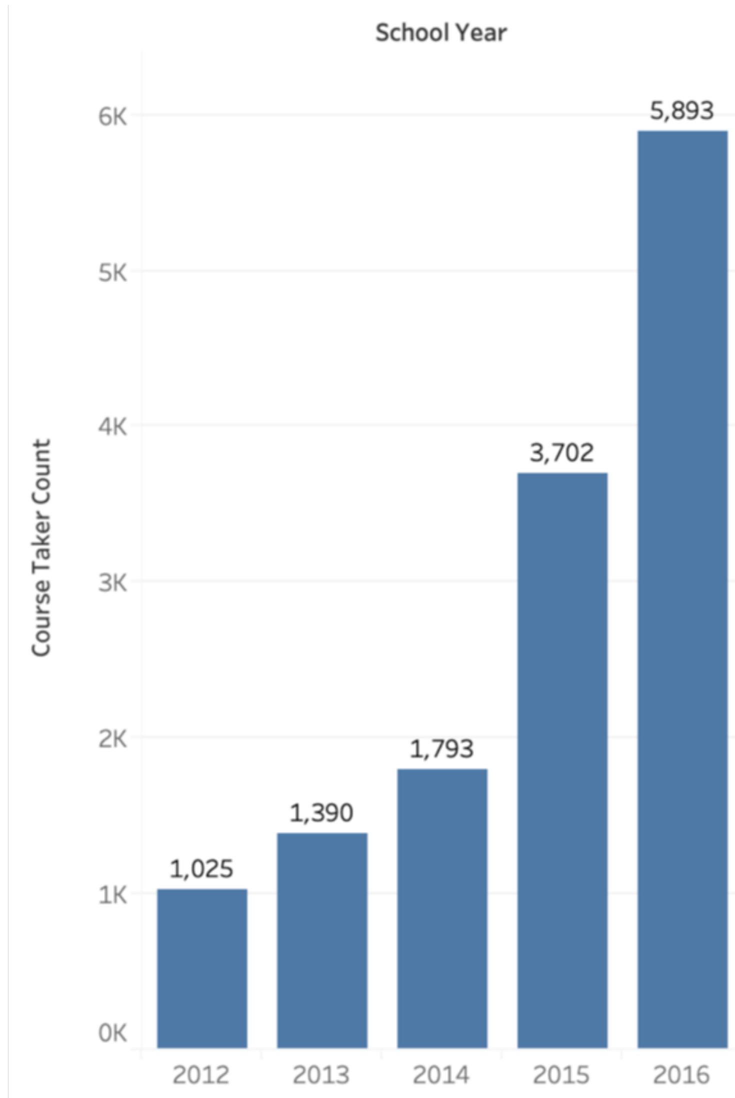


Figure 4.3: Number of students enrolled in CS courses, 2012-2016

enrollment as well. Additionally, the statistically significant, moderate negative correlation between urban and CS course enrollments (for all years except 2012) represents that an urban (as opposed to suburban or rural) area is more correlated with higher CS enrollments. Although the positive correlation between the percentage of Asian students at a school and CS enrollments is always significant, it shifts from a strong to moderate correlation between 2015 and 2016 and again between 2012 and 2013.

Additionally, there was a statistically significant, moderate positive correlation between school enrollment and county population, and a significant, strong negative correlation between the rate of free and reduced lunch status and median income. Because of the similarity between enrollment of a school and population in a county, and between median income in a county and free and reduced lunch status rates at a school, these pairs were treated as redundant. In the regressions, the pair of variables were not included in the models, only one in each instance. For example, median income and free and reduced lunch were never in a regression model together, though they both appear in models individually.

4.2.3 Regression Analysis

In this section, I present the results of multiple types of regression models. I ran simple linear, standard multiple, hierarchical multiple, and binomial logistic regression analyses on the data to answer my research question. It is important to build increasingly complex regressions in attempts to model a system. If I found a simple (one-variable) regression that was a good fit (i.e. explains a large amount of variance in the model) for the percentage of a school enrolled in a CS course in 2016, then the analysis would not need to go much further. However, the simple linear regression models did not have those results. More complex regression analyses needed to be run until a better fit for the model could be found. While the simple regressions failed to explain a lot of variance in the model, that failure is as important as the complex models that fit the data better. Failed models motivate where to go with the next regressions while showing that schools with students taking CS

Table 4.2: Pearson correlations among CS, school, and county variables

	CS16	CS15	CS14	CS13	CS12	Med. Inc.	Enroll	Pop	FRL	White	Asian	Urban
CS16	1.000	-	-	-	-	-	-	-	-	-	-	
CS15	.690**	1.000	-	-		–	-	-	-	-	-	-
CS14	.535**	.645**	1.000	-	-	-	-	-	-	-	-	-
CS13	.566**	.593**	.680**	1.000	-	-	-	-	-	-	-	-
CS12	.438**	.489**	.559**	.628**	1.000	-	-	-	-	-	-	-
Med. Inc.	.321**	.371**	.365**	.301**	.303**	1.000	-	-	-	-	-	-
Enroll	.329**	.407**	.344**	.361**	.308**	.604**	1.000	-	-	-	-	-
Pop	.362**	.403**	.329**	.389**	.286**	.545**	.461**	1.000	-	-	-	-
FRL	-.261**	-.336**	-.406**	-.330**	-.276**	-.601**	-.472**	-.125*	1.000	-	-	-
White	-.041	-.002	.065	-.001	.009	-.022	-.027	-.429**	-.583**	1.000	-	-
Asian	.407**	.502**	.566**	.596**	.443**	.373	.470**	.424**	-.375**	-.051	1.000	-
Urban	-.252**	-.235**	-.239**	-.193**	-.099	-.396**	-.310**	-.538**	-.034	.530**	-.248**	1.000

* represents significance at the 5% level
** represents significance at the 1% level

Table 4.3: A summary of the benefits and downsides of each regression type

Regression Type	Benefits	Downsides
Simple Linear Regression	Could provide high explanatory value on one variable	Only includes one explanatory variable
Multiple Regression	Extends simple linear regression to two or more explanatory variables, including overall and individual impact on the model	Does not include what the model would be with a subset of the variables
Hierarchical Multiple Regression	Allows exploration of how much extra variation in the outcome variable can be explained by the addition of one or more explanatory variables	Increasingly complex and can be hard to interpret
Binomial Logistic Regression	Provides same benefits as multiple regression, but on a binary outcome variable	Answers a different research question than the other regression models

can not be simply explained by one variable. The benefits and downsides of each type of regression that I used in this study can be found in Table 4.3.

The percentage of a school enrolled in a CS course was used as a continuous outcome variable; different school and county variables were used as continuous explanatory variables. Regression analysis results can be seen in Tables 4.4,4.6, 4.7, 4.8, and 4.9. Hetereoscedastic regressions, non-linear results, and results that did not satisfy the assumption of normality are not included in the tables, but some are summarized in Table 4.5. The results are summarized in Table 4.10.

There are multiple outcomes of the regression analyses reported in the regression tables, which are explained here. First, it is important to note that for the simple and multiple regressions the outcome variable (the percentage of a school enrolled in a CS course) was transformed using a base-10 logarithm. This creates a linear relationship among the variables to meet assumptions for the regression. However, this does affect how the regression coefficients are interpreted. The B column indicates the unstandardized regression coefficient. This represents the change in the outcome variable for a one-unit change in the explanatory variable [108]. With a non-transformed outcome variable, the regression coefficient in the first simple linear regression in Table 4.4 would be read as "For every dollar increase in median income in a county, there is an explained increase of 0.00001038 in the percentage of a school enrolled in a CS course." However, since the outcome variable is log-transformed, exponents need to be used to be able to make claims about the percentage of a school enrolled in a CS course. This means 10 is raised to the power of B and that is the percent increase in the outcome variable. Additionally, talking in terms of singular dollars is hard to grasp when considering changes in median income, so B is multiplied by a factor of 1,000 in order to understand what happens to the outcome variable with larger increases in median income. With these calculations, the first simple linear regression can now be read as, "For every \$1000 increase in median income in a county, there is an explained 2.4% increase of the percentage of a school enrolled in a CS course."

As mentioned, within the simple and multiple linear regressions, the percentage of a school enrolled in a CS course was logarithmically transformed to produce homoscedastic results. Homoscedasticity is important for regression models [109]. If homoscedasticity is not present, then the data are heteroscedastic, which can result in some values having more weight than others because of the error variance. One method to produce homoscedastic results from data is to perform a log-transform on the outcome variable. This does change the interpretation of the results, as discussed above. If regressions were not homoscedastic, they are not reported in Table 4.4 but a list of these failed regressions can be seen in Table 4.5. The failure of these regressions does not mean that the independent variables do not explain the dependent variable, only that there is not enough evidence to support those relationships.

Due to the log-transformation, any school that had no CS enrollment (or, CS enrollment was equal to zero) was eliminated since logarithms can not be performed on zero values. Any of the results that are on a log-transform outcome variable are only models of schools that had any CS during that period.

Simple Linear Regression

Median income statistically significantly explained the percentage of a school enrolled in a CS course, explaining 5.2% of the variance in the amount of CS that a school had in 2016 if they had any CS at all. In a separate simple regression, free and reduced lunch did not statistically significantly explain CS enrollment rates at the $p < 0.05$ level. The county population, school enrollment, and urbanicity variables used in separate linear regressions each produced heteroscedastic results and are included in Table 4.5.

Multiple Linear Regression

The county population and median income failed the assumption of linearity that is needed for multiple regression analysis. However, county population and free and reduced lunch rates statistically significantly explained the percentage of a school enrolled in a CS course, explaining 10.1% of the variation in schools that had CS in 2016. However, only the county population statistically significantly contributed to that model. School enrollment and median income as well as school enrollment and free and reduced lunch rate statistically significantly explained the outcome variable and explained 5.7% and 3.8% of the variance, respectively. However, median income was the only statistically significant variable contributing to those models; enrollment and free and reduced lunch rates were not found to be statistically significant variables in the models, based on the t and p values. A multiple linear regression on the percentages of a school enrolled in a CS course in previous years explaining the 2016 CS enrollment rate did not produce linear results.

Hierarchical Multiple Regression

In hierarchical multiple regressions (HMR), as more variables are iteratively added the variance explained should increase. If it does not, it indicates that the variable(s) added do not explain additional variance. In one HMR model, as seen in Table 4.6, prior CS enrollments were loaded onto the outcome variable (the percentage of a school enrolled in

Table 4.4: Results of simple linear and multiple regression analyses

	B	10^B	SE_B	β	Adj R^2	F	df	t	p
Simple Linear Regressions									
Median Income	1.038E-5*	2.4%†	0.000	0.228	0.052	9.470*	1	3.077	0.002
FRL	-0.003	-0.68%	0.002	-0.134	0.018	3.160	1	-1.778	0.077
Multiple Regression Model 1					0.101	9.626**	2		0.000
Population	5.00E-7**	0.12%†	0.000	0.289				3.977	0.000
FRL	-0.003	-0.68%	0.002	-0.109				-1.501	0.135
Multiple Regression Model 2					0.057	5.141*	2		0.007
Enrollment	7.069E-5	17.7%†	0.000	0.080				0.906	0.366
Median Income	8.401E-6*	1.2%†	0.000	0.185				2.089	0.038
Multiple Regression Model 3					0.038	3.351*	2		0.037
Enrollment	0.000	0%	0.000	0.152				1.870	0.063
FRL	-0.002	-0.46%	0.002	-0.077				-0.949	0.344

* $p < 0.05$ ** $p < 0.001$

† These values have been multiplied by a factor of 1000 to more easily speak in terms of the unit

Table 4.5: Heteroscedastic or non-linear regressions

Type of Regression	Explanatory Variables	Outcome Variable
Simple Linear	Urban	$\log_{10} CSRate2016$
Simple Linear	Population	$\log_{10} CSRate2016$
Simple Linear	Enrollment	$\log_{10} CSRate2016$
Multiple Regression	Population Median Income	$\log_{10} CSRate2016$
Multiple Regression	CS Rate in 2015 CS Rate in 2014 CS Rate in 2013 CS Rate in 2012	$CSRate2016$

a CS course), followed by median income, school enrollment, and White and Asian student demographics in subsequent iterations. Inclusion of percentages of a school enrolled in a CS course in previous years produced significant changes in the variance explained, but the other variables did not. The final variance explained in this model was 52%. When the previous CS enrollment rate is not included as an explanatory variable, median income, school enrollment, and percent White and Asian students at the school each explained more variance in the model (see Table 4.7). The total variance explained by this model was 20.4%.

Binomial Logistic Regression

Two binomial logistic regressions were run to answer a different question of *whether* a school had CS rather than *how much* CS a school had (see Tables 4.8 and 4.9). The previous simple, multiple, and hierarchical multiple regressions were unsuccessful in terms of building a model that explains a large amount of variance and that all factors contribute to significantly. This informed my decision to run a regression focused on what factors affect a school's offering of CS, rather than how many students were enrolled in CS courses at each school.

In the first regression, all variables from the hierarchical multiple regression described in Table 4.6 were added to the model to explain the binary variable of whether or not a

Table 4.6: Results of hierarchical multiple regressions with prior CS enrollment

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Variable	B	β	B	β	B	β	B	β	B	β	B	β
CS15	1.021**	0.690	0.874**	0.591	0.787**	0.532	0.771**	0.521	0.772**	0.522	0.774**	0.523
CS14			0.373*	0.154	0.098	0.041	0.074	0.031	0.073	0.030	0.113	0.047
CS13					0.653**	0.223	0.648**	0.221	0.651**	0.222	0.684**	0.234
Median Income							6.141E-6	0.050	6.550E-6	0.053	6.562E-6	0.054
Enrollment									-1.601E-5	-0.006	9.174E-6	0.003
White Students											-0.268	-0.044
Asian Students											-1.665	0.045
R^2	0.477		0.490		0.515		0.517		0.517		0.520	
F	326.819**		172.292**		162.432**		95.355**		76.077**		54.643**	
ΔR^2	0.477		0.014		0.025		0.002		0.000		0.003	
ΔF	326.977**		9.776*		18.177**		1.546		0.018		1.028	

* $p < 0.05$ ** $p < 0.001$

Table 4.7: Results of hierarchical multiple regressions without prior CS enrollment

	Model 1		Model 2		Model 3	
Variable	B	β	B	β	B	β
Median Income	3.933E-5**	0.321	2.364E-5*	0.193	1.838E-5*	0.150
Enrollment			0.001*	0.212	0.000	0.094
White Students					-0.121	-0.020
Asian Students					11.278**	0.306
R^2	0.103		0.132		0.204	
F	41.237**		27.131**		22.844**	
ΔR^2	0.103		0.029		0.073	
ΔF	41.237**		11.1786**		16.246**	

* $p < 0.05$ ** $p < 0.001$

school had CS in 2016. As seen in Table 4.8, only the CS rate in 2015, median income, and enrollment contributed significantly to whether or not a school had CS in 2016. 48% of the variance was explained in this model, according to a Negelkerke R^2 value of 0.480. The regression had an area under the ROC curve of 0.859, corresponding to excellent discrimination [110]. The Wald value is used to determine the statistical significance for each of the explanatory variables (similar to a t value in a simple or multiple regression). The odds ratio is calculated using the B value and shows the change in odds for each increase in one unit of the explanatory variable. The 95% confidence lower and upper bounds demonstrate the range of values the odds ratio could be. As such, having more CS in 2015 increased the odds of having CS in 2016 by 5.377. In other words, the odds of having CS in 2016 was 5.377 times greater the more students a school had enrolled in a CS course in 2015. Overall school enrollment and median income, while contributing significantly, do not change the odds of having CS in 2016. This is likely due to a mismatch in scale. The median income is thousands of dollars, so a unit increase in income (an increase of $1) is not much. This is similar to enrollment, which is on the scale of hundreds of students. An increase of 1 student is not much, but an increase of 10 students, or 100 students, could change these numbers. Future regressions should adjust the scale for these variables when they are loaded into the model.

Table 4.8: Results of binomial logistic regression on hierarchical multiple regression variables

						95% Confidence Interval for Odds Ratio	
Variable	B	SE_B	Wald	p	Odds Ratio	Lower	Upper
CS15	1.682	0.449	14.046	0.000	5.377	2.231	12.959
CS14	0.424	0.509	0.692	0.405	1.528	0.563	4.146
CS13	-0.136	0.647	0.044	0.803	0.873	0.246	3.099
Median Income	0.000	0.000	4.172	0.041	1.000	1.000	1.000
Enrollment	0.001	0.000	16.688	0.001	1.001	1.001	1.002
White Students	0.462	0.451	1.048	0.306	1.587	0.656	3.841
Asian Students	2.372	4.825	0.242	0.623	10.715	0.001	1.37E5

Based on the first regression, a second regression was run that focused on the three significant factors (see Table 4.9. However, the enrollment rate in 2015 was transformed into a binary variable. This answers a more natural phrasing of the question of "Does having CS the prior year explain having CS the next year?" as opposed to the first regression, which was more about how much CS a school had in years prior. A binary 2015 CS variable, school enrollment, and median income were added to the regression model to explain the binary variable of whether or not a school had CS in 2016. All of these variables contributed significantly to whether or not a school had CS in 2016. 55.8% of the variance was explained in this model, according to a Negelkerke R^2 value of 0.558. The regression had an area under the ROC curve of 0.878, corresponding to excellent discrimination [110]. According to the odds ratios, having CS in 2015 increased the odds of having CS in 2016 by 20.03. In other words, the odds of having CS in 2016 was 20.03 times greater if a school had students enrolled in CS in 2015 than if they had no students enrolled in CS. These odds are greater than in the previous model, which looked at how much CS 2015 as opposed to if there was CS at all. Similar to the other binomial regression, school enrollment and median income, while contributing significantly, do not change the odds of having CS in 2016. The reasoning for this is the same as above, concerning the scale of the variables.

Table 4.9: Results of binomial logistic regression on binary prior CS

Variable	B	SE_B	Wald	p	Odds Ratio	95% Confidence Interval for Odds Ratio	
						Lower	Upper
Binary CS '15	2.997	0.376	63.572	0.000	20.03	9.588	41.850
Median Income	0.000	0.000	3.879	0.049	1.000	1.000	1.000
Enrollment	0.001	0.000	10.561	0.001	1.001	1.000	1.002

Table 4.10: A summary of findings from each regression type

Analysis	Key Findings	Explained Variance
Correlations	The only statistically significant, strong correlations with the percentage of a school enrolled in a CS course is prior percentages of school CS enrollment, 2013-2015	-
Simple Linear Regression	Median income is not a significant explanatory factor of the percentage of a school enrolled in a CS course	5.2%
Multiple Linear Regression	The only successful models included wealth and population variables, but still a low amount of variance explained	Up to 10.1%
Hierarchical Multiple Regression	Factors specific to the school play a role, but prior CS enrollment explains the most variance	50.2% when accounting for prior CS enrollment, 20.4% otherwise
Binomial Logistic Regression	Whether a school had CS in 2015 strongly affects if a school had CS in 2016	55.8%

4.3 Discussion

I hypothesized that median income would correlate with and explain CS enrollment. The analysis did not confirm this hypothesis. However, this is an encouraging result. A high median income, as determined on a district- or county-level, is not a prerequisite to offering a CS course. Conversely, a low median income does not inherently restrict a school from offering CS, according to the models.

From the correlations, it is clear that prior CS enrollment matters. The hierarchical multiple regressions were performed to determine how much prior CS mattered compared to median income and school enrollment, variables that were significant in the simple and multiple regressions. The first hierarchical multiple regression, seen in Table 4.6, shows that other variables do not significantly add to the variance explained in the model when prior CS is included. However, the same variables do explain 20.4% of the variance in a model without prior CS. These results indicate that county- and school-level variables matter, but not as much as prior CS enrollment.

The hierarchical multiple regression variables and results were also explored in a binomial logistic regression. The most successful regression model, in terms of variance explained, was one on *whether* a school had computer science, not *how much* computer science the school had. The most successful model, as seen in Table 4.9, includes the variables of whether CS was taught in the high school the year before, school enrollment, and median income. That offering CS in one year increases the odds of offering CS in the next year makes intuitive sense. If a school works out the issues (like where a course goes in a master schedule) and find a teacher in one year, it likely can repeat the offering the following year. The inclusion of school enrollment suggests that it's easier to offer computer science in a larger school than in a smaller school. A smaller school might not be able to afford a teacher, or may not be able to sustain interest. The median income is a factor because offering CS is an additional cost to a school, and wealthier schools can more easily bear the cost.

Qualitative analysis is needed to understand what is contributing to the rest of the variance in the model. I hypothesized that there were idiosyncratic factors at play in each school at the student, classroom, or school levels. Schools might have resources to offer a CS course, but students might not know about the opportunity because of communication failures. Or, a school could offer CS for one year, but the classroom environment is not supportive for students and student interest wanes such that the course does not make the master schedule the following year. Large-scale data sets and models can not reveal these esoteric variables; only qualitative research can. These might include community values and perceptions (e.g., that the community is focused agriculture and the connection to CS is too tenuous to make it important), individual stakeholders or decision-makers, and the availability of teachers.

Qualitative analysis can also help explain how a school starts to offer a computer science course. Due to the need to apply a log-transform to the outcome variable in the simple regression analysis, I cannot make claims on the schools that do not have any students enrolled in CS. I can only say what variables affect schools that currently have some students enrolled in a CS course. The primary explanatory factor in all the models was whether a school previously had CS. But what makes a school have CS for the first time? This is a hard question to answer quantitatively because there's not a statistically significant change in demographics or median income to explain the flip from a school not offering CS to the school having students enrolled in a CS course. Visiting schools allowed me to ask principals, counselors, and teachers, "What lead to you offering CS for the first time?"

Due to the definition of computer science used ("a CS course as offering an in-person computing course that counts towards graduation requirement"), I do not include integrated CS learning opportunities. These opportunities include Bootstrap [111], a programming curriculum that integrates learning algebra alongside computing concepts, or even Hour of Code [43], which encourages students to participate in a one-hour coding tutorial. However, these opportunities are outside the regular curriculum, much like clubs and extracurricular activities, and as such are not mandated to be reported by the school or back to the state Department of Education. Therefore, this data is not publicly reported or maintained, making it difficult to obtain at-large. Although this data can not be included in the quantitative analysis, I do inquire about them in Chapter 5.

4.4 Conclusion

In this chapter, I used publicly available data to build a model of factors that impact public high schools in Georgia offering CS courses and their CS enrollments. Many of the models were unsuccessful, either due to heteroscedasticity or lack of significant factors, or explained only a little amount of variance. My hypothesis was median income would affect CS enrollment the most, which is not supported by the findings. However, it plays a role, since it was the only successful simple linear regression, explaining 5.2% of the variance, and was in the successful binary logistic regressions. The most successful model was one that focused on if CS was taught in a school, rather than how many students were enrolled. This model contained the factors of CS being offered the year prior, median income, and school enrollment, and explained 55.8% of the variance.

These results support the belief that getting started is critical. While it may be challenging to get CS started in a school, the most significant factor in teaching CS next year is that it is offered this year. However, the results also suggest that the size of the school (in terms of enrollment) and wealth (in terms of median income) are important factors. Poorer and smaller schools are less likely to be offering computer science.

Because of the distributed nature of the American school system, I only focused on one state. Even including two states would involve changing fundamental issues like what CS classes were offered, which counted for what kinds of requirements, and how teachers became qualified to teach those classes. This model may serve as an example and a starting place for exploration in other school contexts.

4.5 Contributions

This study was designed to answer the question: What are the quantitative factors that impact CS enrollment and offerings at public high schools in Georgia? The findings of these regression models contribute understanding of what factors can impact CS offerings and enrollment in public high schools in Georgia. Other researchers and evaluators have explored the factors contributing to the offering of CS by K-12 schools [46, 45]. However, these have been within specific states and with a specific focus, such as a particular curriculum or concept (i.e. teacher development). My research adds to this existing area by examining a wide array of variables that could impact CS offerings and enrollment. My findings contribute evidence that prior CS presence at a school is an explanatory factor of future CS presence, both in terms of whether any students are enrolled and how many students enroll. The findings do not support claims that high median income is an explanatory factor of CS in public high schools, but the regression results do indicate it plays a role in a larger model of other factors.

CHAPTER 5
A CASE STUDY OF BARRIERS AND SUPPORTS TO COMPUTER SCIENCE IN FOUR HIGH SCHOOLS

This chapter details the study that aims to answer my second research question: *What do school officials perceive as barriers to and supports for offering CS at their school?* This study provides case studies of schools to better understand the structural and people-oriented barriers to adopting CS. It builds from the research described in Chapter 4, using the data gathered there to select schools for inclusion in the study. I used thematic analysis to study each case, providing maps of themes for each school. I then frame this analysis from the lens of diffusion of innovation, as described in Section 3.5. This framing provides insights into what attributes can be supports or barriers to schools when considering offering CS courses. I provide implications of the analysis to guide future directions of intervention in K-12 CS education on a school level.

5.1 Methods

I use a case study method to collect and compare barriers and supports school officials perceive when considering offering CS. Since my research focuses more on "how" and "why" there are barriers, rather than "how many" or "how much," a survey is not appropriate [112]. Rather, I use case studies to best represent the complexity of the different situations and illustrate the subtleties that can be involved [113]. A unique feature of case studies is that "human systems have a wholeness or integrity to them rather than being a loose connection of traits, necessitating in-depth investigation" [113]. Because of the case study's ability to provide an in-depth investigation into human systems, it can connect traits and variables that quantitative or shallower analyses could not provide. Given my interest in exploring the barriers and supports in-depth and within the varied contexts of schools and the affecting policies, communities, and programs, a case study is the right choice for exploring this issue.

This section describes my methods of selecting schools to feature in the case studies, including a profile for each school that was selected. I also provide my interview methods, including recruitment, my interview protocol, and what role my participants had in their schools.

5.1.1 Selection of Schools

To select my schools, I performed a cluster analysis with 361 public high schools in Georgia. A two-step cluster analysis was run in SPSS. CS enrollment rate in 2016, the median income for the county, and enrollment numbers at the school were used as inputs to the analysis. The number of clusters was set to four according to plans to visit four schools. The analysis showed four clusters defined as follows:

- Cluster 1: low median income, low CS rates, and small enrollment (165 schools)
- Cluster 2: low CS rates, average median income, and average enrollment (99 schools)
- Cluster 3: high CS rate, average median income and average enrollment (43 schools)
- Cluster 4: high median income, high enrollment, and above-average CS rates (54 schools)

The characteristics are listed in order of predictor importance for that cluster. For example, for Cluster 2, the most important predictor was the low CS rates, followed by average median income and enrollment rates.

I wanted to capture a variety of situations within the four schools I selected. Initially, a school in each of the four clusters were proposed as cases, and four back-up schools were selected, also representing each cluster. As I approached schools through principals, teachers, and/or research offices for the district, I was denied by some schools. In these instances, I approached my back-up school for that cluster. In Cluster 1, this worked as planned and I was able to set up a visit to and perform interviews at my back-up school. However, for Cluster 3, both my first and second choice schools deferred my request for research. Due to time constraints, I approached the backup from Cluster 4 because I had already previously visited that school district with my Cluster 2 school and knew the research approval process for that district.

In addition to using the clusters to select schools, I attempted to diversify my selected schools across dimensions of geography and urbanicity. However, not all combinations of characteristics could be represented. Part of this is due to only visiting four schools, and part of this is due to having research requests denied at schools that could have diversified my samples. As such, some characteristics are represented more than others. For example, I only visited one rural school, one school with a non-white majority, and no schools with current enrollment in a CS course.

School Profiles

Each school and its characteristics are summarized below. School names are pseudonyms to protect the school and participant identities. All numbers reported, except for those related to CS data, have been rounded to maintain the anonymity of the school. A summary of school characteristics can be found in Table 5.1. For reference, the average median income for counties in the data set was $50,727.

Cobalt High School Cobalt High School previously had CS courses during a time that not many schools did. The school has since lost most of its CS enrollment, except in the case of Georgia Virtual School. Cobalt was selected from Cluster 2, which is characterized by low CS rates followed by average median income and enrollment. According to our binary regression model, this school should have continued to have CS, making this school is an interesting case to explore.

Table 5.1: A summary of case study school characteristics

	Cobalt	Marigold	Sapphire	Amethyst
Prior CS	Yes	Yes	No	No
Location	Augusta metropolitan area	West Central Georgia	Augusta metropolitan area	Atlanta metropolitan area
Median Income in County	$70,000-$75,000	$40,000-$45,000	$70,000-$75,000	$70,000-$75,000
Average Enrollment	1600-1800	1200-1400	1600-1800	1800-2000
% White students	65%	60%	60%	<10%
% Black students	20%	35%	20%	35%
% Asian students	<10%	<10%	<10%	<10%
% Hispanic students	<10%	<10%	<10%	60%
Free and Reduced Lunch Rate	20-25%	55-60%	30-35%	80-85%
Pupil to Teacher Ratio	1:18	1:16	1:18	1:15
Title 1?	No	Yes	No	Yes
Urban Locale	large suburb	fringe rural	large suburb	large suburb
CCRPI	76	73.6	83.7	67.5

In 2013 and 2014, the number of students enrolled in a CS course was at a high of 21 and 65 students, respectively, resulting in 1.3-1.6% of the school being enrolled in a CS course. However, that number dropped to zero in 2015 and 2016. 2017 and 2018 show some CS enrollment, which is reportedly due to students taking the course through Georgia Virtual School. Cobalt does have an increasing number of students enrolled in computing courses that do not count for fourth-year science credit. 95 students were enrolled in these courses in 2014, 14 students in 2015, and 79 students in 2016. These students were all enrolled in the Introduction to Digital Technology course. Starting in 2017, the school has offered courses in the Cybersecurity pathway.

Cobalt High School is in the Augusta metropolitan area. This area higher-than-average median income. between $70,000 and $75,000 for the county. The school's average enrollment is between 1600 and 1800 students. The school has around 65% White/Caucasian students, 20% black students, and less than 10% each of Asian and Hispanic students. The free and reduced lunch rate at Cobalt averages between 20% and 25%. The school has approximately 90 teachers and a pupil-to-teacher ratio around 1:18. The school is located in a region that is classified as a large suburb. Nearby is Fort Gordon, which is the Cyber center for the United States Military. Cobalt and Sapphire High Schools are located in the same county and school district.

Marigold High School Marigold High School previously had CS courses and has since lost all CS enrollment. This school was selected from Cluster 1, which is characterized by low median income, followed by low CS rates and low enrollment. Between being an outlier to that cluster and defying our model from Chapter 4 by losing the CS enrollment, Marigold High School was selected for our study.

In 2013, 20 students were enrolled in the AP CS A course, approximately 1.4% of the student population. In 2014 and 2015, 13 and 20 students were enrolled in AP CS A, respectively. However, that number dropped to zero in 2016. Marigold has an increasing number of students enrolled in computing courses that do not count for fourth-year science credit. One student was enrolled in these courses in 2014, 15 students in 2015, and 137 students in 2016. These students were all enrolled in the Introduction to Digital Technology course.

Marigold High School is in the west-central portion of Georgia. The county Marigold is located in has a median income of around between $40,000 and $45,000. The school's average enrollment is between 1200 and 1400 students. The school has around 60% White/Caucasian students, 35% black students, and less than 10% each of Asian and Hispanic students. The free and reduced lunch rate at Marigold averages between 55% and 60%. The school has approximately 75 teachers and a pupil-to-teacher ratio around 1:16. Marigold is a Title 1 school. It is located in a region that is classified as fringe rural, meaning it is outside of an urban cluster or urbanized area.

Sapphire High School Sapphire High School did not have CS courses in our study's time frame. This school was selected from Cluster 4, which is characterized by a high median income followed by high enrollment and above-average CS rates. However, Sapphire does not have CS enrollment, which is against the prediction of the clusters and our model.

Sapphire does have some students enrolled in computing courses that do not count for fourth-year science credit. Between 2013 and 2016, less than five students were enrolled in one of these courses in a given year. These students were either enrolled in the Introduction to Digital Technology or Information Technology Essentials course. In years since, the school has offered courses in the Cybersecurity pathway.

Sapphire High School is in the Augusta metropolitan area. This area has a high median income with a median income between $70,000 and $75,000 for the county. The school's average enrollment is between 1600 and 1800 students. The school has around 60% White/Caucasian students, 20% black students, and less than 10% each of Asian and Hispanic students. The free and reduced lunch rate at Sapphire averages between 30% and

35%. The school has approximately 100 teachers and a pupil-to-teacher ratio around 1:18. The school is located in a region that is classified as a large suburb. Nearby is Fort Gordon, which is the Cyber center for the United States Military. Cobalt and Sapphire High Schools are located in the same county and school district.

Amethyst High School Amethyst High School did not have CS courses in our study's time frame. This school was selected from Cluster 4, which is characterized by a high median income followed by high enrollment and above-average CS rates. However, Amethyst has virtually no CS despite being in a high median income area with above-average school enrollment.

The only instance of a student enrolled in a CS course at Amethyst was in 2017, when reportedly one student took AP CS A through the Georgia Virtual School. In 2014, Amethyst offered an Introduction to Digital Technology course, which is a computing course that does not count for fourth-year science credit. 83 students were enrolled in the course that year. It has not been offered since.

Amethyst High School is in the Atlanta metropolitan area. The county Amethyst is located in has a median income between $70,000 and $75,000. The school's average enrollment is between 1800 and 2000 students. The school has around 60% Hispanic students, 35% black students, and less than 10% each of Asian and White/Caucasian students. The free and reduced lunch rate at Amethyst averages between 80% and 85%. The school has approximately 120 teachers and a pupil-to-teacher ratio around 1:15. Amethyst is a Title 1 school. The school is located in a region that is classified as a large suburb.

5.1.2 Interviews

The data collected throughout this study is qualitative, consisting of semi-structured interviews. The interviews were guided by an interview protocol based on the role of the interview participant. A copy of this interview protocol can be found in Appendix B. Each

Table 5.2: A summary of interview participants

School	Participant Job Title
Cobalt	Principal Counselor Cybersecurity Teacher
Marigold	Principal Business Teacher Engineering Teacher
Sapphire	Principal Registrar Cybersecurity Teacher
Amethyst	Assistant Principal Business Teacher / CTAE Department Head

interview took between 15 and 60 minutes.

I interviewed individuals in each school, including CS teacher(s) (if applicable), principals, assistant principals, guidance counselors, and engineering and business teachers. Recruitment was a snowball method after the selection of a school. The principal was first contacted for permission to conduct research at the school with a request made for an interview and other relevant contacts at the school, with suggestions for teachers or counselors. Approval was obtained by the research offices for each school district the four schools were located in.

11 participants were interviewed across 10 interviews. A summary of the interview participants can be found in Table 5.2. Due to scheduling constraints, the business and engineering teachers at Marigold high school were interviewed together.

5.2 Thematic Analysis

I use my data from the interviews, and the quantitative variables from Chapter 4 to provide context, to perform within-case and cross-case analyses on my case studies of schools and their barriers to and supports for offering computer science. To process and analyze my interview data, I used an inductive thematic approach as described by Braun and Clark [114]. A summary of this approach can be found in Figure 5.1. I became familiar with the

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Figure 5.1: Phases of thematic analysis, from Braun and Clark, 2006 [114]

data by personally and selectively transcribing the interviews, where non-relevant discussions were not transcribed. After transcription, I read through each transcript. As I read, I annotated the text to create initial codes. These codes were created by making notes of what is in the data, based on what the participant was discussing or inferring. I recorded all of these codes in a document, organized by school, and grouped similar notes together. I used these groupings of notes to search for themes in the data and create an initial thematic map for each school. I refined the initial map to ensure there were clear distinctions between themes and meaningful cohesion of data within each theme. To do this, I read all the coded quotes for a given theme to ensure they formed a coherent pattern. If they did not, I revised the theme or revised where those quotes belonged among the themes, if at all. Then I reviewed my thematic map to ensure it accurately represented the meanings found in the data. I defined each theme and created an accompanying narrative of each theme based on the extracted, coded data. I followed this protocol for each case individually and then revisited the codes and themes to do a cross-case analysis.

To analyze my findings across the cases, I used multiple methods to prevent premature and false conclusions [115]. One tactic I use to search for cross-case patterns is selecting themes and then look for similarities or differences in those themes across my cases [115]. I also selected pairs of cases and listed the similarities and differences between each pair [115]. This method encouraged me to look for the subtle similarities across cases.

The themes for all the schools fall into two categories: structure and people. This is similar to the duality posed in Giddens' structuration theory [116], which discusses the interaction between societal structures and individual expression (termed 'agency' in structuration theory). For this dissertation, structure refers to topics that have organization among parts to make something more complex. For example, classes require efforts by multiple groups and various policies and paperwork at multiple levels. The people category refers to the different populations that affect and are affected by the structures surrounding computer science opportunities at the school. Students are an obvious example of the People category, but teachers, parents, and the community can also fall into this category. Each of these categories and themes is defined and discussed below, by school, with quotes from the interviews to support each topic.

5.2.1 Cobalt High School

At Cobalt High School, I interviewed the principal, a counselor, and the cybersecurity teacher. Cobalt had students enrolled in AP CS A in 2013 and 2014, but no longer offers the course. The thematic map for Cobalt can be seen in Figure 5.2.

Structure

Within the structure category, the themes defined include *classes*, *pathways*, *registration*, *resources*, and *recruitment*. The *classes* theme refers to issues around starting a computing course at the school, altering existing courses to address computing, or conflicts between computing and other courses. The *pathways* theme refers to the topics of building a computing pathway at the school, the inflexibility that pathways may provide, and competition between computing and other pathways. The *registration* theme revolves around all matters of registering for a course at Cobalt High School, including the physical registration sheet. *Resources* encapsulates the financial incentives under certain grants, the materials needed for the actual teaching of the course in the classroom by the teacher, and the availability of

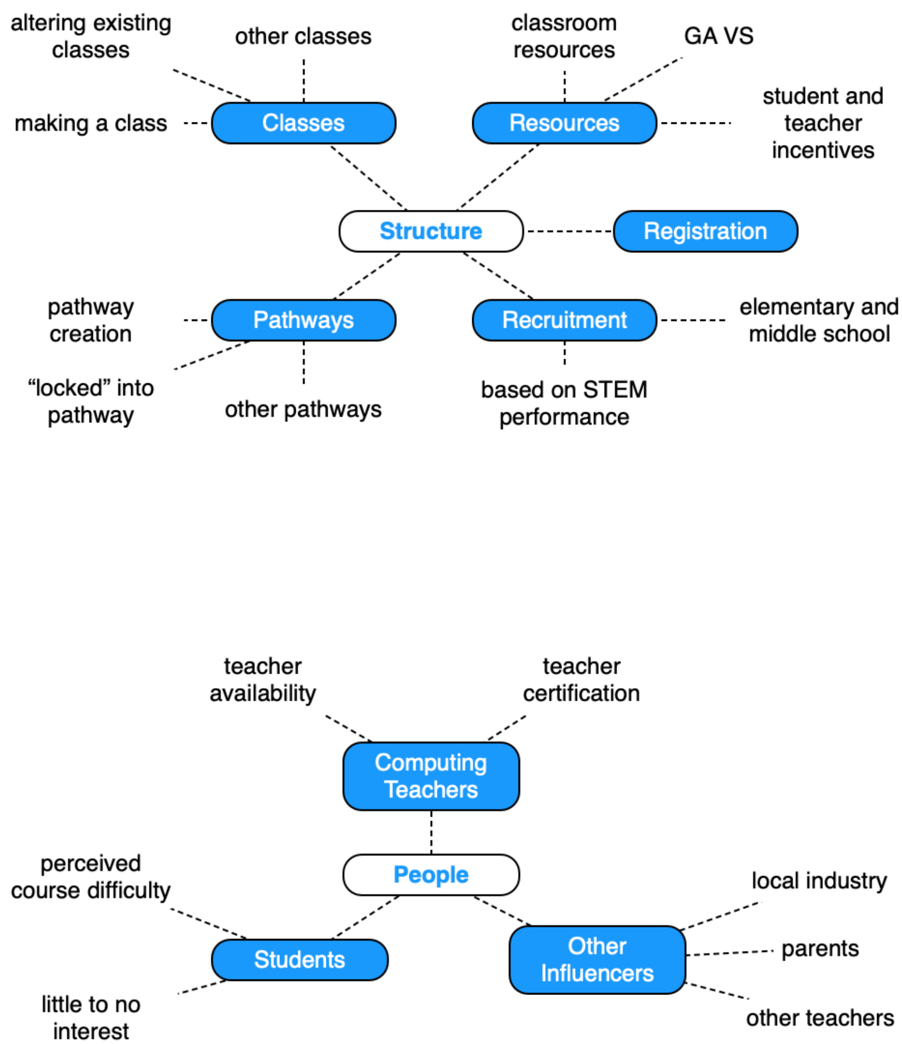


Figure 5.2: Thematic map for Cobalt High School

the Georgia Virtual School for students who cannot take a course at their high school. The *recruitment* theme refers to the recruitment of students into courses, either through schools or targeted efforts geared towards high achieving STEM students.

Classes All of my interview participants at Cobalt discussed what it took to "make," or offer, a class. The computing teacher said that "One of the issues has always been, like, there's a minimum number students we need in order to have a class 'make' and it seemed like it was either 21 or 23, and then we didn't have enough." Going up a level, the counselor simply stated that "If there's an interest, we sign them up for it. And then the numbers, I guess, are how it's determined whether or not a course makes." The principal echoed these sentiments, saying counselors have tried to get AP CS Principles but there hasn't been enough students interested and signed up to have a class make the master schedule. Overall, even if the teacher, counselor, and principal all wanted to have a CS course, it comes down to having enough students signed up for the course.

The teacher shared that they've adjusted the Introduction to Digital Technology course, the first course in the Cybersecurity pathway, to better prepare the students for their future courses. She said, "we do a lot of coding, probably more really than we're supposed to, just because I'm really trying to get them into that mindset, because that mindset is really helpful in cybersecurity when they're creating batch files or they are just, just having the determination to get into those and try to find vulnerabilities." This topic begins to address that computing can be integrated into other courses, or used to make pre-requisite computing courses more computer science oriented.

Courses other than computing were discussed with the principal at Cobalt, who specifically referred to other AP courses they offer as "established". She said that they "have so many established AP classes with established teachers I think some kids are just afraid to go out on that limb of 'Who's teaching it?' and 'How hard is it going to be?'" The principal also mentioned the school has a "very well established AP program" which provides obstacles to offering AP Computer Science by way of competing AP courses, such as AP Physics and AP Chemistry. This indicates that the school is cautious to grow their AP program with a CS course because they do not want to risk losing more traditional courses.

Pathways The principal said that it takes student interest and a qualified teacher to start a pathway, and from there the momentum would sustain it. The principal summarized this by saying "If we could get enough kids to take a class and we had the right teacher in place, I think it's a program we could build here easily with all the other initiatives that we have, it's just getting the first cohort group going." This indicates the activation energy to get a pathway started is a major barrier at Cobalt.

The computing teacher discussed a desire to work outside of the pathway structures because of the commitment it poses to the students. In Georgia high schools, Career, Technical, and Agricultural Education (CTAE) is handled with career clusters and pathways, which consist of three courses in a progression over a three year period. The computing teacher wished there was not a pathway system, because "they never want to get exposed to it because they're like 'Oh I don't want to commit to 3 years' and they go in knowing CTAE, you need 3 years." This idea, of eliminating pathways as a structure for courses, would provide a solution to the barrier created by the activation energy of starting a new pathway, because the school would not need to commit to a three year program of courses.

There is also the issue of sacrificing other pathways when new pathways are established. The principal walked me through the chain of events:

> Let's say we got 20 kids that want to take AP Computer Science Principles, well that takes away one class of Cybersecurity if she teaches it. And if she doesn't teach it, then who does? And if you don't have an entire teacher for it, which is six segments, times 25, it's hard to get something started a segment at a time. Because like I said, if she was the one to teach it, then we lose a segment of Cybersecurity, well, Cybersecurity is thriving so we have to be

> careful about making it difficult for kids to get in, because if they can't get in then they'll start choosing other things and then you'll lose that pathway.

"Losing" a pathway refers to a school's decision to stop offering a pathway ending because of unsustainable, low enrollment. Since pathways consist of three courses, losing a pathway implies losing three courses on the schedule. Because of the way pathways are incentivized with the state, schools generally want whole pathways. A school will end one pathway if enrollments are declining, and create or support another, different pathway. Adding a computing pathway is not as simple as finding students and a teacher, but also requires consideration of the consequences of its creation.

Registration Even though there are nine CS courses that count for the fourth science requirement, it is not listed on the registration form as such. The counselor walked through the form with me, saying:

> When we're looking at a registration sheet, and we're talking fourth sciences, the fourth science, so, [computer science] is not even listed. So these are our science courses, so we go over the basic requirements, the three that you have to have in order to graduation, and the fourth science, it can be any of these, but you see there's not a computer science listed.

This provides an interesting contrast to the computing teacher who said, "I would think in our population of students it would be very critical [to include it on registration forms] because their parents, a lot of times, are making those decisions. With student input, but a lot of times, ultimately, those parents are making those final decisions." The counselor echoed that parents sometimes come to her and say what their student wants to do, but also that having a registration form in from of the student allows them to pick courses they may not know they want to take. The counselor said that "A lot of the time we're going over course selections, we're going over that with them, and they see that as an option, and they're like 'Oh okay yeah that seems interesting, I'd like to try that.'" Especially in this case, where students or parents are picking from a list of courses on a sheet, not having a computing course listed, especially as an option to fill graduation requirements, can provide a biased sense of student interest in computing.

Resources The computing teacher at Cobalt mentioned the need to find resources that not only work for the teacher, but also the student. She also discussed the change in the availability of resources, saying that "initially when we first started we didn't have anywhere near enough resources, and then after a while we had so many resources that it was like 'Where do I even begin?' And so there's been a weeding out process. But I would never complain about having too many resources ever. You know that's a great problem to have." Although availability of learning materials can be a barrier when starting with a course, the teacher recognizes that over time this barrier is diminished as the repository grows.

The principal discussed a grant from the National Math and Science Initiative (NMSI) that provides training and incentives to students and teachers in AP courses. During the school year, "NMSI brings in their own trainers so many Saturdays a year and the students go to these sessions and the focus of those sessions is teaching them about the test so they can do well on the AP exam." After the exam, when scores are released, "the students are rewarded by getting a three or higher there's a certain dollar amount attached to it that they earn, and teachers can also earn money if a certain percentage of their students do well on the AP exams as well." This grant can apply to an AP CS course, but currently is not being used that way at Cobalt.

Georgia Virtual School is another resource that may affect in-person offerings of CS. The counselor shared that "If they know that's what they want to do then we say okay here's how you can do it since we don't offer it here in the building," referring to Virtual School opportunities. Taking a GA VS CS course both allows the student to still take a CS course, and counts those enrollment numbers with the school's course numbers.

Recruitment Current recruitment efforts include parent nights for rising 9th graders and exposure to computing in middle school. When the Cybersecurity pathway was started, the teacher said that “Initially we had to recruit but now we don’t because now, I think, as a school and as a county we do a much better job of preparing for 8th grade registration, and so we have a night where the parents are invited in and the students and we showcase each pathway...they have the opportunity to ask us directly questions and so forth and that seems to have really helped.” More specifically to computer science courses, the teacher also mentioned that “maybe it’s going to help now because I understand at the middle school level they’re teaching more computer science related courses but I think that would be helpful so the kids when they’re coming to high school that’s not the first time they’re hearing about it.” This indicates that although recruiting could be challenging at first, there are ways to lower this barrier.

All my interview participants also discussed recruiting based on STEM performance. The counselor said that “We do try to advise, as far as, ‘okay so I see you’re really good, strong, math student or science students, maybe something in that field would benefit you’ So we kinda talk about it. A lot of the time the kids come in here and they already have an idea.” The principal echoed this, saying that “we looked at certain students who, you know, we felt like would do well in a course like that, maybe had a background in cyber or had a background in some of the upper level math, you know we’ll focus on them and offer it as an elective.” The computing teacher had a similar sentiment, but also stated *why* students should be recruited based on STEM performance. The teacher told me that computer science is “not simplistic and it’s not for everybody. At one point in time I hope it is more for everybody based on them being exposed to it earlier but some kids just based on their own personal characteristics, if they’re not the kind of kid that’s gonna stay with something and if they’re not going to struggle a little bit and be okay with that, they’re going to quit. And that’s sad.” Selective recruitment of students is perceived as necessary by all interview participants, perhaps to ensure success of the course and ensuing pathway.

People

The people category includes the larger themes of *students*, *computing teachers*, and *other influencers*. The theme of *students* includes the topics of perceived difficulty of computing and little to no interest in computing courses. The *computing teacher* theme refers to both teacher availability and teacher certification. The last theme of *other influencers* include other teachers at the school, parents, and local industry.

Students Difficulty is clearly associated with computer science for the students at Cobalt. The teacher shared that when she promotes it in class, "you know the first question is, "Is that an easy AP?"..."Is it something I can just easily memorize and regurgitate information?'" The principal echoed this by saying that "In our students minds, it must mean it's going to be difficult, or that it's going to be something that they're not interested in or something they're not going to need, for whatever reason." Based on this, it might be inferred that one barrier is the student perceptions of CS being a difficult topic to learn, especially compared to other courses available.

All of my interviewed participants at Cobalt said that they perceived little student interest in CS. The principal said that "computer science is something we have tried to get our students to take for the last few years but we haven't been able to get enough kids to sign up for it for whatever reason." Similarly the computing teacher mentioned that "when it was offered as a fourth science, then that seemed to get more people interested but still not enough." The counselor offered a reasoning for the low interest, saying that "Unless somebody has put it in front of them or they've been exposed to it in some way or you know...a lot of them just don't know a lot about it." Perhaps because students do not know much about CS, other than it is difficult, students are not interested in CS at Cobalt, creating a barrier to starting a course.

Computing Teachers The principal of Cobalt discussed teacher availability in her interview. The school previously had a teacher "for one school year...and then at the end of that school year we didn't have enough kids signed up again to offer those courses" so the teacher left. The principal, referring to starting a computer science pathway, said that "the hardest part is just getting it going. If we could just get a couple of classes started without having to lose anything else. That would be very important. If we could find someone that would be willing to start part time and grow into a program of full time, you know that's kinda the perfect storm so to speak and that's hard to do." Given their background of having, and losing, a computer science teacher, it is reasonable that Cobalt is concerned with teacher availability.

This ties in with teacher certification as well. The computing teacher at Cobalt identified the position that being broadly certified puts them in, by saying "if I'm the only teacher that is certified to teach it and there are other courses that have more students enrolled in them, then that's where I get assigned." The principal brought up a similar issue when considering which teachers to recruit to get certified to teach computing, saying that "I think teacher certification has been something we've looked at too because I know we have a teacher here, our AP Physics teacher, who would not mind teaching it, but he doesn't want to lose the AP Physics and I think he's afraid that if he started doing the computer science and it grew, that he'd lose his physics classes." Even though Cobalt has a certified teacher, and could grow those numbers, what teachers end up teaching is dictated by registration numbers over teacher preferences.

Other Influencers The computing teacher mentioned that other teachers at the school can influence the students into being interested, or not, in computer science. The teacher explained, "I honestly have to say, a barrier has been that not other adults in the school understand what it is and so when they are the ones talking to students and recommending classes or just even help just discussing future plans them understanding that computer science is not just Word, Powerpoint, Excel, and then for them to understand that it's not simplistic and it's not for everybody... It's just getting other adults to understand what computer science is." Because not all the teachers in the school understands what computer science is, the students are not encouraged to pursue it or even have a complete understanding of it themselves.

Parents also play a role in the offering of CS at Cobalt. When talking with the counselor, she said she thinks back "to this one particular family that, Mom is constantly calling...Well he's about to graduate, but as long as I've been here she's been calling, "When are y'all going to get these classes?" Or "What are y'all going to get this?"...it always including computer science. It's something that he just knows that he wants to do. Hopefully the interest grows." There are parents that are avid about getting computer science at Cobalt, but perhaps one parent calling one counselor is not enough to change the whole system at the school.

Cobalt High School is located near Fort Gordon, the cybersecurity center for the U.S. military. As such, the principal pointed out "That's why cyber is so strong here because we can find people to teach those courses. That's not a problem at all." Because there is a local industry in cybersecurity, cybersecurity is taught. However, there is not a similar local industry in computer science, perhaps partially explaining the absence of it at the school.

Discussion

In terms of structure, the barriers to CS perceived at Cobalt included the mechanics of offering the class or building the pathway, the resources it would take to offer the course, registration procedures, and recruitment of students into the course. The principal at Cobalt believed the process of adding CS to the schedule is just a balancing act. She believed that if they added a CS course, it would stay in perpetuity. This thought is supported by the results discussed in Chapter 4, but contrary to the past performance of CS at Cobalt. The cybersecurity teacher wished there were other ways to offer a CS course other than the pathways system. There are alternatives to pathways, as evidenced by Marigold and Sapphire High Schools, but pathways, over single elective courses, are encouraged because they can improve a school's College and Career Ready Performance Index (CCRPI) score. There was also concern from the principal that building out a full computing pathway would take away from existing, popular pathways. Although the school does have a grant to bring in more AP courses, with incentives for students and teachers, this is not being used to add an AP CS course to the schedule. The counselor pointed out that CS was not listed on the registration sheet under a 4th year science option. This can influence the perception of student interest, if the students do not even know CS is an option. The cybersecurity teacher wasn't sure where recruiting was happening, but believed students do not know what CS is. This could be the reason why the counselor and principal do not perceive much of an interest in CS.

People that influence the offering of CS at Cobalt include students and teachers, as well as other local influencers. Cobalt High School is located near Fort Gordon, a cyber center for the United States Military. Because of this influence, Cobalt has a Cybersecurity program consisting of that pathway, and a teacher who solely teaches cybersecurity classes. However, there is not as much of a push from local industry or parents to offer CS, as oppose to computing, classes. There's also little perceived interest from the students, who aren't motivated by the fourth science option and are concerned with the difficulty of an AP Computer Science course. The school also doesn't currently have a teacher that could teach CS, without sacrificing other classes such as Cybersecurity or AP Physics. The school previously had a teacher, but that teacher left when student enrollment wasn't enough to offer the class again.

5.2.2 Marigold High School

At Marigold High School, I interviewed the principal, the business teacher, and the engineering teacher. Marigold had students enrolled in AP CS A in 2013 through 2015, but

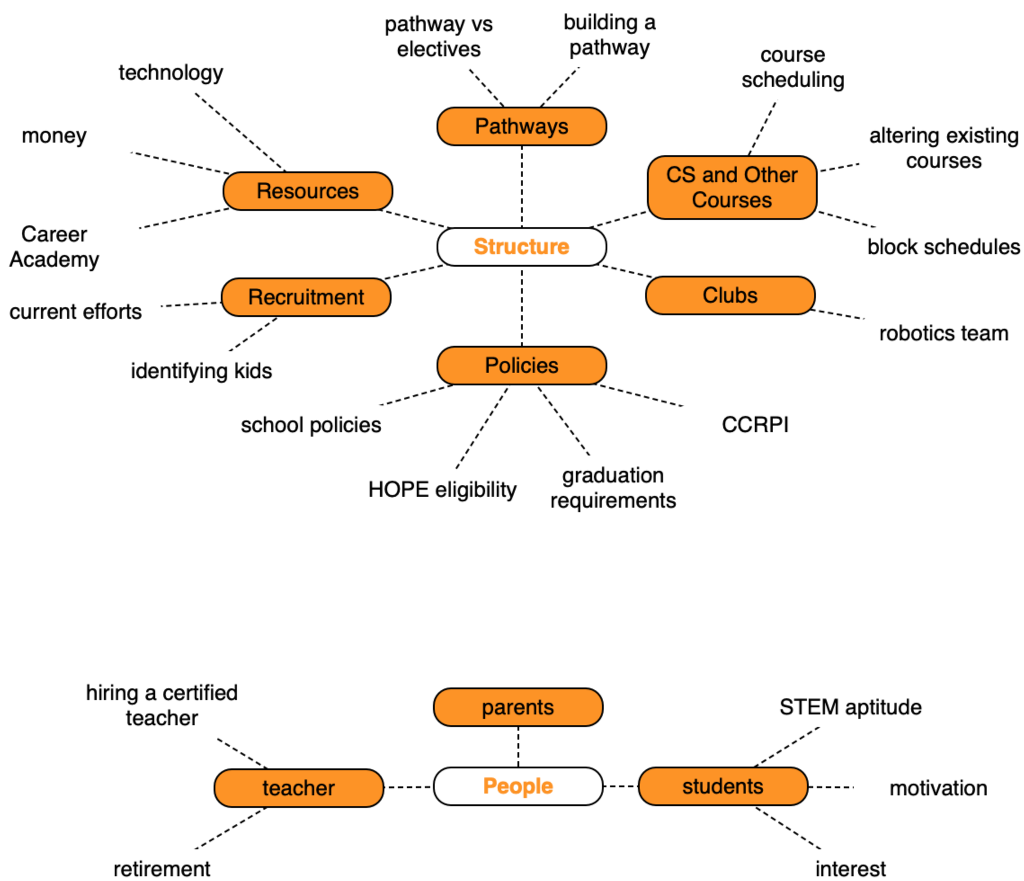


Figure 5.3: Thematic map for Marigold High School

no longer offers the course. Marigold's principal tried to hire a replacement, but the new teacher did not want to get certified in CS so close to retirement and chose to teach in the "Business and Technology" pathway instead. The thematic map for Marigold can be seen in Figure 5.3.

Structure

The structure category at Marigold includes *CS and other courses*, *pathways*, *resources*, *recruitment*, *policies*, and *clubs*. The *CS and other courses* theme refers to course scheduling, altering existing courses to address computing, and block scheduling systems. The *pathways* theme includes the topics of building a computing pathway at the school and the tradeoffs between pathways and electives. The *resources* theme refers to funding, technological resources such as machines and robots, and the Career Academy that serves the county. *Recruiting* students into a CS course at Marigold would likely involve middle school recruitment and identifying students based on STEM performance. There are a number of *policies* discussed that could affect CS offerings at a high school like Marigold, including school-based policies and graduation requirements, HOPE eligibility, and CCRPI. The *clubs* theme represents an option to learn computer science outside of the classroom, though the high school currently only has a robotics team and no computer programming clubs.

Classes The mechanics of offering a new course at a high school can present challenges in terms of the dynamics of adding it to the course schedule. The engineering teacher admitted that he didn't know "how teaching a course would fit into our course schedule. Because you know you want to move [the students] through the pathway to be pathway completers and that's probably above my pay grade." However, Marigold has previously offered a singular CS course, and under the same principal as they have now. The principal discussed how she fit the previous CS course in the schedule, which was simply that "it didn't hurt my numbers in my classes, it didn't push my numbers up to over so I said 'You know what, let's put it in' and it didn't make my other classes go up losing a segment. I didn't have to have 35 sitting in a class to get it. So I was able to. We did it for several years, you know." However, when creating the master schedule, the principal also has to consider graduation requirements and "think about the average kid, not the highest level kid, I got to think about the average kid sitting in an average class." There is a lot to consider if a CS course were to be added to Marigold's master schedule, though it has been done before at the school.

Block scheduling systems were also a discussion regarding scheduling a new course and students being able to take it. The principal detailed the benefits of a block schedule, as opposed to a seven period day, for scheduling courses:

> We're on a block so our kids have many opportunities. But schools that are not on block–a kid's got to earn 23 credits. There's not a lot of flexibility in there with you know 'I got to have 4th science. I've got to have 4 english. I got to have 4 math.' so that's 16 credits right there just in the core content and then they require two years of foreign language, then they require CTAE and they require fine arts, so they've got these requirements. If the computer science is, you know, could be substituted in, you know to count for math or to count for...then that would help schools because sometimes like I said if you're on a seven period day for four years, you can earn 28 credits and you've got to have 23 to graduate, it doesn't leave flexibility sometime for kids, especially if they're trying to get AP classes and other things so they have to stick to what they have to have and then have the five courses they can pick up extra.

The scheduling layout could be a barrier to offering CS, but that is less of a concern at Marigold since they have block scheduling.

Instead of offering a stand alone course, CS could be integrated into other courses. Even now, existing courses are being altered to include programming. Beyond code.org's Hour of Code, the principal shared that the business teacher has their students program with Sphero robots in her "Business and Technology" classes and "they have to program them to go through mazes. Like little robots...They have to design and program to make that thing do what they want it to do based on their design. So she is still incorporating because we have some of the standards embedded, you know and so they still get a piece of that programming." Students are being exposed to CS through other courses, which could help generate interest for a course.

Pathways The process of building a pathway could seem daunting for a school such as Marigold. The principal mentioned that "We're not certain we have that much interest where I can fill up...six courses that would lead that way. I think it's something you would have to transition over...And it just takes time to build it." Because the business teacher isn't certified in CS, she picked the Business and Technology pathway "so that's the pathway that we do instead of computer science." The principal mentioned this as well and said "we've got her in a pathway now where you got kids [that]are trying to do business and technology. And so that's what she's continuing to do because we got to know that we got enough interest to change the whole pathway." The time to build a pathway consisting of multiple courses could be an investment that acts as a barrier to schools considering offering CS.

However, if a pathway is too resource-intensive, the CS course could be offered as an elective, as it was last time CS was at Marigold. The principal discussed that, while the pathway can help "build interest for kids who [are] maybe not sure they even have an interest but would take it and go 'Uh, yeah, I kind of like this. This is kind of good,'" an elective option "just says here it is, those that are interested get it in." Electives depend on recruitment more than pathways, because "if you don't promote those courses, if you don't make kids aware of it, you don't get out and recruit kids for it, then it can fall by the wayside." Additionally, electives "depend on the individual person so like that happened when he left, it crumbled." On the other hand, a pathway can be more sustainable since, if the teacher leaves, "that's all that person does so you can post that as that job and get that person whereas [the previous CS teacher was] only teaching one class of it so I really need a math teacher and hey, you just by the chance have an interest in computer. If I can't find that, I'm still going to hire the math teacher and then I lose [computer science], which is still what happened." When a student completes a pathway, the principal said, it "certainly helps us, you know with CCRPI because they need to be a pathway completer." The tradeoffs between offering CS as an elective and offering it as part of a pathway can seem overwhelming to administrators, and provide a different set of barriers for each option.

Resources Funding for courses and programs were all mentioned during my interviews at Marigold. The principal often mentioned that funding was a barrier for offering CS, saying "we just have to figure out how to make it work and how do we fund it and how do we get that and identifying kids." If CS were to be offered as an elective at the school, "it's just gotta come out of my general budget. And so obviously there's you know I am...in my budget, I'm having to look at every department in our school." However, if offered through a pathway, "of course there's funding through Perkins and things like that which you know you can apply for grants, there's a lot of money out there," and so "It could be a barrier if you don't go that way. But if you go that way then it's a lot of access to get things." 'Perkins' refers to the Carl D. Perkins Career and Technical Education Act of 2006, which is federal funds for schools earmarked for the improvement of secondary and postsecondary career and technical education programs, such as CTAE. Finding money to hire a teacher is an issue, but not as big of an issue if the CS course were part of a CTAE pathway because of the funding model from the federal and state governments.

In terms of technological equipment, all the interview participants acknowledge their good fortune with access to machines and learning tools. The engineering teacher shares that "We partnered with Georgia Tech and CEISMC and...this is my fifth year here and basically minus the computers, everything in my room was provided through that." This includes two 3D printers, a CNC machine, CNC plasma cutter, and a laser engraver. The business teacher uses Spheros, a robot for learning programming, in her classroom. The Spheros were "inherited them from the lady that left before me...I thought, 'They're three thousand dollars, I need to be using them.' And my upper level kids need that challenge. When they get through with their work that was their enrichment. And they wanted to get through with their work so they could do that." The principal also mentioned the Spheros being used by the business teacher, and the 3D printer being used by the engineering teacher. The principal even mentions that "some of the equipment he has in there there's no, I mean, I could have never bought a 3D printer things like that and he has all these things in there that they design on computers. I would have never been able to purchase those things as a school." In the case of Marigold High School, technological resources are abundant.

Marigold also has access to a College and Career Academy in their area. The College and Career Academy offers an way to offer a course that all high schools in the region can send students to, and have those enrollment numbers count for their school. Offering a course at the Academy "would open up an opportunity for those schools. Because those are smaller schools too and it's difficult so then kids would have the opportunity...so we could reach potentially 8,9,10 high schools...if I have four or five kids, they have four or five kids, we could easily get a class." The principal also said "we're a county of poverty, high poverty rate in our county, so [the career academy] provides opportunity for our students for us to get them into college courses." However, there was some discrepancy about whether CS is currently offered at the Academy. The principal wanted it to be, but the business teacher said "they do offer computer science, so our kids do have a way to get computer science through college and career academy so it is a door, so they do have that option." According to the Academy's website, AP Computer Science is a course being offered in the 2019-2020 school year. Although the Academy is a great resource to reach many rural, low-income students, the offerings there may be miscommunicated among people who could recruit students to take courses there.

Recruitment Current recruiting efforts include 8th graders visiting existing classes at the high school. The engineering teacher shared that they "have middle school visits every year where the rising 8th graders come in and they visit, they tour each class and we talk about what we do in the class." However, since there are no CS classes as of yet, 8th grader visits would not work for recruitment to CS. Additionally, these visits seemingly do not include the College and Career Academy.

The principal discussed identifying students that have an aptitude for STEM subjects to recruit into a CS course. In particular, the principal mentioned that they review PSAT letters with recommended courses with the parents and students, which is "eye opening for the kid and the parent because... your test scores indicate you have a high level of aptitude for math and so but you're not taking the level of courses you indicated on this. So I think you have to start doing that kind of stuff to help kids realize their own potential." Even though Marigold does not currently have a CS course, the principal has an idea in mind of how they would recruit, such as through these PSAT letters.

Clubs The robotics team at Marigold competes in the FIRST Tech Challenge, which is a smaller-scale version of the FIRST Robotics Challenge. The engineering teacher, who is the advisor for the club, said that "we were in the top I think two or three in our area and so they did well this year. I had one boy. There's five girls now." This robotics club exposes students to some programming, starting out with "Blockly, which is drag and drop type stuff. But then you can get as deep as you want to with that," said the engineering teacher. The Robotics club introduces students to programming and could raise student interest in having a CS course.

Policies School-based policies could affect a CS course if they affect technology use. The business teacher uses Sphero robots in her classroom "for rigor for my upper level kids when they finish assignments. But I haven't used it this semester because they cut out cell phones in the classroom and that's how I was using them." She did mention that "we're working on getting some device I can use instead of cell phones. System doesn't buy iPads so because it's an Apple product but they're looking at maybe iPods. Do you not feel like that's going backwards though?" The school policy of no cell phones in a classroom has affected the altering of existing courses to include CS elements.

State-based graduation requirements can also affect whether a school has CS. The principal said having CS as a fourth science option can help "drive what schools do. If the state, they start out recommending things and when they say, if they say 'this will count towards graduation' then that certainly opens up the door to help us in many many ways." The principal also said that policies such as those can provide flexibility and motivation for schools and students alike. The principal added that the graduation requirement may not matter for some students, as some "get their sciences out of the way by the 10th or 11th grade year especially if they started in 8th but that doesn't stop them from continuing to take [those courses]."

CCRPI scores can also affect how a school views offering a CS course. The principal said that "CCRPI drives everything about schools. You know I'm constantly having to monitor that to ensure and I can demonstrate that we're actually meeting the needs of students and that higher level, those higher level courses, they count." The principal specified that CS is a course that can "apply to my CCRPI credits and when I have kids doing that, it helps me." Since CCRPI is of critical importance to schools in Georgia, since it is their primary accountability measure, having CS as an option to improve CCRPI scores can motivate schools in offering a CS course.

The principal also discussed the importance of scheduling around HOPE eligibility, which is a Georgia-based program explained in Chapter 2.2. The principal said that CS courses "count towards rigor courses and kids have to have so many rigor courses to get HOPE eligibility," and then continued to outline how the average student at Marigold can become HOPE eligible. Although HOPE is Georgia-specific, having alternative incentives other than graduation requirements or CCRPI scores can add to the motivation for a school considering adding a CS course.

People

The people category at Marigold includes the themes of *students*, *teachers*, and *parents*. The theme of *students* includes the topics of STEM aptitude as it relates to CS, students' motivations to take a course like CS, and interest in CS material. The *teacher* theme refers to the barriers imposed when trying to hire a certified teacher and retirement. The last theme in the people category is *parents* and the role they play in a school, particularly around clubs and courses.

Students When CS was offered previously at Marigold, the principal shared that "we put it out there during course registration to see ... and there was enough interest. I want to say there might have been five to seven kids." Even though the teacher has since retired and CS has not been offered in a few years, the principal believes "kids would be more prone to take it. Because I think there's interest in it. I think kids have a general interest in it." In general, there is student interest in CS at Marigold and thus is not currently acting as a barrier to offering the course.

When speaking of CS counting as a rigor course, the principal mentioned that students are motivated to take those courses if they want to apply to "upscale" schools, referring to Ivy League schools such as Harvard or Princeton. She said, "I think kids are motivated by those things, especially kids like that but I do think it would help the average Joe kid but I don't think it... I think the other kids are motivated by it. I just see an interest in computer science and computer programming." This moves beyond a general interest in CS into students being motivated to take a CS course. Again, it does not seem that student motivation is a large barrier at Marigold High School.

The principal discussed the "aptitude" of students at length. Beyond saying that students need a strong mathematical background to succeed at CS, the principal, speaking of Marigold students, said that "most of the kids that are going to be interested in that are not going to struggle. the kids that I had taking it, they were very successful at it. They had an aptitude for it, they did well in it. So I think they would be fine." Student success in CS is not a concern when considering whether or not to offer a CS course at this high school.

Computing Teachers Losing an existing CS teacher, such as through retirement, can prevent future CS offerings at schools. The previous CS teacher at Marigold was not hired specifically to be a CS teacher. However, the principal said that he had a degree in "computer programming" and "decided to be a teacher and then he became a math teacher and he ended up teaching, like all my AP, so he was teaching AP Computer Programming, AP Physics, AP Statistics and Calculus so he was really teaching all of my advanced level classes and then he retired." However, the principal said that "when you lose somebody like that they're very difficult to...I mean they're those silos. They're very difficult to find. Especially in an older generation where [computer science] was not as prevalent of a push of things." Furthermore, impending retirement can restrict options in selecting someone to teach the course. The business teacher I spoke to was initially meant to be certified, but the teacher told the principal, "'Honestly, I have three years left. I'd hate for you to invest in me.' I was just upfront with her. You know, that was just not fair to her and then I'm going to walk out again and she's going to have to build it again." Retirement can prevent future CS offerings, either by way of directly losing a teacher or preventing someone from desiring to teach it.

One potential barrier for having CS at a school is in hiring a certified CS teacher. The business teacher said the principal "wants to have computer science it's just the money to get the teacher and to find that qualified teacher." The business teacher said she was previously certified in computer science but "that was 27 years ago, so they want us to get re-certified because it has changed so much in 27 years." The principal explained that the business teacher did not get re-certified because "the state switched the qualifications and did not give them time. She couldn't get, get the qualifications by the time, within the period that they gave in order for us to have it for the next school year, 'cause I'm hiring her in June, she obviously can't do it by August that year, so that's kind of how we ended up not having it." A school cannot offer a CS course without first hiring a teacher qualified (which has a meaning that can change from state to state, and even school to school) to teach computer science, which can act as a barrier to offering CS. The principal also mentioned during our interviews that people who "do [computer science] and just took to it but you don't see those type of people a lot of times as teachers so that can be they're doing things at bigger levels, at higher levels." The principal perceived that many people who learned computer science work in industry, and thus cannot be hired as teachers.

Parents Although parents were not a common focus during my interviews at Marigold, the instance where it was mentioned is worth reporting. When talking to the engineering and business teachers, I asked how the robotics club got started. The engineering teacher informed me that "two of the parents worked for the county. And so I already kind of knew them and they're asking, 'we want them to take engineering we want them to be in robotics, we want to make sure they're together in those classes...'" Parent involvement, particularly parents who know the teacher, seemingly played a significant role in bringing robotics to Marigold High School.

Discussion

The structures that exist, or that would need to be built, at Marigold High School influence their decision to offer a CS course. In the past, five to seven kids counted as having enough interest to start a course. It was offered as an elective course, as opposed to within a pathway. Offering CS as an elective has benefits and downsides, including scheduling and hiring priorities. The principal also laid out the flexibility that block scheduling allows in students' schedules, so students could take the CS course and not worry about other requirements. As is, the business teacher works to integrate elements of CS into her class, namely through programming Sphero robots through mazes. In addition to the Sphero robots, Marigold also has a variety of other advanced technological equipment for the engineering classes, thanks to a grant with Georgia Tech's CEISMC. This equipment is also used for the Robotics Club, which is relatively successful and almost entirely female students. There's also access to a Career Academy, though there's some discrepancy about whether or not it currently offers CS. Whenever CS is offered at the school, Marigold would likely use PSAT letters as one method of recruiting students into the class. The class would also help Marigold with a number of school priorities, including CCRPI scores and HOPE eligibility for the students.

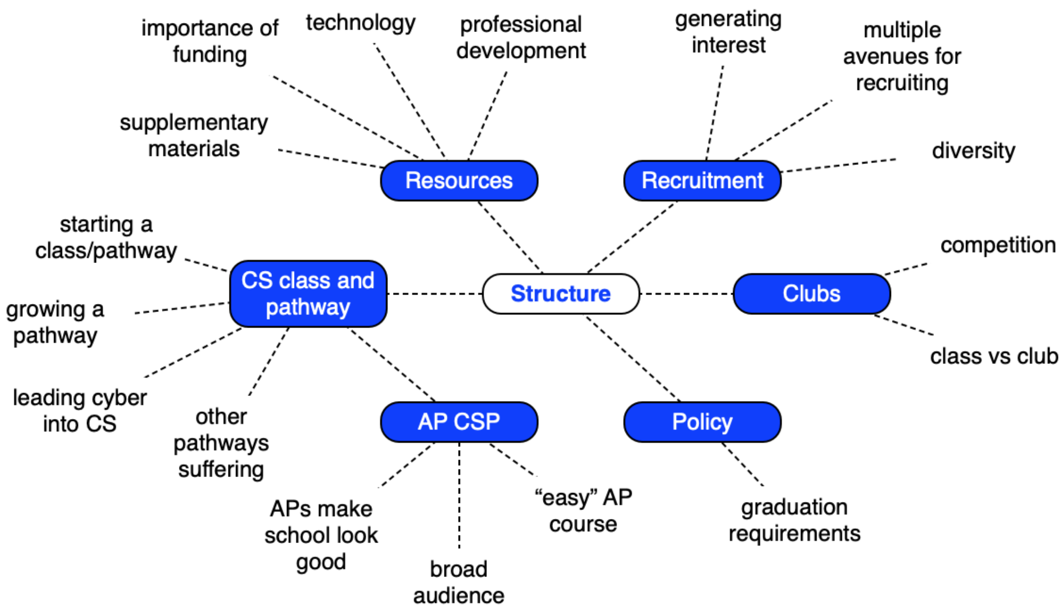
In terms of People, themes surrounding students, teachers, and parents were present in my interviews at Marigold. The principal mentioned the idea of aptitude multiple times when discussing students who take, or should be recruited to take, computer science courses. She seemed confident that, if CS were offered at Marigold again, students would succeed at it. However, there is no teacher at Marigold to teach CS anymore, which disappoints the principal. Between the business teacher nearing retirement and certification challenges, Marigold has been unable to hire a new CS teacher. Additionally, while parents at Marigold have been active in getting their students into Engineering and Robotics, I did not hear about parents advocating for CS.

5.2.3 Sapphire High School

At Sapphire High School, I interviewed the principal, the registrar, and the cybersecurity teacher, who was previously an English teacher at the school. Sapphire did not offer a CS course in our study's time frame, but will be offering AP CS Principles for the first time next year. The thematic map for Sapphire can be seen in Figure 5.4.

Structure

The structure category at Sapphire includes themes on the *CS class and pathway*, including *AP CS Principles*, as well as themes on *resources*, *recruitment*, *policy*, and *clubs*. The *CS class and pathway* theme includes topics surrounding starting a class or pathway, growing a pathway, leading cybersecurity pathway into a CS course, and other pathways suffering when CS is added to the schedule. The *AP CSP* theme includes questions on if the course is an easy AP course, that the course is geared for a broad audience, and discussions around AP courses improving the school's reputation. The *resources* theme refers to professional development opportunities, technology available for the classroom, the role funding plays



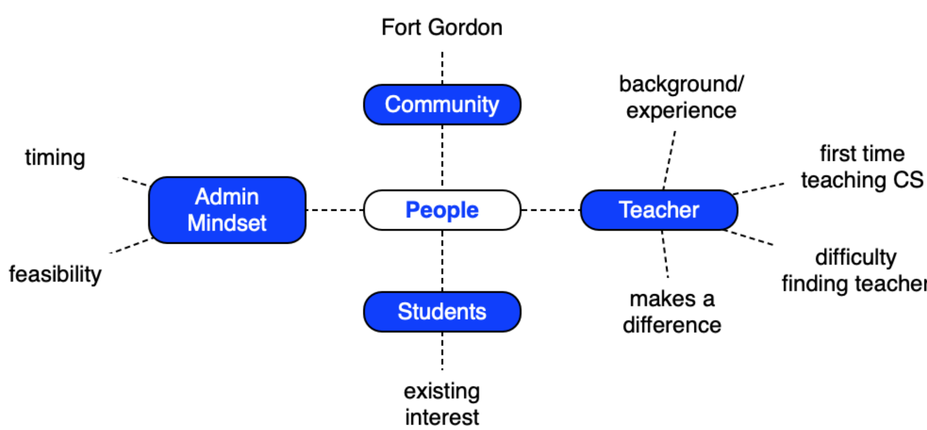


Figure 5.4: Thematic map for Sapphire High School

in offering a CS course, and the use of supplementary material for teaching computing. *Recruiting* students into a CS course at Sapphire involves generating interest, following multiple avenues for recruiting students, and keeping diversity in mind when recruiting. The *policy* theme refers to graduation requirements and the role it plays on offering a CS course. The *clubs* theme includes topics of cybersecurity competitions and the conflicts between competition material and course curriculum.

CS Class and Pathway There are various mechanisms involved in a CS course "making" the schedule at a school. The principal said that "we've been saying for the longest we want to create a computer science class, but just finding someone that's trained, getting the kids to sign up for it" has been barriers to the course. However, the registrar shared that "for the second year we tried to offer the computer science principles class and it made. We have 25 students. Some incoming 9th graders." When the Cybersecurity program was starting out, the registrar shared that "the very first year when we're offering just the first year courses, [the teacher] taught cyber and he taught English, so as we moved more into more and more cyber classes, then we moved him out of the English department." Next year, the teacher "will be totally straight cyber all the way across" his schedule. Over time, Sapphire has been able to, now, successfully add a AP CSP course to the schedule and transition a teacher completely from English to Cybersecurity and CS.

Once a course has made the schedule, the pathway that course fits into needs to be "grown." Looking at the master schedule on the wall, the registrar said that "this is the second year of the [Cybersecurity] program. So his class didn't fully make [the master schedule] as a cyber class all the way across so we filled it in with two [study hall courses]...but this coming year he is teaching straight cyber. It takes a while to grow a program." And, now that they have a AP CSP course on the schedule, the registrar said "we're hoping after the first year to continue to grow [AP CSP]," because, as she puts it, "now that we have it I really don't want to lose it." Growing the Cybersecurity and CS programs are a concern for Sapphire, but so far that concern hasn't prevented them from continuing their efforts.

Sapphire High School has been creative in handling how AP CSP will be offered, as they do not have a full pathway to support it according to the CTAE pathway guidelines. The registrar shared that they "go ahead and list it as a fourth class" in the Cybersecurity pathway, which normally consists of three courses. But, the registrar said, "we've got some of them taking [AP CSP] as ninth graders and tenth graders just because they want to and they're interested in it." Additionally, students "don't have to take it in sequential order, they can take it anytime they want to, any student can take it, they don't have to be enrolled in that program." Since AP CSP is being handled as part of the Cybersecurity pathway, it would seem that Cybersecurity leads into AP CS P. However, there's some debate about this at Sapphire. The registrar said that "it was just logical as we grow the cyber to offer the Principles class because we were told by everybody...it's not as intensive and cyber-ish as Computer Science [A]." However, the teacher had to brace his students before giving them some AP CSP material by saying "'just bear in mind that a lot of the stuff in there is going to be too simple for you because it's like starting over again.' Because they know binary so I said a lot of it you're going to be able to breeze right through." It is debatable whether AP CSP leads into the Cybersecurity pathway, or the other way around, but AP CSP is now part of the Cybersecurity pathway at Sapphire.

When a new pathway starts, that is generally a sign that another program, be it a pathway in CTAE or other electives, is downsizing. The principal shared that "what's killing me though is my Engineering program. Because a lot of kids instead of taking that Engineering are taking that Cyber and that Computer Science." Put a little more directly, the principal also shared that offering CS "is going to end another career pathway somewhere. Some of my kids right now, Chorus has taken a big hit. A lot of my kids have signed up for different pathways so some of my fine arts classes have taken a hit because of the different options put on the table. But it's...still a good thing." The fear of losing another pathway, or diminishing successful pathways, could feasibly prevent schools from considering a new pathway in CS.

AP CSP Within the theme of starting a new course and pathway is the theme of AP Computer Science Principles.

Sapphire emphasized to their students during registration that AP CSP was for everyone. When AP CSP was first explained to the administrators at Sapphire, the registrar said that a neighboring school "helped explain it to us, you know it's like 'Look, it's for anybody. It's not just the true geeks who can get in there, it's for anybody.' So we're like okay that would be great." Then, when talking to parents and students during registration, they "talked about it not just being computer science A, the more advanced one, computer science principles general, you know, and that it was geared towards 9th through 12th so we informed [them] about it."

This advertisement of AP CSP being for everyone was understood by students as it being an 'easy' AP course. The registrar phrased it as a "regular AP class," which factored in to the decision to enroll for 9th graders, she said. The teacher mused that some of the students enrolled are "looking at it as an easy credit in their senior year and maybe it is." Even the teacher has the impression that the course "is like computer science for dummies...because it doesn't really feel like they can do anything and they kinda know something." Whether or not this is a correct or appropriate characterization of the course, the AP moniker did seem to help get students registered for the course that otherwise may not be intested in a CS course.

The AP distinction also helps the school's reputation. The teacher said that "obviously the school, you know, from our viewpoint wants to offer more APs, you know, that seems to be the big push is we want to offer more things that are of value." He added that offering these courses are "for parents to look and say 'oh this is a quality school because look at all the AP program they have and they can get all this college credit' and you know that looks good if that's what you want." Offering another AP course helps the school and could have played a role in motivating them to offer AP CS P.

Recruitment The first step to recruiting students is arguably generating interest in CS among the students. The registrar and principal both repeatedly used the terms ”generating an interest” when referring to exposing students to CS and cybersecurity. The principal shared that “biggest thing is just getting the kids...generating the interest. I think our Cyber class has really generated the interest.” Similarly, the registrar mentioned that when school announcements are made that contain positive results of the cybersecurity teams, she thinks “the interest has generated to increase the enrollment not only in the Cybersecurity program but also you know it’s like ‘Yeah, let’s take that class.’” The Cybersecurity pathway, and associated competitions, has helped to generate interest in cybersecurity and CS at Sapphire High School.

Beyond generating interest, there were multiple methods of recruiting students that the staff at Sapphire High School employed to enroll students in their new AP CSP course. The registrar shared that there was word of mouth recruitment “letting everybody know that it is an option,” “counselors visit[ed] the classrooms and talk to the whole classrooms, tell them about the new classrooms and programs that we are starting,” “the teacher himself talk it up among his students, which they spread the word to their friends,” “we listed it on the registration form,” “a ninth grade parent night in which the rising ninth graders from the middle school come over, we talked about it being offered,” and “through PSAT the College Board gives us an AP potential letter in which they figure the classes that the student would be most successful in based upon their performance on the PSAT and AP Computer Science Principles is listed.” The teacher added to that list, saying he gave students a handout “and I said this is what we’re going to do” and that “when they come for the 9th grade orientation night, I always bring a couple of kids from the program with me and I send them out” to recruit students. However, the teacher also expanded on this, saying that he instructs those “kids from the program” specifically who to recruit, telling them that “‘If anybody’s over there wearing an Avengers t-shirt or you know Star Wars anything, bring them over, they belong to us.' I say 'See the kid that's looking at his shoes? Bring him over here.' Right, so, you know, I do some profiling." This practice of profiling can encourage stereotypes and bias recruiting, furthering inequities in CS that are well known [74, 117].

However, the same computing teacher also did targeted recruitment to bring in a more diverse student population to his courses. Passionate about not making his classrooms "just the domain of white males," he shared how he tried to increase female enrollment in his courses:

> Every year the middle schools come and they do to a tour for us. So starting with that first year I took two or three of my best girls that were in the class and I had them be the face of the program when the people came through. And I looked at them and I said your goal, because I knew the gamer boys were going to sign up no matter what, so I said, I looked and them and I said 'I want you to recruit more people like you. So when you're in there talking, I told them, tell them things that excites you about the program, that you like about it, everything else, that's your pitch. And I said, I want you to pitch it hard to any of the girls in there...

To this end, he shared that his attempts to increase diversity in his classroom have worked so far. He said that he's "got girls in the program and I've got a lot more you know students of color in the program...if you go back to the beginning here, I had 90 students and I think I had 4 girls." Through these recruitment efforts, the teacher at Sapphire is trying to lower the barrier for entry for students into CS courses, across a range of demographics.

Clubs Sapphire High School is proud of their participation in cybersecurity competitions. Their participation in an all-girls competition had, according to the teacher, "all the right words in it: it was free, there's a cash prize, and there was a cash prize for 1st, 2nd, 3rd in each state, so there's an investment there." The teacher also mentioned two other competitions they participated in, both were "the price is right: free." Because these competitions are free, the teacher feels they can participate. And as discussed above, because of the students' success at these competitions, more interest is being generated in the school.

The teacher also mentioned the tradeoffs between the cybersecurity competitions and the Cybersecurity course. For some competitions the teacher has all his students in class participate, but for most competitions he's made them "exclusive to kids in my class because I want to build my program and so that's the way to get them in. You want to play? You got to be a part of my class." This is one of his recruiting tools, mentioned above. However, in the competitions "sometimes the the things they want you to do are beyond the scope of what you've taught in class," such as doing more exploitation than defensive cybersecurity. The teacher also recognizes that "the primary measurement of my success or failure as a program has nothing to do with any of the things I might be getting guts and glory." Although Cybersecurity is not one of the CS courses defined in Section 1.4, this tension between a computing course and a computing club or competition could exist, and provide barriers for starting clubs that can serve as significant recruitment tools for the class.

Policy Although certain CS courses can count as a fourth science graduation requirement, the registrar said that wasn't a big selling point for the course. She said that the students taking a CS course "are not the ones that are saying 'Oh I have my fourth science, I'm not taking anything else.'" Computer Science counting for something for graduation, outside of elective credit, may not be enough to motivate students to take it at Sapphire High School.

Resources Sapphire's computing teacher has acquired interactive computing tools to help engage his students. The teacher has ten Raspberry Pi kits that we got from "a simple drawing out of a hat and I said 'okay' so you know I kinda get plugged into [relevant organizations] because basically they go and do all the begging to the federal government for the money and then they disperse it so it saves [time].” He also has Ozobots that he used as a test for his students, where he “gave them a maze to go through and gave them a couple other things to do and I’m like, make it do this.” Not having these tools could be a barrier to recruiting and retaining students to CS courses.

There was a discordance in my interviews over whether funding played a role in Sapphire’s adoption of CS. The registrar and principal both said that a grant from the National Math and Science Initiative (NMSI) did not play a large role in their decision to offer AP CSP. Despite this, they acknowledged the grant did help, as the registrar said, “the NMSI grant influenced the kids to start looking at the different options that we have out there.” However, the principal later said that funding was the most important issue when considering starting a new course and pathway. When asked to rank the barriers to computing, the principal said:

> Funding. Interest is there, it’s just the funding piece. Funding. As long as there is funding and the kids that we’re getting, we’re going to continue to grow this pathway. It’s going to continue to grow. And the kids are going to start realizing that there are a a lot of opportunities out there with this particular pathway. So I don’t think it’s an issue with interest...our number one issue is going to be funding. Because even with computers they’re going to need a certain type of monitors, certain types of computers, a certain type of network to run those labs, so the interest is there, it just comes down to funding.

It is hard to say for sure what role funding played in offering the CS course at Sapphire, but it does need more investigation based on these contradictory responses.

The teacher at Sapphire has found and purchased supplementary materials for when he teaches the AP CSP course. The teacher said that “it’s not difficult to find stuff...so someone who wanted to do that I think that they could certainly find grant money and everything you don’t have to look too hard. ” He has been able to find textbooks and resources to help him teach AP CSP for the first time next year, which will help lower his barrier to entry in teaching the course.

The teacher also has opportunities to go to professional development sessions. He previously went to one run by code.org, and said that “most of [the other PD participants] had computer backgrounds but then I looked around...and I realized that I should have never waited the year because that was actually a wasted year because I could I could have done that, I can do that.” Put another way, he said that the professional development workshop “made me realize that, okay, I’m not the least smart person.” Admittedly, if he were to teach AP CS A, rather than AP CS P, he acknowledged that he “need[s] more training. I mean that is going to be that’s that end of my [training], you know, and someone’s going to have to pay for it because I would consider it but I know myself I’m not going to enjoy it.” However, for teaching CS Principles, he has had the training through PD workshops to feel confident in teaching the course.

People

The people category at Sapphire includes the themes of *students*, *teachers*, *community*, and *administrator mindset*. The theme of *students* refers to the existing interest in CS of students at the school. The *teacher* theme includes topics of background and experiences, first time teaching CS, difficulty in finding a teacher, and how a teacher can make a large difference in a program. The *community*, especially Fort Gordon, plays a role in CS offerings at Sapphire High School. The last theme is *administrator mindset*, which includes perspectives on timing and timelines of offering a CS course, and the feasibility of offering a course.

Community Fort Gordon, being the cyber center for the military, influences the course offerings at Sapphire. As the principal put it, “I think with the military coming in, with cyber coming in, with all these folks coming to this area, that’s what’s building this interest with computer science and with cyber.” The registrar echoed this sentiment by saying that they're "really trying to grow the program especially since...Fort Gordon is going to be the Cyber Headquarters of the world...the influx of not only military people but also civilians that support that area is just growing exponentially here." The registrar also added that "we were mandated, every school in the county will offer a Cybersecurity pathway in order to support the program, Fort Gordon, parents." The surrounding community, namely Fort Gordon, motivated Sapphire High School to offer cybersecurity and CS courses.

Teacher The computing teacher at Sapphire was previously an English teacher at the high school. The registrar shared, and the teacher confirmed, that "he's a retired military personnel who worked in cyber. Got his degree in English, came back was an English teacher, so when we talked about starting the program, he's like 'Look, that's my love, that's what I did for so many years, I would love to be a part of it.'" The registrar mentioned the benefits of this with growing the program because they "were very lucky to have him on staff to be able to grow it but took our time and knew it would be a couple years before we got to full implementation and that's where we are, there." Sapphire used an existing teacher at their school, trained them a little more, and transitioned them to computing over time.

Although the teacher worked in cybersecurity in the military, he has never taught or worked significantly with computer science. When he was first asked to teach a CS course, his "first inclination was I'm not qualified to teach," and because they were starting the Cybersecurity pathway at the time, he did not "want to try and do two new courses at the same time so I kind of waved off on it for a year and delayed that." However, now that he's preparing to teach a CS course, AP CS P, for the first time, he piloted some of the materials with his cybersecurity students "That way I could try to get a feel for it. I will tell you that the way it worked over the summer [in PD] and the way it worked over the classroom, completely different." Because this is his first time teaching AP CS P, he is striving to be prepared for the year. Not all new CS teachers have the test bed that he has, which could cause hesitation when a teacher is asked to teach a CS course.

While Sapphire High School was able to find someone already at the school to teach their new CS course, they did admit it is hard to find teachers in CS. The registrar admitted that "you can't find somebody. And then the problem also comes in, too, that they can make more money in the private sector than they can at school." In regards to having trouble finding a teacher, she also added that "you've got to know what is feasible to offer and what is not." The principal also brought this topic as one of their initial difficulties in offering a course, because they were "saying for the longest we want to create a computer science class, but just finding someone that's trained, getting the kids to sign up for it." Although Sapphire did find a teacher, they acknowledge it is hard to find one and that it is the first step to offering a CS course.

Everyone I spoke with at Sapphire High School discussed how big a difference the teacher can make to the program. The registrar said that "our teacher has been instrumental in the clubs and the organizations and competitions that he has competed in." The principal heaped praise, saying "my cyber teacher has done an amazing job, just building the program. We started with two classes, now there are three, then four...so it's just growing." Even the teacher recognized the importance, considering future parents choosing between schools in the county, saying "what's the difference between School X and School Y? Both of them have the program. Well this teacher competent and that one's not right?" The teacher went on to summarize the importance of a good teacher by saying that "you know they say that all they need are teachers, which basically on the one level is true, but when you encounter the problems in the classroom you realize you need much more than [that]. " Even when schools find a teacher, having a teacher that is "competent" and "instrumental" can make a program grow.

Student Any discussion of the students at Sapphire High School centered on the students' interest in CS. The principal brought this up the most, saying that offering a new CS course is “all about the kids’ interests,” and that “they’re definitely interest in it. It’s thriving. We just gotta keep going in the right direction with it.” He also tied the student interest to jobs, saying that they could recruit students because “those kids are interested in coding. They’re learning that these jobs out there are hiring them just like that.” The principal mentioned multiple times that students had an interest in CS at Sapphire and that is what helped the school start a CS course.

Administrator Mindset Although it is less tangible, the mindset of the administrative team at Sapphire High School has clearly played a role in the school offering a CS course. Between being mindful of timing, feasibility, and their ‘hope for the best’ attitude, offering CS was more than possible, but eventually inevitable.

The registrar at Sapphire High School was very mindful of timing throughout the process of offering a CS course. In our interview, she often emphasized the amount of time it took to get to a point where they could have a CS course on the schedule. She mentioned that they “It takes time to really grow it and develop it instead of rushing in and then not being successful and we wanted to do it the right way and we’re there.” She also spoke of the vision of offering CS, that “Seeing it long term, you know, because you know what you want to do next year but it’s like you have to look past next year and it’s like, okay, what’s the vision? What’s the end goal? Couple years down the road, where do we want to be?” The school having this understanding of the time it takes to eventually offer a course helped them prepare appropriately.

The registrar also considered what was feasible with offering a CS course. She said that the first year they put it on the registration form, “we kinda hoped it wouldn’t make [the master schedule], we only had like 12 or 13 [students] and we’re like, no, let’s wait until we have a full group and then we’ll go from there.” She also said that she think they were “very realistic in starting the program because we know that you grow small. It takes a couple years to get to where we are next year to where we have full implementation of it.

So we were patient enough." This perspective of what needs to work for a CS course to be offered was critical to offering CS at Sapphire, according to the registrar.

Discussion

Sapphire High School is the only case study school that has a CS course scheduled for the following school year. They have AP Computer Science Principles scheduled, which they advertised as being for everyone. Students understood this to mean that it would be a relatively 'easy' AP course. Individuals I spoke with at Sapphire focused more on courses than pathways, likely because they were just starting a CS course which will be added to the existing cybersecurity pathway. However, the principal did recognize that building a CS pathway would end another pathway or program, such as Engineering or Chorus. This is due to the fact that student enrollment is relatively constant, with not enough swings to accommodate new courses without old courses being put in jeopardy. If a student signs up for CS, and all their required courses as well, they are limited in what else they can sign up for. All of my participants noted the interest in cybersecurity and CS due to the cybersecurity competitions that students are relatively successful in. This has helped recruit students, and the teacher has also made efforts to recruit in a way to improve the diversity of the students in his classroom. The fourth science option was not motivating factor for students, though. The teacher has access to resources and professional development opportunities. However, the principal waivered on the importance of funding when considering previous barriers to offering the course. On one hand, a NMSI grant reportedly did not play a large role, but at other times the principal said that funding was the biggest issue when offering a new course.

Where most schools find hiring a teacher as the biggest barrier to offering CS, Sapphire had an English teacher with a cybersecurity background that wanted, and volunteered, to start the new program. The principal and registrar recognized the work the teacher has put in to both the classes and the competitions, crediting him with the growth of the program.

While it will be his first time teaching a CS course next year, he's confident, in part because of the PD he's attended and because he piloted some materials in his cybersecurity classes this year. The school is also located near Fort Gordon, the cyber center for the U.S. military. All of my participants were open in acknowledging the impact the community has had on the school's offerings. Additionally, the mindset of the administration, expressed with the registrar and principal, acknowledged that offering a course and pathway takes time, and patience was required to get to the point they are now.

5.2.4 Amethyst High School

At Amethyst High School, I interviewed an assistant principal who oversees the CTAE department and a business teacher who is the head of the CTAE department. Amethyst has never offered CS on campus. For the thematic map of Amethyst High School, please refer to Figure 5.5.

Structure

Within the structure category for Amethyst High School, the identified themes are: *alternative options to offering CS*, *other pathways*, *block scheduling*, *cost*, and *school priorities*. The theme of *CS learning opportunities* includes current CS concept integration into other courses. *Alternative Options* refers to opportunities to take CS through independent learning, Georgia Virtual School, or a Career Academy that is currently under construction. *School priorities* includes the Amethyst's need to raise graduation rates, improving learning for special education and English language learners, raising the school's CCRPI score, and increasing the rate of pathway completers. The *other pathways* theme refers to Engineering and Business pathways. The remaining themes (*block scheduling* and *costs*) are self-contained, with no additional topics within them beyond the theme itself.

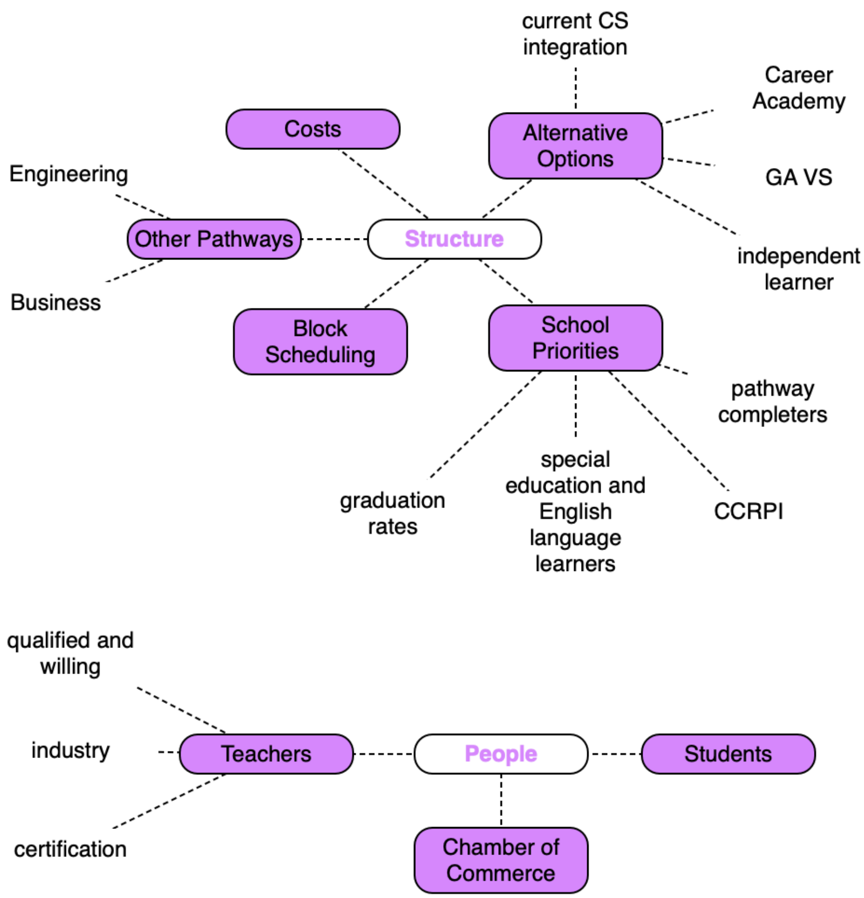


Figure 5.5: Thematic map for Amethyst High School

Costs The perceived costs associated with offering a CS course was mentioned as a barrier to offering one at Amethyst. The business teacher starting explaining the computer labs they already have for the business classes, including 5 labs with "28 to 30 Dell desktops. Which, computer science can be taught on that but I'm not sure, computer science might have a little bit more of equipment, an equipment issue...to put in a new lab, is probably going to cost you 30 to 40 thousand [dollars], especially when you're talking network and everything else." He also discussed the laptop carts they have on campus, but added that he did not know if "you could program as effectively on laptops." Even if the cost to add infrastructure to support CS is less, the belief that the cost is high, for the business teacher, seems prohibitively expensive.

CS Courses and Integration Current computing courses are in the Business and Technology pathway, and revolve solely around applications, such as Microsoft Word or Powerpoint. The business teacher said "I don't necessarily call it computer science because I've only been teaching applications." However, "every now and then we might sprinkle in some database, but it's a hard thing to teach. It's a hard thing for kids to understand."

CS is not seen or discussed as a possibility for a future course at Amethyst.

Alternative Options The most common alternative option to take CS when it is not offered at the school is to take it through Georgia Virtual. The assistant principal said that some students at Amethyst have taken it through Georgia Virtual, and told the story of one student that took it this way. The student "actually ended up being our valedictorian had a not great experience and he ended up going to Georgia Tech for that exact thing so he was really disappointed that that was his experience through Georgia Virtual." The business teacher added that "the success rate on Georgia Virtual for our kids here is not that great." Although taking CS through Georgia Virtual is an option, it seems past experiences with the program does not make it an appealing option at Amethyst.

Another option for learning CS at Amethyst is through independent study. The business teacher said that "if the teacher finds that student has a great aptitude for it, he's going to push him off and let him not necessarily have free reign but let him be an independent learner." But, between not having a lot of students they see like that and that they "don't have the resources for independent study," independent study is not often, if ever, utilized for CS.

When I visited Amethyst High School, there was a Career Academy under construction next door. The business teacher mentioned that, when it opens, it "is supposed to have a cybersecurity [program]." The Chamber of Commerce for the county influenced the offerings in the Career Academy, as discussed in the People category of themes. The Career Academy could lower the barrier for interested students to take some level of computing courses.

School Priorities Offering a CS course is not a top priority for Amethyst. What is a top priority is raising graduation reates, meeting needs of all students, raising CCRPI scores, and increasing the number of pathway completers.

The assistant principal frequently spoke of graduation requirements and rates. When creating a master schedule for the school, she said "the first thing we look at is 'What are the courses that the students have to have to graduate?' and so we want to make sure that our master schedule allows for enough sections of those classes and we have enough teachers obviously to fill that." She mentioned multiple times the need to raise graduation rates, with pressure from the administrative team and due to being a Title 1 school. She said that "pretty much just about everything we do has to...there has to be some type of relevance or some type of way we can say 'Hey this is why we're doing it because it's going to raise graduation rate eventually.'" Since CS does not inherently help with graduation rates, it is a lower priority for the school at the moment.

The second priority the assistant principal listed was meeting the needs of all students. She said that they aim to meet "the needs of special ed, English language learners, especially at a school like this with large populations." For reference, out of about 2000 students enrolled at Amethyst in the 2015-2016 school year, about 300 of them were classified as needing special education, around 15% of the school.

The assistant principal next listed considering the CCRPI score in the list of school priorities. She said that "they give you bonus points for the number of students that take honors and AP courses so there's always a push there from both the district and the state to get more kids to take those courses." She mentioned that it is a balancing act between core classes, in order to help kids graduate and on time, and offering honors and AP courses to raise the CCRPI score.

Lastly, the assistant principal noted that CCRPI also measures pathway completers. She said that "if a kid starts a pathway, we really try to push them to finish it, even if that's maybe not their mode...even if they're not interested in it. And of course we're not going to put a kid in a class that they're totally miserable in." The school would certainly consider if they have enough students that would complete a CS pathway before offering one at Amethyst.

Block Scheduling Scheduling a course, both from the student perspectives, can affect whether a school can offer a CS course. Amethyst has a block schedule, which, the business teacher said, means "I've got some kids that finish three pathways. Because we're on block [scheduling] and they can get 32 credits." Because block scheduling lets students take 8 courses in a year (as opposed to 7 courses with the seven period day scheduling) across four years of high school students can earn 32 credits. This means that there is space to take courses, so it becomes more feasible for students to multiple three-course pathways. Because Amethyst students have more than enough credits to fit in graduation requirements, they have enough room to add elective courses such as CS, if it were to be offered.

Other Pathways When considering whether to offer a CS course or pathway, other pathways at Amethyst are considered. The closest ones to computing are Engineering and Business.

The Engineering pathway is thriving at Amethyst High School. The assistant principal said that the school has "good success with that pathway, with 100% success rate," in terms of pathway completers and End of Pathway Assessments. When talking to the business teacher about what classes students might take if they're interested in computing, he said "some of those may end up in Engineering program, and will kind of gravitate to that." The Engineering program, by way of not wanting to diminish it, could be a barrier to offer CS at Amethyst.

The Business programs are very popular at Amethyst. The business teacher detailed that "we're going to need six to seven different business teachers. There's no other school in the county that has that many... We just hired one. So next year we'll have six." So when considering offering a computing course, such as Web Design, he discussed it as a function of allotments, which are allotted funds for teachers, saying "to get another Business allotment, I don't know that it will happen." Although having a CS course may not be a function of a Business allotment, it still stands to reason that the business program and it is popularity could prevent resources being dedicated to building a CS course or pathway.

People

The people category at Amethyst includes the themes of *students*, *teachers*, and *Chamber of Commerce* involvement. The themes of *students* and *Chamber of Commerce* are topics in and of themselves. The theme of *teacher* includes discussions around finding a qualified and willing teacher and the role industry plays in hiring individuals to teach CS.

Students There is perceived student interest in CS at Amethyst High School. The assistant principal said that if they had a teacher, Amethyst would offer CS "in a heart beat.

Because there was student interest at the time." She reiterated this again when she said it was a personnel issue, "student interest will come if they have a person." Interest may come with a teacher because then the CS course would be on the registration form. The business teacher said that if a course is "not part of the offering sheet for a freshman, the freshmen have no clue we had it originally." Student interest is not a concern when considering whether or not to offer a CS course at Amethyst.

Teachers The biggest barrier that my interview participants at Amethyst identified with offering a CS course is teachers. This theme is broken down into finding qualified and willing teachers and industry influence on potential teachers.

Previously, Amethyst had web design and networking classes. The business teacher used to teach "web design a couple years, I really didn't enjoy it. Because I wasn't good at it, you know. It just wasn't a strong suit." He also said that "between five and seven years ago" they had a networking class, where they hired a "teacher that we really liked to come into that position to start that...after the second year, she gets offered a position at a school five minutes from her house. So she ended up going there...once she was gone, that program was gone." Although Amethyst has had computing (but not CS) courses in the past, these courses did not last very long due to personnel issues. Even discussions of future CS revolve around personnel. When discussing whether Amethyst will offer CS in the future, the business teacher said that he doesn't "foresee us pulling that together," though they might "hire a teacher that has a web design background, and I think she would enjoy teaching that, but I'm betting if we do that, it's three years out." The assistant principal echoed these sentiments, saying:

> Honestly, it's not something that has been brought up. Not something that's really been on the edge of 'Hey, let's consider down the road in the next three to five years.' So I would say no, unless...I mean we never thought we would offer Astronomy here and then we hired someone who was passionate about

> astronomy and now we offer it. So I think if we have a situation like that, then that might change, but right now, I would say probably not.

There was a theme of finding teachers that were qualified and willing to teach CS. The assistant principal said this explicitly when said said, “I know that we have tried to offer AP Computer Science, and I know that we had a really hard time finding faculty that were A. qualified or B. willing to teach it.” The topic of willingness was also expressed during the business teacher’s discussion of teachers only teaching what they want and enjoy teaching. After teaching keyboarding, applications, and web design, he said “the admin knew me, they understood and kind of changed the track. And over the past six or seven [years], I’ve been able to say this is what I want, where I want to be.” As the business teacher shows with himself, teachers strive to only teach courses they want to teach. Since there isn’t currently anyone willing to teach CS, Amethyst would have to hire someone. However, as the business teacher put it, “Hiring for those positions is hard.” There is a barrier of not being able to hire, or not having in-house, a teacher who can teach CS at Amethyst.

Certification can be an issue when hiring teachers for CS. The business teacher said that people who could teach CS either go into industry “or they have issues with certification...in some fields, if it’s a field that’s hard to fill, maybe you can get a waiver and get around it.” Even if prospective teachers do not go into industry, certification can be a barrier to getting a CS teacher in a school.

There was also discussion of the impact that industry has on finding CS teachers. The business teacher discussed the similarities between CS and other fields, such as law and television, where “Anybody that is really good in that is probably going to be working in industry.” If someone from industry is hired to teach part time, the business teacher was saying “that’s basically a [contracted] employee that’s picking up a gig here and a gig here and a gig here and they want something stable and they want benefits. And so that doesn’t necessarily mean that it’s going to be a great fit, education wise, because they don’t have certification.” The fact that CS is an industry with open and high paying positions is a barrier to hiring teachers for CS.

Chamber of Commerce The Career Academy being built next to Amethyst was influenced by the county's Chamber of Commerce. The business teacher mentioned that when the school district "started putting together the programs for [the career academy] they met a lot with [the county] Chamber [of commerce] and [the] Chamber said this is, these are some programs that we need to have candidates come out of high school." Amethyst's local Chamber of Commerce said Cybersecurity was an industry that needed to be supported by the new Career Academy, and so Cybersecurity will be offered there.

Discussion

Amethyst did not offer a CS course in the time frame of this study and they do not plan on offering one in the next three to five years. Currently, elements of CS, such as databases, are occasionally taught in other classes. If students want to take a CS course, they could take it through Georgia Virtual School, though there has not been good experiences with it in the past. Cybersecurity will be available to the students through the Career Academy, which was under construction next to the school and is expected to open in two school years. Amethyst is primarily concerned with raising graduation rates, meeting the needs of special education and English language learners, and raising CCRPI scores, in part through increasing the number of pathway completers at the school. Other pathways, especially Business, are thriving at Amethyst and the business teacher did not think hiring another teacher in the department, even if to teach a different course, was feasible in the foreseeable future. Meanwhile, there were concerns raised by the business teacher about costs and certification associated with a CS course or pathway.

The biggest issue with offering CS identified by my participants at Amethyst is finding a qualified and willing teacher. The business teacher expressed concerns that most people who could teach CS go into industry, making teachers harder to find and hire. There are no

Table 5.3: A summary of themes at each school

Cobalt	**Marigold**	**Sapphire**	**Amethyst**
Classes	CS and Other Courses	CS Class and Pathway	Alternative Options
		AP CS Principles	
Pathways	Pathways		Other Pathways
Resources	Resources	Resources	Costs
Recruitment	Recruitment	Recruitment	
Registration	Policies	Policy	School Priorities
	Clubs	Clubs	
Computing Teacher	Teacher	Teacher	Teacher
Students	Students	Students	Students
Other Influencers	Parents	Community	Chamber of Commerce
		Administrator Mindset	

parents, according to the assistant principal, that are currently advocating for courses at the school, computer science included. Students have some level of perceived interest, enough that both interview participants were convinced that students would fill the course if one were offered at Amethyst.

5.2.5 Cross-Case Analysis

After performing within-case analyses for each of the four schools, the thematic maps were compared across the cases. This analysis provides insights on what barriers and supports are common amongst schools, and what might be unique at different locations. This section describes the cross-case analysis including what differentiates the schools at the extremes, and what is similar between cases. A summary of the themes can be found in Table 5.3

Sapphire is the only school that will offer a CS course in the following school year. This begs the question: what are they doing that other schools are not? When comparing the thematic map of Sapphire with the other schools, there are a few themes that are present only for Sapphire. Sapphire High School was the only case that discussed diversity in the

CS classroom. This was discussed directly with the teacher and the registrar mentioned it through discussions of AP CS Principles being for everyone. Sapphire was also the only school to mention and discuss AP CS Principles. This might be due to it is on their schedule for next year for the first time, so it is a natural topic of conversation. But, it is interesting that no other school mentioned this course; perhaps, other schools are unaware of the CS options available. Additionally, Sapphire was the only school that had clubs and competitions related to programming. These activities were cited as helping to grow student interest in cybersecurity to the point where they could offer a CS course as well. While other schools discussed having Robotics teams, it seems the prominence of the success of the cybersecurity competitions had a greater effect on student interest at Sapphire than the Robotics teams at the other schools.

At the other end of the spectrum from Sapphire is Amethyst High School, which has not recently offered any CS courses, nor do they foresee offering any in the next three to five years. What characterizes Amethyst compared to schools that want to offer or are offering CS? There were several themes absent in Amethyst's thematic map. There were no clear discussions on CS courses as a whole at Amethyst, merely an integration of CS and what students could do if they were already interested in the subject. This suggests there is not much consideration of what it would take to create a course or build a pathway in computing. Likewise, there was no discussion of what recruitment for a CS course, or even any course, looks like. At other schools, they discussed using PSAT letters or a myriad of events around registration time. Rather, at Amethyst, the focus was more on other pathways, teachers, and more pressing school priorities.

Amethyst and Marigold were similar thematically. They were the only schools to directly mention CCRPI and consider graduation rates when scheduling courses. They were also the two schools to mention local Career Academies as options for giving students access to CS without offering it at the school. Both schools also discussed block scheduling, and how easy it is for their students to take more classes than at schools not on block schedules. These similarities are striking given how dissimilar the Amethyst and Marigold attitudes towards CS were. Where Amethyst does not strive to have CS in the near future, Marigold's principal ardently wants CS back on her schedule. However, the similar themes between these two schools suggest these schools have bigger, more pressing issues than adding CS to a list of courses offered, which could be why they do not have CS courses at the moment.

There were similarities across most of the case study schools. The two schools in the vicinity of Fort Gordon, Sapphire and Cobalt, cited community and local industry involvement as a motivator for teaching cybersecurity courses. Similarly, Amethyst mentioned that the Chamber of Commerce in their county is deciding what is taught at the forthcoming Career Academy. Students, namely student interest, were mentioned at every school, though no school said or intimated that it was their deciding factor. Parental involvement and advocacy for CS played a similarly small role at the schools I visited. That is not to say that these variables cannot affect a school's decision to offer CS, but they did not play large roles across these four schools. Teachers, especially discussions of availability and hiring of teachers for a CS course, were mentioned in almost every interview and at every school. Primarily, the topic of teachers centered around the difficulty to find and hired a person who has a background in CS and has the proper certifications to teach CS. This includes discussions at three schools of the computing industry playing a role in the challenge to hire individuals who can teach CS. Previous CS teachers retiring or potential CS teachers nearing retirement also were discussed as barriers to sustainably offering CS in schools.

As for the structure category of themes, every school visited discussed altering existing classes to include CS concepts. These include integrating robotics, databases, or coding in courses that do not stipulate their inclusion in the course standards. All schools mentioned scheduling, with Sapphire's registrar showing me the master schedule and walking through the changes over the years. In the same vein, Amethyst and Marigold discussed block scheduling making it easier to add adding courses to the schedule. Additionally, all schools mentioned other pathways and courses, especially how the creation of a CS pathway would mean the demise of a different pathway or course, be it Engineering or Business. No school had a large number of students in, or positive experiences with, Georgia Virtual School, indicating this option may not be a viable option for all students interested in CS without a course at school. Every school expressed some level of concern about budgets, funding, or costs when it comes to offering a CS course, be it through the technology requirements for such a course or what it would take to offer the course as an elective rather than in a pathway, which would mean finding room in the school budget rather than getting funds from the state.

5.3 Offering CS as a Diffusion of an Innovation

If CS as a course, or set of courses, can be taken as an innovation, then we can start to explore the diffusion of CS, comparing the innovation attributes (*relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability*) across the cases. Sapphire, the school that will offer CS next year, has reached a point within each of the attributes that make CS able to be offered. This is in contrast to the other schools where those attributes are perceived differently and thus are not making CS compelling to offer. This section draws on language introduced in Chapter 3.5.

In terms of *relative advantage*, participants at Sapphire High School saw CS as different from the cybersecurity pathways, distinctly providing their students with job opportunities in the future. The principal at Sapphire mentioned the benefits of offering a CS course in terms of providing skills for his students to get jobs in the future. Meanwhile, Amethyst and Cobalt did not feel CS added more to their course offerings than business or healthcare courses. Marigold and Amethyst also acknowledged the expense of having CS, either through finding room in the budget if it is an elective course or from the cost of computer labs and other resources those courses would require.

Sapphire school officials saw CS as *compatible* with their current course offerings. This is shown by the decision to informally add it to their cybersecurity pathway to provide a fourth course for their cybersecurity students or an elective for interested students outside the pathway. The other three schools expressed CS being incompatible with their current courses. In some cases, this was because CS courses were not perceived as helping them attain goals (such as raising graduation rates at Amethyst) or would draw students away from other pathways or courses (such as AP Physics at Cobalt or Healthcare at Marigold). While the latter was still a concern for Sapphire, the principal expressed that adding CS was worth the risk of losing students elsewhere.

Complexity is a critical aspect of CS as an innovation based on these case studies. Sapphire's registrar expressed that the school's administration did not understand the audience for AP CS Principles until another local high school's administration assured them that the course was for a broad set of students. Before then, Sapphire's administration did not understand the dynamics associated with a CS course. Once they understood, and were assured, they started considering the course the following year. However, the Amethyst, Cobalt, and Marigold participants did not mention AP CS Principles. Beyond simply understanding the options for CS, there was also a difference in perceived complexity in offering a CS course among the schools. Sapphire figured out a way to offer the course such that it complimented their existing course offerings and provided a benefit to the school through an improved CCRPI score with the added AP course. The other schools were concerned about offering CS as a pathway, which would mean building infrastructure and interest for three courses, versus offering it as an elective, which would reduce funding from the state because it would not be a part of Perkins funding. Marigold's principal understood how to offer a CS course since AP CS A was previously offered at the school as an elective, but the reduced complexity of CS did not outweigh the other perceived attributes, such as low compatibility.

Trialability is also an attribute of CS that Sapphire's teacher and registrar were able to work with. Sapphire's cybersecurity teacher trialed AP CS P materials in his cybersecurity class in order to understand where he would need supplementary material and where students might struggle. The registrar at Sapphire also expressed aspects of trialability through putting AP CS P on the registration list the year before, to gauge interest while hoping the class did not make the final schedule. This way she, and the other administrators at Sapphire, could continue to recruit students and increase interest in the course over the following year before offering it. Cobalt also has trialed certain aspects of CS courses in their cybersecurity classes, adding in programming modules to the curriculum where it was not called for. However, Marigold and Amethyst have a harder time trailing CS material since they do not offer any courses in the CTAE IT pathway. Both high schools have integrated CS elements into other courses, but it is not trialing material per se.

Observability of CS influenced Sapphire to offer a CS course themselves. Part of the path to offering CS included conversing with officials at another local high school who was offering AP CS P and could advise Sapphire to do the same. Also, the teacher at Sapphire was able to attend a professional development session where he could observe other teachers planning on teaching AP CS P and gain confidence and knowledge from those interactions. Cobalt is in the same district as Sapphire and thus should have the same availability of interactions with local schools as Sapphire does. However, those conversations were not mentioned during my visit to Cobalt, though perhaps with Sapphire offering CS as well, the likelihood of observability will increase. Marigold does not have the same advantage as Sapphire and Cobalt, as it is more rural and nearby schools do not have CS courses. Amethyst does have schools in its district that have CS, and thus could observe them, but the other attributes of CS outweigh the benefits of the observability currently.

Throughout these five attributes, Sapphire High School stands above the rest as perceiving CS as an innovation that can be adopted. Within each of these are the elements of communication, time (an element directly acknowledged by Sapphire's registrar), and social system, all culminating with Sapphire offering AP CS Principles in the Fall of 2019, while the other schools will not.

5.4 Implications

There is a vast amount of information and nuances contained in these interviews and the ensuing analysis. In this section, I highlight takeaways that I identified from the within-case and cross-case analyses. These identified themes have implications for policy and can help frame future research in this area.

5.4.1 Teachers Are Key

Every school discussed teachers to some degree, including how hard it is to find and hire qualified teachers. Sapphire High School, the one school that is offering a CS course next year, had an English teacher with a background in cybersecurity volunteer to start the cybersecurity pathway. This pathway has now led the school to the creation of an AP CS Principles course that he will teach. Meanwhile, Marigold High School had a teacher for AP CS A, who also taught other AP STEM classes, but he retired. The principal hasn't had success hiring a teacher to replace him, which is a mix between CS not being a higher hiring priority than core subjects, Marigold being located in an impoverished and rural area, and a Business teacher that is also nearing retirement and so doesn't want to be certified, only to leave Marigold in the lurch for CS again in a few years. Amethyst doesn't plan on having CS in the near future and, similarly, Cobalt isn't opposed to having CS but doesn't have a plan for it. These schools still talk about how hard it is to find and hire teachers for CS, though, and Amethyst cites it as the biggest issue preventing them from having a CS course. Cobalt has teachers currently at the school who could be trained to teach CS, but that would mean taking courses away from them that they enjoy teaching or that the school needs to be taught more than a CS course. Additionally, three of the four schools expressed how a teacher can make-or-break a program. Where Marigold discussed this in terms of a CS course dissolving when the teacher retired, Amethyst discussed how a wrong teacher can "kill" a program where a right one can help it grow. This was echoed at Sapphire, where everyone admired the work the teacher had put into the cybersecurity pathway to make it flourish.

These issues are echoed in the current literature of the field. A Google Gallup Survey found that 22% of high school principals without CS classes cite a lack of qualified teachers as the main reason for not offering CS [17]. As a community, we have acknowledged for a while now that teachers make a large difference in offering AP CS A [118]. Meanwhile, we have also known that growing the number of teachers is difficult [119]. These issues were acknowledged in the interviews, which provided depth into the issue from the multiple perspectives of principals, counselors, and teachers.

5.4.2 Community Values Matter

When a school is located in a region that values computing, schools in the area will offer computing courses to prepare their students for that industry. The two schools with the strongest existing computing programs, Sapphire High School and Cobalt High School, are located near Fort Gordon, the cyber center for the United States Military. As such, the schools have full cybersecurity pathways, with teachers that are now only teaching cybersecurity courses. The registrar at Sapphire shared that all high schools in their district were mandated to teach cybersecurity because of the local interest in it. Now, Sapphire is offering an AP CS Principles course to go along with the cybersecurity pathway, in part because of the interest that pathway has raised around computing in the school.

In contrast, the other schools, Amethyst and Marigold, do not have any computing courses and are not located in an area with a strong computing influence or industry. Marigold is rural, and the main industries in the county are Retail, Manufacturing, and Healthcare. Amethyst is in the Atlanta Metropolitan area and thus closer to computing occupations and industry, but it is not a strong influence at this particular school, in this particular district. Furthermore, Amethyst and Marigold have thriving pathways in the industries that are around them. Amethyst has a large Business department and partners with various businesses in their region to provide integrated, real-life experiences for their students. Marigold has successful healthcare pathways, which is an area with 17 different possible pathways under the Georgia Department of Education.

5.4.3 What Is CS?

If schools do not know what Computer Science is, looks like, or entails, they are less likely to offer it. At Sapphire High School, the registrar walked me through the steps of how they came to offer AP CS Principles. Sapphire did not have plans to offer AP CSP until another high school in their district explained the course to them, saying "Look, it's for anybody. It's not just the true geeks who can get in there, it's for anybody." Then the school decided to try to offer it and add it to the pathway. However, even within Sapphire, there may be some confusion over what CS is.

The other schools did not talk about AP CS Principles, and if they mentioned a specific CS course at all, it was the AP CS A course. It seemed for a lot of my participants that AP was synonymous with CS and that they were unaware of the non-AP options for CS. There are 5 CS courses in Georgia that count for fourth science credit that are not AP or IB affiliated. If schools do not know that these are an option, and only know about the traditionally difficult AP, then their perception of, and desire to offer, CS is skewed.

There is also an issue of tangibility with CS courses. Every school had instances where CS concepts were being integrated into the classroom, be it robotics or databases or programming. However, the courses that are being offered are tied with jobs, which may be difficult to do for some CS courses. For example, Sapphire and Cobalt are offering cybersecurity courses because there are jobs in cybersecurity at Fort Gordon. But schools may not understand what jobs are helped by students taking AP CS A or CS Principles.

5.5 Limitations

As with any study, there are limitations to this work. I did not visit any schools that were currently offering a CS course. The closest situation was Sapphire, which will offer CS next year. I had planned on visiting a school with CS, based on the cluster analysis described in Section 5.1.1, but I was unable to form research partnerships with those schools. There is also a limitation in only one researcher performing the analysis. This limitation was minimized by drawing supporting quotations for every theme. However, it is reasonable to think that another researcher could have selected different quotes or different themes.

The biggest limitation is that this study is limited to Georgia public high schools. However, this was a necessity given the scope of feasibility and resources. It is difficult and time-intensive to investigate multiple states, all with their own state policies and education systems. Education being state- or district-centric makes comparing between states naturally difficult. However, there are elements identified in the thematic maps and cross-case analysis that are not Georgia-specific and could be found as barriers in other states. Furthermore, the implications of teachers, community, and understanding are not state-specific. These topics should be explored more in other states and compared to these findings.

5.6 Conclusion

In this chapter, I outline a case study of four public high schools in Georgia and their experiences with CS courses. I interviewed principals, counselors, and teachers and asked about prior CS offerings, if they want to offer CS, and what prevents them from offering CS. After thematically analyzing the interviews at each school, thematic maps were developed. A cross-case analysis was also conducted to consider the similarities between schools and unique instances of themes. The studies are also framed using diffusion of innovation, providing insight into what attributes support a school when deciding to offer a CS course.

A schools decision to offer a CS course is a balancing act between supports and barriers.

Structural elements, such as school priorities or scheduling courses, as well as personnel, such as teachers and community, can be weighed in the decision-making process. The choice is not as simple as one barrier or one support but is rather affected by multiple factors acting simultaneously. The main implications of this study are that teachers are of critical importance to CS adoption, community values influence schools, and the lack of adoption of CS may be due to lack of knowledge of CS and course options. However, these implications do not exist in a vacuum and thus should not be taken as the only factors involved in the decision-making process.

This study confirms aspects of the model discussed in Chapter 4. For school funding in Georgia, 10-60% of a school's budget is provided by local taxes. Given that most schools mentioned school funding and budgets, it makes sense that median income in a county, which can affect local taxes, was a factor in the binary regression model, which analyzed the factors that affect whether or not a school has CS. Another variable in that model was enrollment, which schools did not directly mention. However, participants did refer to student interest, and having more students enrolled at the school would increase the odds of having more students interested in CS. Of course, other factors can influence student interest, such as community values, parent jobs, and other methods of exposure. The biggest factor in that model, as well as other models explored, was the school having CS before predicting the school having CS now. However, this could not be confirmed with the cases because no schools visited currently have CS courses. Instead, two schools had previously offered CS and do not anymore. In both cases, it was because the teacher had left and a new one was not able to be hired. However, the attitudes of participants at all the schools do confirm this variable, given that the consensus was that starting a course, pathway, or program is the hardest part. After one year, most participants indicated the momentum would keep the course going, especially if it was part of a pathway.

5.7 Contributions

This study was designed to answer the question: What do school officials perceive as barriers to and supports for offering CS at their school? The thematic analysis of case studies of schools provides the answers to this question. The findings contribute to a theory of supports and barriers to offering CS in high schools. This theory was built from case studies of four public high schools in the state of Georgia, from interviews with principals, counselors, and teachers. The case studies were thematically analyzed and framed using diffusion of innovations which highlight what factors and attributes are supports or barriers for these schools.

CHAPTER 6
CONCLUSION: A THEORY OF SUPPORTS AND BARRIERS TO CS

There is a movement towards making computing education more available and more accessible than ever before. However, the diffusion of formal computing education opportunities has been slow. This dissertation combines my prior experience in computer science education to contribute a theory of supports and barriers to adopting computer science for public high schools in the state of Georgia.

In Chapter 4, I discussed the research question "What are the variables that characterize public high schools in Georgia that offer a CS course?" I outlined my method for identifying variables through landscape surveys and collecting data on those variables through the Georgia Department of Education, American Community Survey and other Census Bureau data sets, and the National Center for Education Statistics (NCES) Elementary and Secondary Information System (ELSi). I described visual, correlational, and regression analyses between various factors (e.g. median income, urbanicity, school enrollment) and enrollment in a CS course in 2016 in public high schools across Georgia. I found that median income can explain CS enrollment, but explains only a little amount of variance (5.2%). However, a binary logistic regression with median income, school enrollment, and a binary variable for if a school had CS in 2015 explains whether a school had CS in 2016 and explains 55.8% of the variances. These results indicate that offering the first CS course at a school is a critical point that creates momentum to continue to offer CS courses. The findings are also positive in that median income is a significant factor but, since it does not explain much of the variance in the model, it does not seem to be a necessity to offer a CS course.

In Chapter 5, I describe a case study approach to answer the question, "What are the systematic and structural barriers that are preventing selected schools in GA from adopting

CS?" I selected and visited four schools across the state that represented different subsets of median income, school size, and CS enrollment. I interviewed principals, counselors, and relevant teachers at each school to understand what they perceived as barriers to offering CS, and what could help a school overcome those barriers. I transcribed these interviews and used thematic analysis to develop mappings of the interviews to compare across schools. All barriers could be categorized as either structural or people-oriented. A consistent barrier was teachers, primarily hiring someone for the role. Community values also played a part, influencing schools to adopt curricula that could add or detract from CS courses. Additionally, there was a misunderstanding of what CS is or what jobs might be associated with it, which was not true for the school that is offering AP CS Principles in the Fall of 2019. Findings also indicate that using a frame of diffusion of innovation, wherein CS courses are treated as an innovation, can be useful for considering the tradeoffs in attributes in schools considering offering CS.

Together, these studies provide quantitative and qualitative factors that inform a theory of supports and barriers to schools offering CS courses. From the quantitative study, I identified prior CS enrollment, median income, and school enrollment as partially explaining CS offerings and enrollment in schools. However, there are more esoteric factors that cannot be explained by current data sets. From the qualitative study, I identified factors that could add to the explanatory power of the quantitative factors. These qualitative factors were divided in terms of either being structure-oriented or people-centric. This includes teachers, community values, and a misunderstanding of what CS entails in terms of courses and careers. These qualitative factors cannot be added to the quantitative model and so the total explained variance cannot be ascertained. However, I theorize these qualitative themes add to the quantitative factors to explain more of the variance of, and thus create a better model of explaining, CS offerings and enrollment in public high schools in Georgia.

This theory of supports and barriers to schools offering CS courses is not the be-all and end-all of research on access to computing at the school level. This theory stands to be tested in other states and across different time frames. Furthermore, not every public high school in Georgia was surveyed regarding their experiences offering a CS course. Rather, four schools were selected as case studies. This resulted in a theory of supports and barriers, rather than a list of the top or most-often reported barriers via a survey. However, the theory can be tested in other states which could result in revisions to our understanding of supports and barriers on a school level.

6.1 Limitations of Analysis and Findings

All research has its limitations. In this section, I denote threats to the external and internal validity of my studies. I also discuss the limitations of applying the findings.

For my quantitative work, it was necessary to do this study at the level of a single state due to the state-run nature of education in the United States. Because this work focused on the state of Georgia, it may not apply to other states or speak to the state of CS across the United States. My studies were limited to public schools to make an appropriate comparison between school contexts, and thus private schools, informal education, or integrated computer science experiences are not included. These issues can threaten the external validity of my work, or the ability to extend my findings beyond the scope of my study population [120, 121].

Another limitation is that two of my four case studies were built around schools within the same school district. This school district was located near Fort Gordon, a cybersecurity hub for the United States military. This creates a perceived monopsony in the market, where Fort Gordon employs a large number of parents and guardians of students enrolled at those two schools. In particular, due to its nature, Fort Gordon is employing a large number of individuals in the cybersecurity sector. This seemingly created community values around cybersecurity, encouraging schools to offer cybersecurity courses to support community values and fill future demands in those roles. Community values could be a large factor in school curricular decisions, but the claim is weakened by two cases having the same community and thus the same community values.

My qualitative studies, including the case studies and thematic analysis of data, rely on me and my actions. This means there may be instrument bias in my research. When visiting schools, there may be participant reactivity from the teachers and administrators behaving differently with me around than any other day. These threats to internal validity affect my ability to justify relationships among the variables I explore [121, 120]. Through conducting my research, I strove to minimize these limitations through conscious consideration of the components that threaten the validity of my work.

It also deserves to be mentioned that my studies included consideration of Advance Placement (AP) courses, especially AP Computer Science A. As discussed in Section 3.3, AP courses have equity implications within themselves such that the equity of CS enrollment across the state can be affected as well.

Even with more evidence of factors that influence schools and the choices to offer a CS class, there are factors that we, as researchers and policy influencers, can not change. Median income was not found to have a large role in explaining CS offerings and enrollment, but it still had statistical significance. However, this is a factor that can't be simply changed. Similarly, community values were explored during the case studies as influencing a school's curricula and course offerings. These are also not easily changed, nor would it be advisable to, as they are tied to local industry and a diversity of community values lead to a diversity of perspectives, interests, and careers.

6.2 Implications for Schools, States, and Higher Education

The findings from this work can have an impact on future decisions made by schools, states, and higher education. These implications are discussed below to advise these different audiences on how to interpret these findings. The goal of this section is to promote change in CS education through the operationalization of the results of these studies. These discussions are not to imply that the onus of CS education is on one of these groups individually. Rather, all of these stakeholders must collaborate and cooperate if CS is to be accessible for all students.

6.2.1 Schools: Teachers, Counselors, and Principals

There are different types of change-makers in K-12 schools. Principals are the leader of the school, guiding future directions and providing the final decision on school policy, scheduling, and budgeting. However, counselors and teachers are also decision-makers within schools that can make a difference. Counselors can talk to students and encourage (or dissuade) them from a pathway of courses. Teachers can inspire and excite their students about certain subjects and careers, beyond simply instilling knowledge in the area. All of these roles have effects on students, and sometimes those effects can be overt while others are subtle. If no one in these roles knows about, promotes, or encourages opportunities in CS, students are unlikely to understand or have access to CS. Based on my interviews with school officials, there are actions that principals, counselors, and teachers can take to lower the barriers to offering CS at their school and beyond.

Hiring qualified teachers for CS was one of the biggest barriers identified during my school visits. While it can be hard to make CS a hiring priority when it is not a core subject, it can also be challenging to convert a current teacher at a school from their subject to CS. In the school that will offer CS next year, an English teacher had a prior background with cybersecurity and would rather teach computing courses instead of English. However, at other schools without plans to offer CS, they were concerned about transferring a teacher from Business or AP Physics to CS because of the lack of aligned interest. If those teachers taught one CS course, it could grow to two, three, or more CS courses, drawing the teacher away from the courses they prefer and enjoy teaching. Careful consideration of the trade-offs is needed and the decision between hiring a new teacher or converting a teacher to CS will vary by school. There is also an option for part-time instructors, but that can bring different challenges to the table in terms of scheduling and sustainability.

The school in my study that will offer CS next year has a successful cybersecurity club. Everyone I talked to at that school cited the club as an avenue for building interest in cybersecurity and CS. If there is a teacher interested in computing, even if not necessarily teaching CS, advising a computing-related club can be a way to gauge and increase interest in CS. Clubs can be a way to bring in opportunities to engage in CS concepts and ideas without committing to a full course or pathway. Future Business Leaders of America (FBLA) and Technology Student Association (TSA) are organizations that already exist within many schools and have tracks for CS competitions, including coding and software development. Robotics clubs are also popular and provide opportunities to be exposed to a myriad of disciplines, including CS to program the robot.

As I visited different schools, I noticed how concerns that one school may have could be addressed by strategies that another school had taken. Increased discussions between neighboring schools about CS can help spread tips and tricks for offering CS. If school officials are interested in offering CS, I would advise them to talk with the closest school to them that has a CS pathway; ask them what it took to get it started, how long it might take, and if there are any lessons they have learned along the way that they can share. If school officials are at a school with a CS program, mentioning the program and the process at district or area meetings with other schools can plant the seed of offering a CS course at those schools, if that isn't there already.

6.2.2 States: Education Decision and Policymakers

Educational decision and policymakers at the state level directly impact the CS education landscape. The visualizations in Chapter 1.5 show the impact of the policy change that added more CS and computing classes to the state registry and created the CTAE IT pathways. In Georgia, the state legislature passed a bill in the Spring of 2019 (Senate Bill 108) that requires all middle and high schools in Georgia to offer CS by the 2024-2025 school year [122]. However, to offer a course is defined in the bill as providing an on-site course or a course through virtual means. While this law may increase the number of schools that technically offer CS, the loop-hole of allowing schools to provide the course through Georgia Virtual School may diminish the effect seen. To promote more students enrolled in CS, policymakers can work on additional initiatives to provide motivations for schools and students. The HOPE program is a Georgia-specific example of additional motivations. The HOPE program provides an alternative incentive for schools and students other than graduation requirements or CCRPI scores because it includes requirements for students to take a certain number of 'rigor' courses, which CS courses can count towards. These mandates and programs have the potential to increase access to CS for students, but the more supports that schools are provided, the more likely they are to offer an in-person CS course.

One of the findings from the case studies was that schools may have a misunderstanding of what CS is. This includes what CS courses are available, what is included in those courses, and what careers CS can lead to. This indicates that more work can be done to inform the schools, at multiple levels (principals, counselors, teachers), about the options of CS courses available to offer, beyond emails and newsletters. Although time or resource-intensive, one option could be to send representatives from the Department of Education directly to schools to talk about CS course options. This promotes more direct communication about CS opportunities and allows school officials to ask any questions about incentives, scheduling, and teacher certification.

Based on the qualitative findings from the case studies, there are implications for more data collection to explain more variance in regression models of CS enrollment and offerings. This data would likely be gathered by the Department of Education. This data could include professional developments (PD) attended by teachers including the subject area, cost, length, and organizer. The school in my study that will offer CS next year sent their teacher to a PD session for AP CS Principles a whole year before he taught the course. Knowing this, and tracking when teachers go to PD as opposed to when they teach the course, could inform future models of barriers and supports to CS education. Information can also be gathered on integrated CS opportunities, such as which course it is integrated into, and what CS concepts are integrated. Every school I visited had some level of computing concepts included other courses, such as robotics in a Business and Technology class or programming in the Introduction to Digital Technology course. Currently, this information is hard to keep track of, but understanding how often this occurs and which concepts are being integrated into which courses can give a better sense of how much students are being exposed to computing. Data on club activities could also be collected, including what kind of club, rankings if competition-based, and the number of students in the club. Similar to computing concepts being integrated into other courses, this information can track how many students are receiving informal computing exposure. The downside of having more data to inform the models better is the onus this put on school officials. This data requires schools to gather and report more information, which would require more time on their parts. Careful consideration will be needed in order to gather more data without increasing the burden on school officials.

6.2.3 Higher Education: Professors and Researchers

Although this work focused on high schools, it also has implications for institutions of higher education. From the basic analysis in Chapter 4.2.1, less than half the high schools in Georgia offered a CS course in 2016 and only 1.3% of all students enrolled in public high schools in the state were enrolled in a CS course. Based on this, professors who teach introductory CS at the college level should not expect their students to have seen CS concepts or taken CS courses before. Higher education is currently seeing booming CS enrollments [123], and it can be easy to forget that those trends are not as reflective of the K-12 realm.

This work also has implications for future research and can provide a piece of the puzzle for K-12 CS education researchers. This work presents a theory of supports and barriers to

CS in public high schools, which can be further refined and adapted to new states, as new policies are enacted, and as CS, as a field, continues to evolve. This dissertation represents the first two steps in an iterative mixed-methods cycle in exploring the supports and barriers to offering CS. Future research should build on this and continue a quantitative analysis with the information that has been received from these first two steps. For example, the next round of regression analysis can include CCRPI scores, a factor discussed during the qualitative case studies. This work is in no way definitive as-is and can continue to improve as more information is gathered and data collected.

While this work is situated in computer science education, it can have broader implications for the general education and equity audience. This work can be extended to create similar analyses for other subject areas, which can be compared and contrasted with each other to provide insights into potential interventions. Considerations of equity should not be limited to only computer science, and thus similar work can be done to show barriers and supports to equity in education as a whole.

Appendices

APPENDIX A

FACTOR DEFINITIONS, ABBREVIATIONS, AND SOURCES

CS enrollment rate refers to the number of students enrolled in a CS course as a percentage of total school enrollment. Each CS variable represents the CS enrollment rate for the given year:

- **CS16** means the CS enrollment rate in the 2015-2016 school year. Sometimes it is referred to as CSRate2016.
- **CS15** means the CS enrollment rate in the 2014-2015 school year.
- **CS14** means the CS enrollment rate in the 2013-2014 school year.
- **CS13** means the CS enrollment rate in the 2012-2013 school year.
- **CS12** means the CS enrollment rate in the 2011-2012 school year.

All of the CS data was obtained from the Georgia Department of Education.

Med. Inc. stands for median income, which is measured at the county level. It was obtained from the 2016 American Community Survey 5 year estimate.

Enroll is short for enrollment, which is the number of students enrolled at the school during the 2015-2016 school year. This data was obtained from the National Center for Education Statistics (NCES) Elementary and Secondary Information System (ELSi).

Pop is population on a county-level, as reported the 2016 American Community Survey 5 year estimate.

FRL stands for Free and Reduced Lunch, and is expressed in the data as a percent of the school enrolled in the program. This data was obtained from the NCES ELSi.

The **White** and **Asian** categories refer to the percent of students enrolled at a school that identify as that demographic. This data was obtained from the NCES ELSi.

Urban is how urban a school is, which is defined on a scale of 1-12, where 1 is the most urban (a large city) and 12 is the most rural (remote rural). This data was obtained from the NCES ELSi.

APPENDIX B
INTERVIEW PROTOCOL

These questions have been adapted in part from the Teacher Interview Guide for the Barriers and Supports to Implementing Computer Science (BASICS) project from Outlier [14]. These questions will be adjusted further based on selection of schools to include into case studies, so some questions regarding adopting or not adopting computer science will be removed accordingly.

School-specific:

Teachers (CS or Math/Science)

1. I know that there are a lot of ways that people define and think about computer science. I'd like to hear what you thinkwhat is computer science? What does teaching computer science mean to you?

2. How does your school, including fellow teachers as well as administrators, think about computer science? Note: If needed, prompt with categories, such as school logistics, advocacy for or against teaching computer science, fit with student interest and community industries,etc.

3. What is your role at the school? How do you affect course offerings? How does that affect CS?

4. Do you want to teach computer science? Please explain. If you don't, would you want it to be taught at all in your school?

5. You've mentioned A, B, and C as supports for teaching computer science. Of these, what is the biggest support? Are there any others?

6. What supports do you need that you don't have?

7. You've mentioned A, B, and C as barriers for teaching computer science. Of these, what is the biggest barrier? Are there any others?

8. What barriers do you feel you/the school/the district can change?

9. If you were sitting with district or school leaders right now, what would you ask them to do to help eliminate these barriers or increase these supports?

10. Are any of the supports and barriers you identified unique to teaching this particular course? Or are they similar to those encountered in other subjects, like mathematics, science, language arts, etc.? How?

Guidance Counselor

1. I know that there are a lot of ways that people define and think about computer science. I'd like to hear what you thinkwhat is computer science?

2. How does your school think about computer science? Note: If needed, prompt with categories, such as school logistics, advocacy for or against teaching computer science, fit with student interest and community industries, etc.

3. What is your role in helping the school create its master schedule? How do you plug into the process of changing the schedule? [do they make recommendations, do they help students choose their classes, how is the list of possible courses curated]

4. How does CS fit into that framework?

5. What is your personal process for recommending a student take computer science? For encouraging them to pursue it in college?

Assistant Principal

1. I know that there are a lot of ways that people define and think about computer science. I'd like to hear what you thinkwhat is computer science?

2. How does your school think about computer science? Note: If needed, prompt with categories, such as school logistics, advocacy for or against teaching computer science, fit with student interest and community industries, etc.

3. What is your role at the school? How do you affect course offerings? How does that affect CS?

4. You've mentioned A, B, and C as supports for offering computer science. Of these, what is the biggest support? Are there any others?

5. What supports do you need that you don't have?

6. You've mentioned A, B, and C as barriers for offering computer science. Of these, what is the biggest barrier? Are there any others?

7. What barriers do you feel you can change? The school? The district?

8. If you were sitting with teachers right now, what would you ask them to do to help eliminate these barriers or increase these supports? What about your principal, school board members, superintendent, or curriculum coordinators?

9. Are any of the supports and barriers you identified unique to computer science? Or are they similar to those encountered in other subjects, like mathematics, science, language arts, etc.? How?

10. What is your role in helping the school create its master schedule? How do you plug into the process of changing the schedule? [do they make recommendations, do they help students choose their classes, how is the list of possible courses curated]

11. How does CS fit into that framework?

12. How do you think the school reacts to changes in policy? [what would you do for new math standards?]

13. Specifically regarding computer science policy? Note: if needed, prompt with policies, such as computer science being counted for 4th year science credit or foreign languages, or Microsoft offering vouchers for end of course exams.

Principal

1. I know that there are a lot of ways that people define and think about computer science. I'd like to hear what you thinkwhat is computer science?

2. How does your school think about computer science? Note: If needed, prompt with categories, such as school logistics, advocacy for or against teaching computer science, fit with student interest and community industries, etc.

3. What is your role at the school? How do you affect course offerings? How does that affect CS?

4. You've mentioned A, B, and C as supports for offering computer science. Of these, what is the biggest support? Are there any others?

5. What supports do you need that you don't have?

6. You've mentioned A, B, and C as barriers for offering computer science. Of these, what is the biggest barrier? Are there any others?

7. What barriers do you feel you can change? The school? The district?

8. If you were sitting with teachers right now, what would you ask them to do to help eliminate these barriers or increase these supports? What about with school board members, superintendent, or curriculum coordinators?

9. Are any of the supports and barriers you identified unique to computer science? Or are they similar to those encountered in other subjects, like mathematics, science, language arts, etc.? How?

10. How do you react to changes in policy, specifically regarding computer science? Note: if needed, prompt with policies, such as computer science being counted for 4th year science credit or foreign languages, or Microsoft offering vouchers for end of course exams.

District-specific:

Curriculum Coordinators

1. I know that there are a lot of ways that people define and think about computer science. I'd like to hear what you thinkwhat is computer science?

2. How does your district think about computer science? Note: If needed, prompt with categories, such as school logistics, advocacy for or against teaching computer science, fit with student interest and community industries, etc.

3. What is your role at the school? How do you affect course offerings? How does that affect CS?

4. Are any of the supports and barriers you identified unique to computer science? Or are they similar to those encountered in other subjects, like mathematics, science, language arts, etc.? How?

5. How do you think the district reacts to changes in policy, specifically regarding computer science? Note: if needed, prompt with policies, such as computer science being counted for 4th year science credit or foreign languages, or Microsoft offering vouchers for end of course exams.

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