Exploring ECS Teacher Persistence and Attrition in Chicago Public Schools

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Capstone Project

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About the Authors

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To my children, I am endlessly grateful for the sacrifices, pep talks, laughter, chocolate runs, coffee shop homework sessions, motivation, and most of all love and understanding through this process. To my husband, you are my rock, my coffee brewer, my supporter, and my true love. Thank you so much – I could not have done it without YOU. To my colleagues and friends in Cohort 4, we formed a bond and a community that will last well beyond the three years of this program. I am so grateful for each of you and the expertise and different perspectives you bring to the table. I learned so much from all of you. To Ken, my research partner, we have overcome obstacles, faced challenges, and yet we always persevere and get it done. I am grateful for your partnership in this and many projects and your true friendship from the start. I will graduate a better person having known and worked with you.

With all my heart,

Mom/Toni

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Love to all,

Ken

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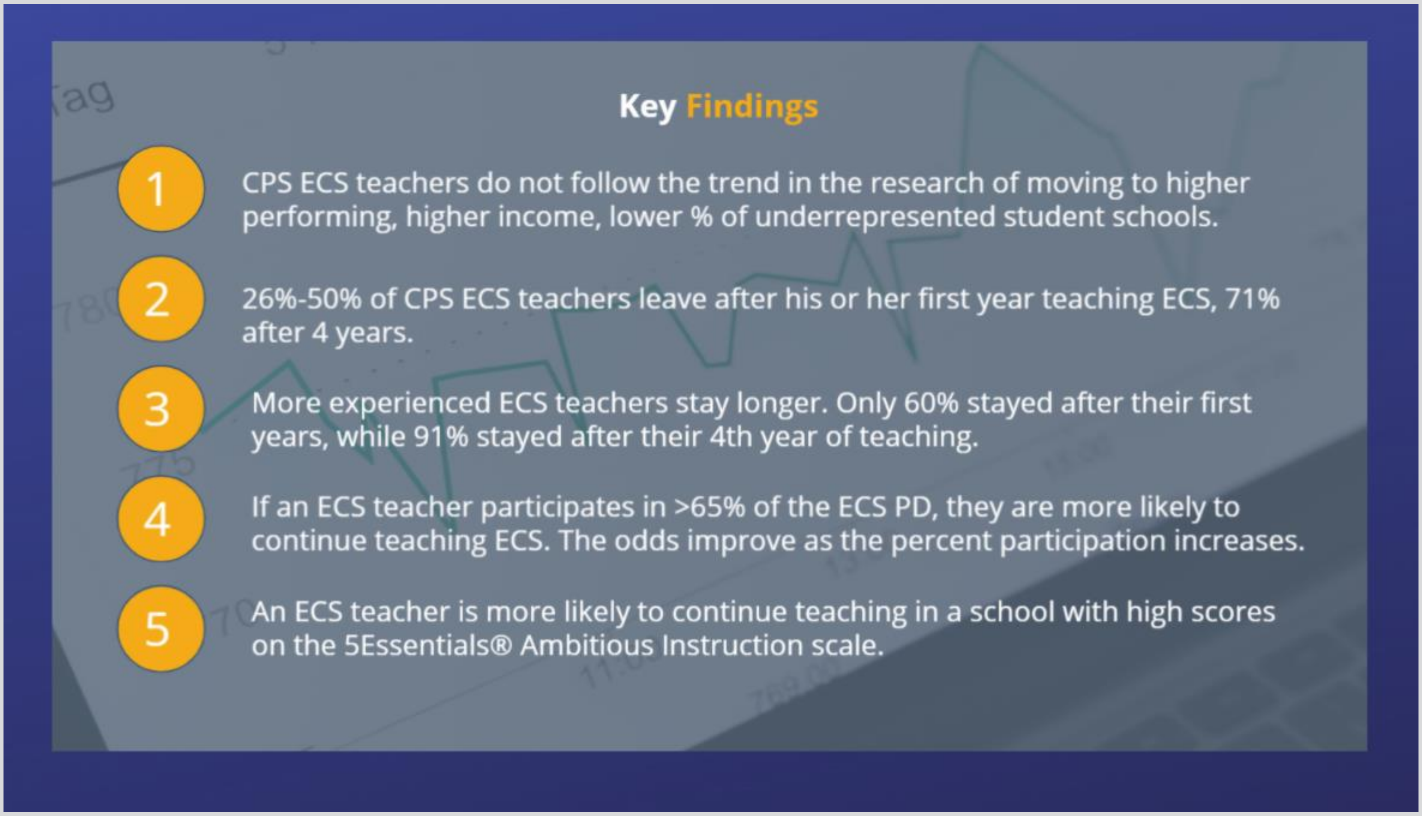
Executive Summary

This ECS teacher persistence study was conducted in collaboration with Vanderbilt University doctoral students and the Chicago Alliance for Equity in Computer Science (CAFÉCS). This research-practice partnership (RPP) includes Chicago Public Schools (CPS), The Learning Partnership, and computer science faculty from University of Illinois Chicago, DePaul University, and Loyola University. This study was made possible by a data sharing agreement between CAFÉCS and CPS to use collaboration and research to further the mission to provide engaging and equitable computer science to all CPS high school students.

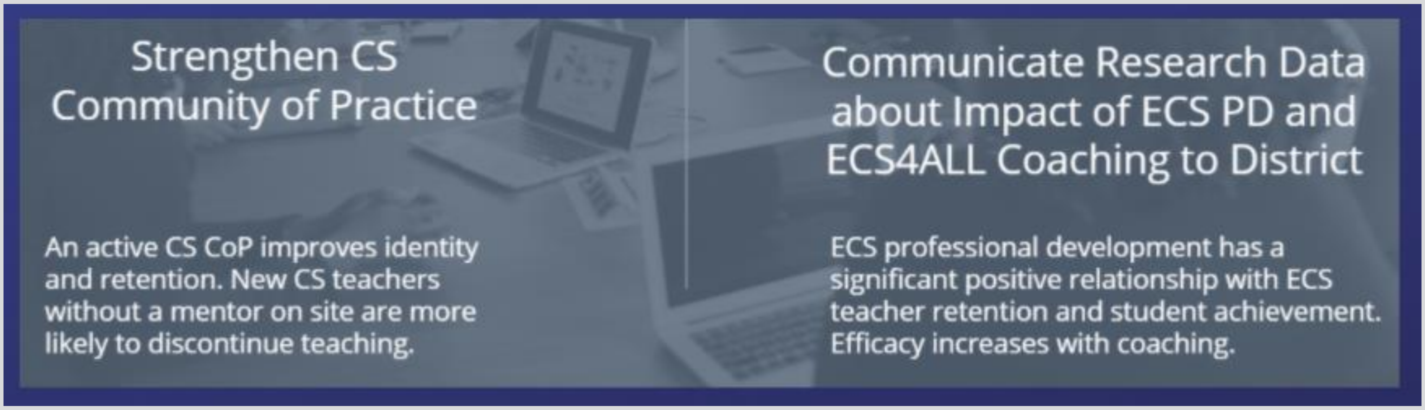
As part of the Computer Science for All initiative, Chicago Public Schools enacted a high school computer science class for graduation in winter 2016 to take effect with the incoming freshman class in fall 2016. They adopted the Exploring Computer Science curriculum because it was designed to expand participation among young women and students traditionally under-represented in the field of computer science. Previous research has reported equivalent computer science outcomes from ECS courses regardless of gender or race (M et al., 2018).

The CAFECS problem solving cycle provided the context for collaboratively identifying the problem facing the Computer Science Department of CPS (Henrick et al., 2021). The Computer Science Department of CPS expressed concern to CAFÉCS that as many as 60% of ECS teachers had discontinued teaching ECS since 2015. **CPS Computer Science Department wanted a better understanding of the scope of the problem of teacher attrition and to understand any relationships between ECS teacher persistence and teacher, student, and/or school factors for which they had data.** Teacher attrition in a program with intensive PD and teacher endorsements can both have financial ramifications and cause instability and discontinuity to the ECS program, negatively affecting student performance and interfering with the ability to assess program impact.

Using both descriptive statistics and logistic regression models, we made the following **key findings:**



Following the CAFÉCS problem-solving cycle (Henrick et al., 2021), we shared and discussed study findings with the CAFÉCS leadership team to clarify the problem and determine how the findings could be used to address the problem of ECS teacher attrition. The following **recommendations** were made using feedback from CAFÉCS leadership team and information gathered from research:



We also recommended areas to consider furthering the CAFÉCS research agenda:

Introduction

"Providing a relevant and compelling computer science experience for every Chicago student" is the Chicago Alliance for Equity in Computer Science's (CAFÉCS) mission (*Chicago Alliance for Equity in Computer Science*, 2021). In addition to ensuring that high impact instruction in an introductory computer science class is part of every high school student's experience, equity for Chicago Public School (CPS) students is at the core of the Alliance. Situated within a deep-rooted partnership with computer science higher education faculty, school administrators, teachers, and education researchers, CAFÉCS is in a unique position to use the program, conduct research, and support teachers in the facilitation of the well-researched and -backed Exploring Computer Science (ECS) class (Detorri, Greenberg, McGee, & Reed (2016); Reed, WiIkerson, Yanek, Dettori, & Solin, 2015). ECS is an inquiry-based, culturally relevant curriculum. It is supported with effective professional development and has shown to have great promise in improving student achievement and the likelihood of a student taking a second computer science course (Goode, Margolis, & Chapman, 2014; McGee, et al., 2019; McGee, et al., 2018).

A huge challenge in implementing a computer science program is finding (Whitehead, Ray, Khan, Summers, & Obando, 2011) and retaining (Ingersoll, 2001) qualified teachers. Not only is student achievement negatively affected by high teacher turnover (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2008; Carver-Thomas & Darling-Hammond, 2017; Dillon & Mallick, 2020; Hanushek, Rivkin, & Schuman, 2016; Moore, Rosenblatt, Badgett, & Eldridge, 2018; Nguyen, Pham, Springer, & Crouch, 2019), but there is also a huge cost to the school system (Carver-Thomas & Darling-Hammond, 2017; Dillon & Malick, 2020; Dixon, Griffin, & Teoh, 2019; Papay & Bacher-Hicks, 2017; Sorenson & Ladd, 2020; Nguyen, Pham, Springer, & Crouch, 2019), minority students are more highly affected because teachers are inequitably distributed across schools (Carver-Thomas & Darling-Hammond, 2017; Allensworth, Ponsiciak, & Mazzeo, 2009; Goldhaber, Gross, & Player, 2011; Hanushek, Rivkin, & Schuman, 2016; Moore et al., 2018), and high teacher turnover makes it difficult to evaluate program effectiveness (Chao, Park, & Boruch, 2016). This is no different for the ECS program in CPS. In fact, members of CAFÉCS described teacher turnover as constant constraint as the district aims to provide high quality computer science opportunities to all students across the district. To address ECS teacher attrition and to support teacher effectiveness and efficacy, ECS professional development was implemented starting in the summer before the 2012-2013 school year. Since then, members of the CPS CS Department speculated that in CPS only one-half to one-third of the teachers who completed ECS professional development are still teaching the course after 4 years. Knowing that teacher turnover is detrimental to the mission of the program, CAFÉCS would like to better understand ECS teacher persistence in Chicago Public Schools. This issue is particularly acute since computer science is a graduation requirement.

CAFÉCS: Chicago Alliance for Equity in Computer Science

Chicago Alliance for Equity in Computer Science (CAFÉCS) aims to ensure that all Chicago Public School students have access to inclusive, high-quality, introductory computer science education (*Chicago Alliance for Equity in Computer Science*, 2021). They define themselves as a Research-Practitioner Partnership (RPP), following Coburn, Penuel, and Geil's (2013) model, which described an RPP as a way for districts to implement educational innovations to result in beneficial new teacher and administrator actions and behaviors and improved student learning. An RPP is typically defined as a long-term, mutually beneficial collaboration designed to promote the production and use of rigorous research about problems of practice (*National Network of Education Research - Practice Partnerships, 2021*). CAFÉCS states RPPs "hold promise for improving the relevance of the research produced, the use of research by organizations, and outcomes for youth" (*Chicago Alliance for Equity in Computer Science*, 2021). CAFÉCS partners include CPS Computer Science (CS) Department, The Learning Partnership, the University of Illinois Chicago, and DePaul and Loyola Universities.

CAFÉCS

CAFÉCS was formalized as an organization in 2017. However, its origins date back to 2008 when two CPS high school computer science teachers returned from a conference and began talking about areas of concern for their field: a dwindling number of students enrolling in computer science, poor access to computer science classes at the high school level, and low representation of minorities taking the AP classes that were available, specifically African-American and Hispanic students (Henrick et al., 2019). This group of teachers connected with a University of Chicago Illinois, computer science professor and together they established the Chicago chapter of the ACM Computer Science Teacher Association. Simultaneously, faculty from both University of Illinois Chicago and Loyola University Chicago were funded through a National Science Foundation (NSF) grant to boost high school students' interest in majoring in computer science (Henrick et al., 2019). Over the next several years and through a series of NSF funding, the groups found, implemented, and studied the evidence-based ECS curriculum. In 2017, the Chicago colleagues formalized the partnership as CAFÉCS.

Starting with the incoming class in 2016-2017, CPS has required all students to complete a year-long computer science course and CAFÉCS has sought to provide support to CPS computer science teachers and to hold all CPS schools accountable for offering the required classes. To meet the requirement, CPS CS Department chose the extensively tested ECS curriculum and its mandatory Professional Development (PD) program (Chicago Alliance for Equity in Computer Science, 2020). To supplement PD, CAFÉCS, in conjunction with the CPS CS Department, began a coaching project for ongoing support of ECS teachers called Accelerate ECS4All (Wachen, McGee, Yanek, & Curry, 2021). In CPS, this computer science initiative affects around 15,000 students annually. According to the CAFÉCS leadership team, this initiative means that some teachers are placed in positions to instruct ECS, rather than volunteering, as they had before this time.

Chicago Public Schools

Chicago Public Schools, founded in 1837, is an urban district located within the city of Chicago, IL, and is the third largest school district in the United States. For the 2020-2021 school year there were 638 schools within the district, 340,658 students enrolled, and a total of 38,168 employees. Of those schools, 92 are district-run high schools, 62 are Charter high schools, 7 are contract high schools, and 1 is considered a SAFE high school. A total of 105,197 students were enrolled in CPS high schools. CPS reported student racial makeup as 46.7% Hispanic, 35.8% African American, 10.9% White, 4.3% Asian, and 2.3% who identify themselves as Asian/Pacific Islander, Multi-Racial, Native American/Alaskan, or unavailable. Teacher racial makeup was reported as 21.6% Hispanic, 20.7% African American, 49.8% White, 4% Asian, and unavailable at 7.9% (Chicago Public Schools, 2021).

Chicago Public Schools Computer Science Department

CPS implemented the first Computer Science 4 All (CS4All) initiative in the United States, which grew into the current CPS CS Department. The mission of the CS Department is to facilitate student growth as a member of the worldwide community through "equity, empowerment, and opportunity" in computer science (*Computer Science (CS) | Chicago Public Schools* 2021). The CS Department accomplished this by providing students with CS opportunities, which the CS Department implements using a philosophy of inquiry to stimulate curiosity and problem-solving, equity to reduce barriers to accessing computer science, and real-life applicable content to improve engagement and interest (*Computer Science (CS) | Chicago Public Schools* 2021). As of two years ago, the school system trained 1,000 elementary and high school teachers in over 300 elementary and high schools so that an increasing number of K-12 students receive CS preparation. CPS made a huge step toward the mission of equity and student growth when it partnered with Los Angeles Unified School District's Exploring Computer Science Curriculum in 2012, which had shown great promise in equipping all students for participation in technologically advanced society (*Computer Science (CS) | Chicago Public Schools* 2021). Starting in the 2016-2017 school year, ECS became a CPS high school graduation requirement, and the curriculum was supported district-wide by ECS professional development and, more recently, the ECS4All Coaching Program.

Problem of Practice

According to the Bureau of Statistics, computer science occupations are expected to expand by 11% from 2019 to 2029, with a median income of $91,250, as reported in May 2020. This is a much quicker increase than average and a relatively high salary (*Computer and Information Technology Occupations : Occupational Outlook Handbook*, 2021). Although this sounds like good news, The United States is not producing enough qualified candidates to fill these positions (Gal-Ezer & Stephenson, 2009), and those students who are in the education pipeline do not adequately represent women, Hispanic students, or African-American students (Dettori et al., 2016).

In early 2016, President Obama, in the Computer Science for All Initiative, supported the investment of federal funds to increase participation in high school computer science, which began a multitude of efforts to provide every student the opportunity to participate in computer science instruction (Goode, Skorodinsky, Hubbard, & Hook, 2020). This initiative and other bipartisan calls (Vakil, 2018) have led to the development and widespread adoption of computer science classes, one of which is Exploring Computer Science (ECS), which focuses on student engagement, cultural relevance, and inquiry techniques, and has shown great promise in improving student learning, racial and gender equity, and student interest in continuing to enroll in computer science classes (McGee et al., 2018). In CPS, an introductory computer science course is a requirement for graduation. ECS was chosen as the curriculum for this introductory course, and by taking this class, approximately 75% of ECS students increased their interest in taking another computer science class and even majoring in computer science in college. Notably, from an equity perspective, of these students, there was no racial or gender differences in interest (Dettori et al., 2016).

A constraint of these programs has been the difficulty schools face in filling computer science teacher positions (Yadav, Gretter, Hambrusch, & Sands, 2016) and retaining qualified computer science teachers once employed (Ingersoll, 2001). Concern regarding substantial teacher attrition is valid, as research shows the repercussions to be “marked, and lasting negative consequences for the quality of instructional staff and student achievement” (Sorensen & Ladd, 2020).

One of the goals of CAFÉCS is to work collaboratively within their RPP to use both research and practice to improve the CPS CS Department goal of providing equitable, engaging, and challenging computer science classes for all CPS high school students. (Henrick et al, 2021). As part of this process, CAFÉCS developed a problem-solving cycle to create an infrastructure to guide the collaborative work.

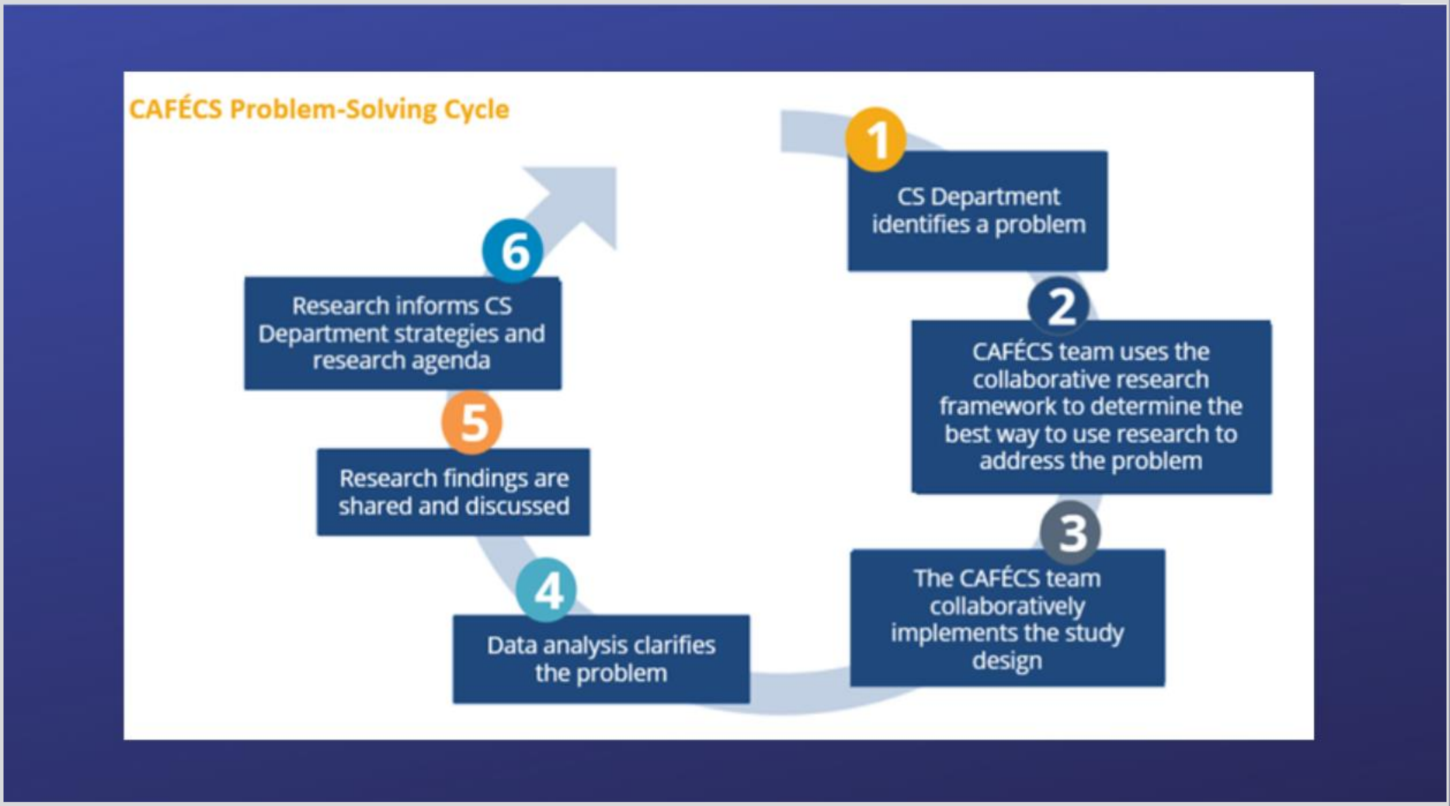


Figure 1. (Adapted from Henrick et al., 2021)

As seen in Figure 1., the CAFÉCS (Henrick et al., 2021) problem-solving cycle includes six steps. In our work with the CPS CS Department, we followed this problem-solving cycle. The first step in the process is problem identification by the CPS CS Department. Through a collaborative process with CAFÉCS leadership to determine if there were any problems or issues that the CS

Department had shared that had not yet been investigated empirically, we came to understand that the CPS CS Department had expressed concern over losing ECS teachers post professional development. We entered a collaborative relationship with CAFÉCS to use research to begin to address the CS Department's concern. Over the course of several meetings, it became clear that after discussing the proposed problem, CAFÉCS speculated that only one-half to one-third of the teachers who were trained to teach ECS are still teaching the course three to four years later. CAFÉCS would like to understand the scope of the problem of ECS teacher attrition in CPS, as well as any teacher, student, or school characteristics related to ECS teacher persistence to inform policy.

Review of the Literature

Step 2 of the CAFÉCS (Henrick et al., 2021) problem-solving cycle is to use a collaborative research framework to decide on the best way to research a problem. To fully understand ECS teacher persistence in CPS, it is important to understand the literature around teacher retention, attrition, and mobility in general and, although limited, for relevant specialty teachers (e.g., STEM and computer science). The following review of the literature will synthesize the results of multiple studies, which have been conducted to explain the state of retention, cost of attrition, why teachers make retention decisions, and attempts to improve retention.

Teacher Retention

For this study, retention is defined as an ECS teacher who continues to teach in the same district from one year to the next. Teacher attrition is defined as an ECS teacher who leaves teaching ECS. There is little to no research on ECS teacher retention and attrition, so the broader literature will be reviewed with an emphasis on STEM and CS teacher retention and attrition when available.

Teacher retention is an ongoing and high-priority concern at local, state, and national levels (Allensworth et al., 2009; Holmes, Parker, & Gibson, 2019; Moore et al., 2018; Nguyen et al, 2019; Sorenson & Ladd, 2020). According to Carver-Thomas and Darling-Hammond (2017), at the national level, 90% of the demand for teachers is the direct result of teachers leaving the profession of teaching. In 2003, Minarik, Thornton, & Perreault publicized their concern that teachers' attrition rate (25% after the first year and 50% by the fifth year of teaching) is much higher than attrition rates in corporate industries, which expect staff attrition of about 6%. This was supported by Papay et al. (2017) who reported 19% of teachers left within one year and 58% left within five years. In Illinois, teacher retention has held steady over the past five years between 85-86%, with CPS retention rates slightly lower, between 77-81%, over the past five years (*FIND YOUR SCHOOL*, 2021). High school teacher retention in CPS is significantly lower at 63% (Chao et al., 2016). Although no data is available for CPS, studies have found that math and science teachers tend to leave at even a higher rate than teachers who teach other subjects (Carver-Thomas & Darling-Hammond, 2017; Guarino, Santibañez, & Daley, 2006; Ingersoll, 2001; Nguyen et al., 2019).

Teacher Mobility

Recent literature has placed emphasis on the role teacher mobility plays within the conversations involving teacher retention, attrition, and equity. Ingersoll (2001) stressed that it is important to make a distinction between mobility and retention because over 50% of teachers leaving their positions migrate to another school. Even if a district retains a teacher, the negative effects that are associated with attrition hold true for a teacher who moves to a different school within the same district, and can be even worse for the students in schools whose teachers leave to go to higher-achieving, lower-underrepresented-student-percentage, or more supportive schools (Allensworth et al., 2009; Boyd et al., 2008; Carver-Thomas & Darling-Hammond, 2017; Chao et al., 2016; Guarino et al., 2006). When teachers are highly mobile within a district, it is generally referred to as having "high instability" (p.1), which is how CPS is described because only 54.8% of high school teachers who taught full-time between academic years 2007-2008 and 2011-2012 stayed at the same school (Chao et al., 2016).

Repercussions of Teacher Attrition and Mobility

Significant research has been conducted to better understand the impact of teacher attrition and mobility on schools and students. The data show that teacher attrition and mobility have negative effects on student learning and achievement, cost to schools, school organizational characteristics, and the ability to implement and see impact of school-wide interventions.

Teacher attrition and mobility has been shown to affect student learning and achievement directly and negatively (Carver-Thomas & Darling-Hammond, 2017; Sorenson & Ladd, 2020; Nguyen et al., 2019), especially in urban schools (Hanushek et al., 2016; Moore et al., 2018; Nguyen et al., 2019). If staying in the field, highly effective teachers tend to move to higher-performing schools, while less effective teachers tend to stay in the lower-performing schools, which negatively affects student learning opportunities (Boyd et al., 2008; Feng & Sass, 2017; Sorenson & Ladd, 2020). In addition, high instability disrupts teacher collaboration, collective teacher efficacy (the cohort of teachers in a school collectively believe they can have a positive effect on student achievement), and implementation of new practice models, which impedes teacher learning and instruction and negatively affects student learning and outcomes (Darling-Hammond, Hyler, & Gardner, 2017; Donohoo, 2018; Pedersen & West, 2017). When a new teacher comes in to replace a teacher who left, especially if he or she is new to teaching computer science, student outcomes suffer unless the teacher has support from other experienced teachers (Boyd et al., 2008; Yadav et al., 2016). Specifically for ECS students, ECS teachers need robust professional development (McGee et al., 2018; Neutens & Wyffels, 2018) and more years teaching (McGee, Greenberg, Dettori, Rasmussen, McGee-Tekula, Duck, & Wheeler, 2018) to have a positive effect on student achievement and to lower student failure rates.

In addition to student achievement, teacher attrition and mobility negatively affect school and district finances. It is expensive in terms of time and money to recruit, hire, and train new teachers (Boyd et al., 2008; Sorenson & Ladd, 2020). A National Commission on Teaching and America's Future reported costs between $10,000 and $17,000 per teacher who leaves (Nguyen et al., 2019). The cost is even higher for a teacher who leaves an urban district, with estimates showing $20,000 or more per teacher who leaves (Carver-Thomas & Darling-Hammond, 2017; Dixon et al., 2019; Papay et al., 2017). Nguyen et al. (2019) reported that CPS spends upwards of $86 million every year because of teacher attrition and mobility.

Schools suffer in more ways than decreased student achievement and financial burden from high rates of attrition and instability. While new teachers are being recruited, the workload of teachers who remain is increased and important classes may be unavailable for students (Allensworth et al., 2009; Hughes, 2012; Papay et al., 2017). Allensworth, et al. (2009) also found that high turnover may result in loss of lead teachers, shortages in core subjects, and poor continuity of professional development efforts. Ingersoll (2001) found a double-edged sword in that high turnover is linked to poor organizational effectiveness and performance, which makes the school less attractive to new recruits. Also making it hard to fill the vacant positions, the overall quality and composition of teachers in a school (Sorensen & Ladd, 2020) and workplace relations (Swars, Meyers, Mays, & Lack, 2009) decrease with high turnover.

Finally, and directly related to the efforts of CAFÉCS in implementing ECS curriculum, PD, and ECS4All coaching, Darling-Hammond et. al. (2017) found that when there is high instability of the teaching staff, designing, implementing, and getting a clear picture of school-wide interventions is significantly decreased. These researchers explain further that many interventions designed for a multiple-year roll-out are interrupted by turnover, which may impede impact when, otherwise, with more stable teacher retention, they could be successful. As we try to expand the ECS program, which has already shown an initial positive impact on student achievement and equity, it becomes even more important to truly understand turnover in computer science teachers in CPS.

Factors of Teacher Attrition and Mobility

Given the serious ramifications of high attrition and instability, there have been numerous studies looking at student, teacher, and school characteristics to provide insight for policy development around teacher recruitment and retention. The three areas studied are student characteristics, teacher characteristics, and school and organizational characteristics.

Student Characteristics

The National Bureau of Economic Research reported that teacher attrition is highest in schools with low student achievement (Boyd et al., 2008). Since then, multiple studies have supported these results (Feng & Sass, 2017; Goldhaber et al., 2011; Moore et al., 2018; Nguyen et al., 2019). The literature also suggests that teachers are more likely to leave schools with a high percentage of students who are African American and/or Hispanic and low-income schools (Allensworth et al., 2009; Boyd et al., 2011; Carver-Thomas & Darling-Hammond, 2017; Feng & Sass, 2017; Goldhaber et al., 2011; Guarino et al, 2006). However, in a recent meta-analysis of factors associated with teacher attrition and retention, Nguyen et al. (2019) found no relationship with the percentage of either Hispanic or African-American students but did find a significant relationship with the percentage of students receiving free and reduced lunch (FRL). This discrepancy could be due to confounding factors of concerns around classroom management and student behavior, which are higher in schools with higher percentages of underrepresented students (Allensworth et al., 2009; Holmes et al., 2019; Ingersoll, 2001; Ingersoll, 2000; Pederson & West, 2017; Minarik et al., 2003). The percentage of minority students has also been linked to working conditions, which is highly related to attrition (Boyd et al., 2011). Other student factors that have shown up in the literature as having a relationship to teacher attrition are the percentage of students with IEPs (Moore et al., 2018), a higher percentage of students at risk (Moore et al., 20180), weaker parent and teacher relationships (Hughes, 2012), and lack of student motivation (Ingersoll, 2000). In a study of high school computer science teachers, 80% reported lack of student interest as being one of the biggest challenges, which is consistent with the idea of poor student motivation affecting retention (Hug et al., 2013).

In CPS high schools, approximately 100 out of 118 have chronically high teacher turnover. Most of these schools are composed of a student population that is predominately

African-American and Hispanic. Most of the differences in instability in CPS when comparing based on percentages of race are in the areas of teacher-parent relationships and teacher-reported student behavior (Allensworth et al., 2009).

Teacher Characteristics

According to Allensworth et al. (2009) and Nguyen et al. (2019) most personal characteristics of teachers do not have a relationship with teacher attrition (e.g., race, gender). However, in a recent study, Dixon (2019) dug deeper with case studies and a focus group to understand why teachers of color leave at a higher rate than White teachers. Although just a beginning, six interesting areas were reported as underlying reasons for leaving: feeling of being undervalued, poor recognition, decreased agency, poor working conditions, lack of leadership support, and psychological and financial ramifications of being part of an underrepresented group. Aside from race and gender, age plays a role in retention, with teachers who are under 30 and over 50 having the highest attrition rates (Ingersoll, 2001, Minarik et al., 2003). Many studies reported relationships between teacher attrition and effectiveness, education background and certifications, teaching experience, and specialty areas. Less effective teachers are more likely to leave than more qualified teachers (Allensworth et al., 2009; Hanushek et al., 2016; Papay et al., 2017), regardless of the school being high- or low-achieving (Boyd et al., 2008). It is important to note, however, that when less effective teachers do stay, they tend to stay at low performing schools, which serves to exacerbate inequity and achievement gaps (Boyd et al., 2008). Often more effective teachers move to higher-achieving schools and those with a lower percentage of minorities and low-income students (Goldhaber et al., 201). (Feng and Sass (2017) found that the most effective (top quartile) and least effective (bottom quartile) teachers were more likely to leave. They offered an explanation that the most effective teachers may have better job opportunities and the lowest may leave due to realizing their ineffectiveness as a teacher. For computer science teachers, they need to know substantial amounts of content, understand pedagogy, and understand effective content-specific ways of teaching to be effective (Yadav, 2012).

Teachers with higher certifications and graduate degrees are more likely to have high turnover within a district (Feng & Sass, 2017). One explanation is that teachers with certifications or a history of testing high (e.g., pre-service exam scores) have more bargaining power to move to higher-achieving schools or leave the profession for a higher-paying job (Goldhaber et al., 2011). A more recent study by Nguyen et al. (2019), however, did not find significant differences between teachers with graduate degrees and those with only undergraduate degrees.

Teachers with fewer years of experience teaching have higher attrition rates than those with more. The longer teachers stay, the more likely they are to continue teaching (Guarino et al., 2006; Hughes, 2012; Ingersoll, 2000; Moore et al., 2018; Smith & Ingersoll, 2004; Nguyen et al., 2019). One explanation is that new teachers are not as likely to view the school environment in a positive light as more experienced teachers (Pederson & West, 2017). In addition, teachers are more likely to stay when they see a path to a leadership role or oversee something of impact to the school, which is a less likely scenario for a new teacher without experience (Workman & Wixom, 2016). For computer science teachers, if a teacher has little to no experience, he or she is even more likely to leave if there is not a more-experienced computer science teacher at the school to act as a mentor with pedagogy and content (Yadav, 2016).

Ingersoll (2001) and Nguyen et al. (2019) reported that math and science teachers have a higher rate of turnover than other types of teachers. There are factors pointing in both directions, as math and science teachers both are more likely to stay as they have more years teaching and also more likely to leave due to job dissatisfaction (e.g., low salary, lack of student motivation, lack of agency, poor student motivation) than their non-STEM peers (Ingersoll, 2000). They are also the most likely to migrate from one school to another, usually with higher overall performance (Ingersoll, 2001). Interestingly, in ECS, student failure rates go down with the more years of experience ECS teachers gain (McGee et al., 2018), which is consistent with teacher retention increasing with student achievement.

School and Organizational Characteristics

When examining the relationships between school factors and teacher attrition and mobility, there are two distinct sets of characteristics in the literature: school demographics and organizational characteristics. This is consistent with a shift in thinking from an economic framework to a sociocultural framework, which places more emphasis on working conditions as a factor in teacher retention decisions.

School demographics are well-linked to teacher attrition and mobility in the literature. More teachers leave schools with a high percentage of students receiving Free and Reduced Lunch (FRL) than schools whose students are from families with higher incomes (Allensworth et al., 2009; Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006; Ingersoll, 2001; Nguyen et al., 2019). Contrary to this literature, Hughes (2102) found that teachers were more likely to stay until retirement in low-income schools. Also, teachers leave urban schools more often than they leave rural schools (Ingersoll, 2001). Likewise, school size has been found to be a factor in teacher attrition, with more teachers leaving small schools than larger schools (Allensworth et al., 2009; Guarino et al., 2006; Ingersoll, 2001), although some researchers did not find enrollment or school size to be significant (Boyd et al., 2011). Further, high principal turnover correlates with low stability (Allensworth et al., 2009). In addition, schools that are on probation under the School Quality Rating Policy tend to lose more teachers (Allensworth et al., 2009). Another demographic is overall student achievement, which is also a factor in teacher attrition and mobility (Boyd et al, 2008; Fend & Sass, 2017; Hanushek, 2004; Swars et al., 2009; Nguyen et al., 2019). For STEM teachers, Carver-Thomas and Darling-Hammond (2017) reported that they have a 70% greater chance of leaving a Title I school than a non-Title I school.

According to Ingersoll (2001), teacher attrition and mobility cannot be fully explained without looking beyond student, teacher, and school demographics to the organizational characteristics of the schools where teachers work. Carver-Thomas and Darling-Hammond (2017) explains that schools with good collaboration between teachers positively affects retention and poor collaboration is often a reason cited for leaving. The importance of teacher relations and collaboration is strongly supported in the literature (Allensworth et al., 2009: Boyd et al., 2011; Darling-Hammond et al., 2017; Hughes, 2012; Ingersoll, 2011; Skaalvik & Skaalvik, 2011; Swars et al., 2009; Pedersen & West, 2017). For STEM teachers, including computer science, Neutens and Wyffels (2018) reported that collaboration between teachers is essential to minimizing teacher attrition and mobility. Yadav et al. (2016) highlighted that collaboration with other computer science teachers is especially important for teachers with only one to two years of experience. Support from administration is also strongly linked to retention (Allensworth et al., 2009; Boyd et al., 2001; Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006; Ingersoll, 2000; Ingersoll, 2001; Minarik et al., 2003; Skaalvik & Skaalvik, 2011; Swars et al., 2009; Pedersen & West, 2017). Hug et al., 2013, reported that 74% of the computer science teachers in their study cited lack of support for their programs. Other characteristics strongly related to teacher retention are a focus on improving instructional rigor and quality (Allensworth et al., 2009; Moore et al., 2018), inclusive leadership (Allensworth et al., 2009; Dixon et al., 2019), opportunities for growth and teacher leadership (Allensworth et al., 2009; Boyd et al., 2011; Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006), competitive compensation (Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006; Hughes, 2012; Ingersoll, 2000; Ingersoll, 2001), teacher agency and influence over decision making (Boyd et al., 2011; Dixon et al., 2019; Guarino et al., 2006; Ingersoll, 2000; Ingersoll, 2001), and the school's provision of effective professional development and support (Boyd et al., 2011; Darling-Hammond et al., 2017; Minarik et al., 2003; Moore et al., 2018; Neutens and Wyffels, 2018; Smith & Ingersoll, 2014; Pedersen & West, 2017).

Teacher Retention Efforts

Many publications offer recommendations for improving teacher retention and/or reducing attrition and mobility. Efforts address predominately school-wide, organizational characteristics such as professional development and support, salary and compensation, teacher leadership and agency building, developing communities of practice, and leadership training.

The purpose of professional development and support is to address the issue of teacher effectiveness and efficacy, which directly relate to retention (Boyd et al., 2011; Darling-Hammond et al., 2017; Minarik et al., 2003; Moore et al., 2018; Neutens and Wyffels, 2018; Smith & Ingersoll, 2014; Pedersen & West, 2017). In fact, when schools report the introduction of new practices and professional development, it is assumed that the teaching staff is relatively stable (Allensworth et al., 2009). Second, making efforts to give teachers a competitive salary is often recommended (Carver-Thomas & Darling-Hammond, 2017; Dixon et al., 2009). Guarino et al., 2006; Hughes, 2012; Ingersoll, 2000; Ingersoll, 2001). Competitive salaries have been mentioned as especially important with STEM and computer science teachers, as the option to leave the field of teaching for more lucrative occupations is always present. In fact, Carver-Thomas and Darling-Hammond (2017) recommend providing compensation commensurate with other occupations and doing so district-wide so all district schools can compete for high-quality teachers. Another recommendation is for schools to provide more opportunities for leadership positions and agency building (Boyd et al., 2011; Dixon et al., 2019; Guarino et al., 2006; Ingersoll, 2000; Ingersoll, 2001). Boyd et al., 2011 reported that when there is a positive change in one working condition, such as teacher influence, other working conditions tend to improve as well, such as administration support. Dixon et al. (2009) explained that this is especially important for retention of teachers of color. A fourth recommendation found in the literature is to use the idea of developing communities of practice with computer science teachers, as there can be so few of their peers at the same school (Ni & Guzdial, 2012). Working together in communities of practice either at a school or within a district serves to facilitate a congruent belief system between teachers' perceptions and practices, which has been shown to improve retention (Swars et al., 2009). Finally, leadership training is recommended because, as with most organizations, inclusive and supportive leadership leads to employees staying (Allensworth et al., 2009; Boyd et al., 2001; Carver-Thomas & Darling-Hammond, 2017; Dixon et al., 2019; Guarino et al., 2006; Ingersoll, 2000; Ingersoll, 2001; Minarik et al., 2003; Skaalvik & Skaalvik, 2011; Swars et al., 2009; Pedersen & West, 2017).

Conceptual Framework

Following a review of the literature, and as part of Step 2 of the CAFÉCS problem-solving cycle (Henrick et al., 2021), conceptual frameworks are reviewed to guide the members of the partnership in developing hypotheses and research questions. There are many theoretical frameworks proposed to explain the problem of teacher attrition, both in general and specifically for computer science teachers. The three main areas that emerge as significant to the attrition and mobility of Exploring Computer Science teachers are: adult learning and professional development, teacher identity, and organizational systems and sociocultural framework.

First, adult learning and professional development link directly with teacher effectiveness and efficacy, which in turn are linked to higher teacher retention. Teacher effectiveness, or the ability to meet goals around student achievement and classroom climate, is a strong indicator of teachers persisting in the field (McGee et al., 2018; Skaalvik & Skaalvik, 2011; Swars et al., 2009). Teacher efficacy, teachers' perception of their own ability to teach a subject, manage a classroom, and have a positive effect on student growth has also been shown to improve retention and persistence in teaching, especially when the efficacy of most teachers in a school is strengthened – also known as collective teacher efficacy (Donohoo, 2018; Ingersoll et al., 2014; Ivy, Hollis, Frantz, Lee, & Reese, 2017; et al., Zhou et al, 2020). This has been especially important in STEM fields and specifically computer science (Yadav et al., 2016; Ivey et al., 2017). How do we increase teacher effectiveness and efficacy? Studies show that teacher participation in professional development is an important factor in improving teaching effectiveness, which leads to improved efficacy and student growth (Darling-Hammond et al., 2017; Donohoo, 2018). Features that foster teacher participation include an active learning component, modeling best practices, providing support and coaching, incorporating hands-on learning, offering feedback and allowing for reflection, facilitating collaboration, taking place over time (Darling-Hammond et al., 2017), and being equity-based (Goode et al., 2020). ECS professional development encompasses all seven of these characteristics (Goode et al., 2014), and has already proven effective for decreasing student failure (McGee et al., 2018) and increasing teacher effectiveness (i.e., student growth) (McGee et al., 2019; McGee et al, 2018). In addition to offering effective professional development, Margolis et al. (2017) studied a program that used coaches for ECS teachers and found that teachers believed the program provided a sense of collaboration, improved pedagogy, and improved content knowledge. CPS recently began ongoing and sustained support and mentoring with the ECS4All coaching program with a small subset of ECS teachers. Early findings suggest that teachers had a positive experience with the program and that efficacy in delivering content was found to be a clear benefit of having a coach (Wachen et al., 2021).

Second, teacher identity plays a role in ECS teacher commitment and retention (Ni & Guzdial, 2012). Computer scientists who have become teachers may like engaging in computer science, but have difficulty seeing themselves as an educator with the pedagogical skills to manage a classroom (Sjöström, 2018). On the contrary, a teacher who does not have a background in computer science but has become a CS teacher may understand classroom management and pedagogy but may not have the identity as a computer science teacher needed to lead the class and field student questions (Bender et al., 2016). Ingersoll et al. (2014) points out that math and science teachers have much more content matter training and graduate degrees than knowledge and training about pedagogy and instructional methods, which was significantly related to attrition. Ni and Guzdial (2012) identified four things that influenced teachers' identity as a CS teacher: education background and certifications, the CS curriculum, the presence of a CS community, and teachers' perspectives on the CS community at large. Their beliefs about the CS community and education directly related to efficacy, and the lack of a community stymied learning opportunities and created a poor sense of belonging at the school.

The third framework moves beyond the teacher and the classroom and takes a sociocultural and organizational systems approach, looking at the teacher within the overall system at the school, department, and district. Instead of looking at demographics alone, the sociocultural framework assumes that school and district climate help shape student and teacher experiences and decisions

(Hug et al., 2013). School and organizational culture, including workload, compensation, available technology and resources, opportunities for collaboration, leadership support, focus on improving instruction, safety, level of agency, room for advancement, inclusivity, and teacher influence directly affect teacher effectiveness and decisions around attrition and mobility (Allensworth et al., 2009; Boyd et al., 2011; Carver-Thomas & Darling-Hammond, 2017; Dixon et al., 2019; Guarino et al., 2006; Hu et al., 2017; Hughes, 2012; Ingersoll, 2001; Minarik et al., 2003). There have also been studies showing the benefit of active computer science teacher communities of practice within districts that have served to empower those teaching CS classes (Hu, et al., 2017; Ni, Guzdial, Tew, Morrison, & Galanos, 2011). Finally, many studies have named teacher mobility as a factor in attrition with teacher characteristics and organizational characteristics as mediating factors (Allensworth et al., 2009).

These frameworks informed the above model of teacher retention and mobility as a product of teacher, student, and school characteristics, as well as the opportunity to participate in effective and ongoing professional development.

Hypotheses

The review of the literature, the above frameworks, the available data, and discussions with the CAFÉCS leadership team led to hypotheses in four areas: teacher persistence and mobility; school demographics and organizational conditions; teacher demographics, experience, preparation, and support; and student achievement. See figure 2.

Research	Hypotheses
Teacher Persistence and Mobility • STEM & CS teachers have higher attrition and mobility rate than other teachers.	• There is high ECS teacher attrition • ECS teachers moving to higher performing schools. • Teachers teach ECS intermittently
School Demographics and Organizational Conditions • School demographics are related to work conditions and retention. • School culture and organizational factors play a role in retention decisions. • Community of practice improves teacher identity and retention.	• Teachers leave schools with high % FRL, high % underrepresented students, larger populations, high % special education, and high % bilingual students • Teachers leave schools with lower SQRP ratings • Teachers leave schools with poor organizational factors and support
Teacher Demographics, Experience, Preparation, & Support • Effective PD improves retention and student outcomes • Education background is part of identity. • Teachers need content and pedagogical knowledge to have efficacy.	• Teacher demographics do not relate to teacher persistence • Teachers with related CS degree/endorsement persist • Teachers with more ECS experience persist • Teachers who participate in ECS PD persist
Student Achievement • Student overall performance and class performance is related to mobility and retention. • Teacher efficacy and effectiveness are strongly related to retention decisions.	• Teachers of high achieving students persist • Teachers of students who earn a good grade in ECS persist

Figure 2. Conceptual Framework and Hypotheses

Research Questions

The Computer Science Department of CPS expressed concern to CAFÉCS about the number of ECS teachers discontinuing teaching ECS and they wanted to further understand this persistence issue, the degree to which the problem existed, and to explore factors that could be affecting ECS teacher retention. The school years beginning with the 2015-2016 school year became the focus to capture the year before the graduation requirement was implemented. The CAFÉCS problem-solving cycle (Henrick et al., 2021) provided the framework and hypotheses used to integrate input from CPS and CAFÉCS and to drive our discussions with CAFÉCS. For this study, we use teacher persistence interchangeably with teacher retention. After collaborating with the team, they chose the term persistence to mean continuing to teach ECS after the first year with intention to foster engagement and facilitate student success through a sense of connectedness, commitment, and preparedness (Moore, et al, 2018). This stems from the teachers participating in the PD and the ECS curriculum being grounded in engagement and equity.

We defined the persistence categories into which teachers could fall after digesting input from CAFÉCS and reviewing existing literature. Six categories defined teacher persistence. See Figure 3.

1. Teachers who continue to teach ECS at the same school as the year before. **(Stayer_same)**
2. Teachers who continue to teach ECS, but at a different school. **(Stayer_dif)**
3. Teachers who cease teaching ECS and remain at the same school as the year before. **(Leaver_same)**
4. Teachers who cease teaching ECS and move to a different school. **(Leaver_dif)**
5. Teachers who intermittently teach ECS at the same school. **(Revolver_same)**
6. Teachers who intermittently teach ECS at a different school. **(Revolver_dif)**

Figure 3. CPS ECS Teacher Persistence Categories

Research revealed that issues relating to teacher persistence fall into two primary areas: teacher characteristics and school characteristics. Student data is also important, but it typically pertains to teachers or schools. Student achievement and interest affect teacher retention (Goldhaber, Gross, & Player, 2011) and can be looked at through the lens of teacher effectiveness and efficacy, both of which affect retention (Pedersen, D. & West, R., 2017). Similarly, student demographics and academic performance are often aggregated to become school characteristics. We created research questions in the category Teacher Persistence and Mobility to better understand the scope of the problem, and then divided our other research questions into three areas: School Demographics and Organizational Conditions; Teacher Demographics, Experience, Preparation and Support; and Student Achievement. These questions stemmed directly from our hypotheses, which, as previously discussed, were derived from the review of the literature and conceptual frameworks. See Figure 4.

Hypotheses	Research Questions
Teacher Persistence and Mobility • There is high ECS teacher attrition • ECS teachers moving to higher performing schools. • Teachers teach ECS intermittently	1. How does CPS ECS teacher retention compare to CPS and IL retention? 2. What are the ECS teacher attrition rates by cohort for the past four years in CPS? 3. Are ECS teachers changing CPS schools?
School Demographics and Organizational Conditions • Teachers leave schools with high % FRL, high % underrepresented students, larger populations, high % special education, and high % bilingual students • Teachers leave schools with lower SQRP ratings • Teachers leave schools with poor organizational factors and support	1. Is there a relationship between school demographics and ECS teacher persistence? 2. Is there a relationship between SQRP ratings and ECS teacher persistence? 3. Does the number of ECS teachers at a school relate to teacher persistence? 4. How do 5Essentials® scores relate to ECS teacher persistence?
Teacher Demographics, Experience, Preparation, & Support • Teacher demographics do not relate to teacher persistence • Teachers with related CS degree/endorsement persist • Teachers with more ECS experience persist • Teachers who participate in ECS PD persist	1. How do teacher race and gender relate to ECS teacher persistence? 2. Is there are relationship between education & type of endorsement with ECS teacher persistence? 3. Does teacher experience teaching ECS relate to ECS teacher persistence? 4. Does ECS PD participation level relate to ECS teacher persistence?
Student Achievement • Teachers of high achieving students persist • Teachers of students who earn a good grade in ECS persist	1. How does the cumulative GPA and student performance in the ECS course relate to ECS teacher persistence?

Figure 4. Hypotheses and Research Questions.

Project Design and Methods

Consistent with step 3 of the CAFÉCS problem-solving cycle our study design was collaboratively developed and implemented with the help and support of CAFÉCS who was responsive to requests for feedback and input throughout the study (Henrick et al., 2021).

Design

We conducted a quantitative study to define the problem of ECS Teacher persistence in CPS and to determine relationships between the dependent variable, ECS Teacher persistence, and the numerous independent variables available in the database. Sampling was not necessary as the database included all ECS teachers who taught from the school year ending 2016 to the school year ending 2020. Due to restrictions related to the COVID 19 pandemic we were not able to employ a mixed methods design – interviews and surveys of teachers, students, school administrators, and others were not permissible.

Study Data

Study Identifiers	Study Independent Variables	Not Used in Study

Teacher Data	Unique Teacher ID	Endorsements	Race	Gender	Undergraduate Degree (STEM, Non-STEM, Computer Science
	Graduate Degree (STEM, Non-STEM, Computer Science	% Professional Development Workshops Attended	Specific PD Workshops Attended		

Teacher Assignment Data	Unique Teacher ID	School ID	School Year	Course Name	Class Type (ECS, Comp Sci, None/Neither
	Number Years Teaching ECS before Study Year				

Student Data	Unique Student ID	Unique Teacher ID	School ID	School Year End	AGC
	Gender	Race	Special Education Indicator	Free/Reduced Lunch Eligibility	
	Course ID	Course ID-Short	Course Name	Class Type	Days Attending
	Attendance Rate	Cumulative GPA	Annual GPA	Fall Grade	Spring Grade

School Data	School ID	School Year	School Year End	6 PARCC Categories	14 PSAT Categories
	Percent African American Students	Percent Asian Students	Percent Hispanic Students	Percent White Students	
	Percent Bilingual Students	Percent Special Education Students	Percent Free/Reduced Lunch Students		
	*Scores for each Five Essentials Category (Environment, Families, Instruction, Teachers, Leaders)				
	**School Quality Rating (SQRP) Status	School Quality Rating	School Quality Rating Points Earned		
	Number of ECS Teachers	School Size	Average School SAT Score	6 Other SAT Categories	

***Five E's:** The 5Essentials is an improvement framework and diagnostic survey with research-tested scoring and interactive reporting that provides insights into schools' organizational strengths and areas of opportunity across the five essential factors for school improvement: Effective Leaders, Collaborative Teachers, Involved Families, Supportive Environment, and Ambitious Instruction. The system also includes professional learning designed to help educators leverage 5Essentials data to inform improvement planning and drive improved school and student outcomes. (https://uchicagoimpact.org/our-offerings/5essentials)

****School Quality Rating Policy (SQRP):** The CPS School Quality Rating Policy (SQRP) is the district's policy for measuring annual school performance. The SQRP is a five-tiered performance system based on a broad range of indicators of success, including, but not limited to, student test score performance, student academic growth, closing of achievement gaps, school culture and climate, attendance, graduation, and preparation for post-graduation success. (https://www.cps.edu/about/district-data/metrics/sqrp/)

Table 1. Data from data CPS sharing agreement.

We used secondary deidentified data originating from CPS and obtained from CAFÉCS through a data sharing agreement between the two organizations. See Table 1.

Four cohorts of teachers were included in the study, those who taught ECS in school years ending in 2016, 2017, 2018, and 2019. Data from 2020 was used to determine persistence categories of teachers from the four cohorts, but teachers who began teaching ECS in 2020 were excluded due to a lack of data from the school year ending in 2021 which would be needed to determine persistence for those teachers.

The data was provided in four separate data bases: Teachers, Students, Teacher Assignment, and Schools. Each data base included data fields related to the category focus. [Move this Table to Appendix X and indicate what each color means]

Data Cleaning

Since our study pertained to ECS Teacher Persistence we focused on ensuring the number of unique teachers in the data set was accurate and that the pertinent identifiers and fields of independent variables were populated to a usable degree. There were 1,291 teachers in the data base originally, and after cleaning the data there were 360 unique teachers subject to the study. The following steps were taken to clean and organize the data:

Teachers

- Removed all rows without a Teacher ID.
- Converted class type to two categories, ECS and CS/Other.
- Eliminated teachers who taught at multiple schools each year.
- Eliminated teachers who never taught ECS during the study period.
- Eliminated teachers that did not have data regarding ECS/Non-ECS assignment during study period.
- Eliminated teachers who began teaching ECS in 2020 – no persistence data was available for subsequent years.
- Examined the data base to identify and eliminate teachers teaching multiple ECS sections simultaneously in a study year – none were found.
- Categorized Undergraduate and Graduate Degree variables into STEM, Non-STEM, Computer Science (CS), and No Data.
- Gender – left as provided; 20% empty fields.

- Created variable for teachers attending second summer of Professional Development.
- Removed variables not needed for analysis.
- Created a cohort variable to examine persistence through the study period.
- Identified revolving teachers (those teaching ECS more than one year, but not consecutively) – There were only 6 such teachers, so they were eliminated from the data set.

Students

- Removed students that were not associated with teachers in the sample.
- Created a spring-fall grade average variable – if only one of the grades was included, that grade became the variable.

Schools

- SQRP status was converted to numerical values: 1, 2 and 3.
- Five ranges were created to demonstrate school size. These were ultimately not used. Actual school size was more informative in regressions run later.
- Developed a variable regarding the Five Essentials to identify strong and weak schools.

Final Data Frame

- Merged all the independent variables back to the Teacher table for ease of accessibility for analysis.
- Made a data frame called ECS with all teacher-, student-, and school-level study variables.
- Since there were only 6 teachers who taught ECs intermittently (Revolvers) CAFÉCS agreed to eliminate them from the study. That also eliminated two of the previously determined persistence categories:
- Teachers who intermittently teach ECS at the same school. **(Revolver_same)**
- Teachers who intermittently teach ECS at different schools. **(Revolver_dif)**
- Since 25% of the teachers in the study discontinued teaching ECS and dropped from the data set because they did not teach another CS course, the persistence category Leaver_Unknown was created.

The data showed only six teachers changed schools during the study period whether or not they continued to teach ECS. Therefore, the persistence categories were reduced to two for the data analysis, those who continued to teach ECS and those who discontinued teaching ECS (Stayers and Leavers).

After cleaning and organizing the data and finalizing the research inquiries the result was a data set with 360 unique teachers, 20 independent variables, 13 research questions, 4 cohorts ranging in size from 60 to 91 teachers, and a range in teachers per year from 87 to 237. See Figure 4.

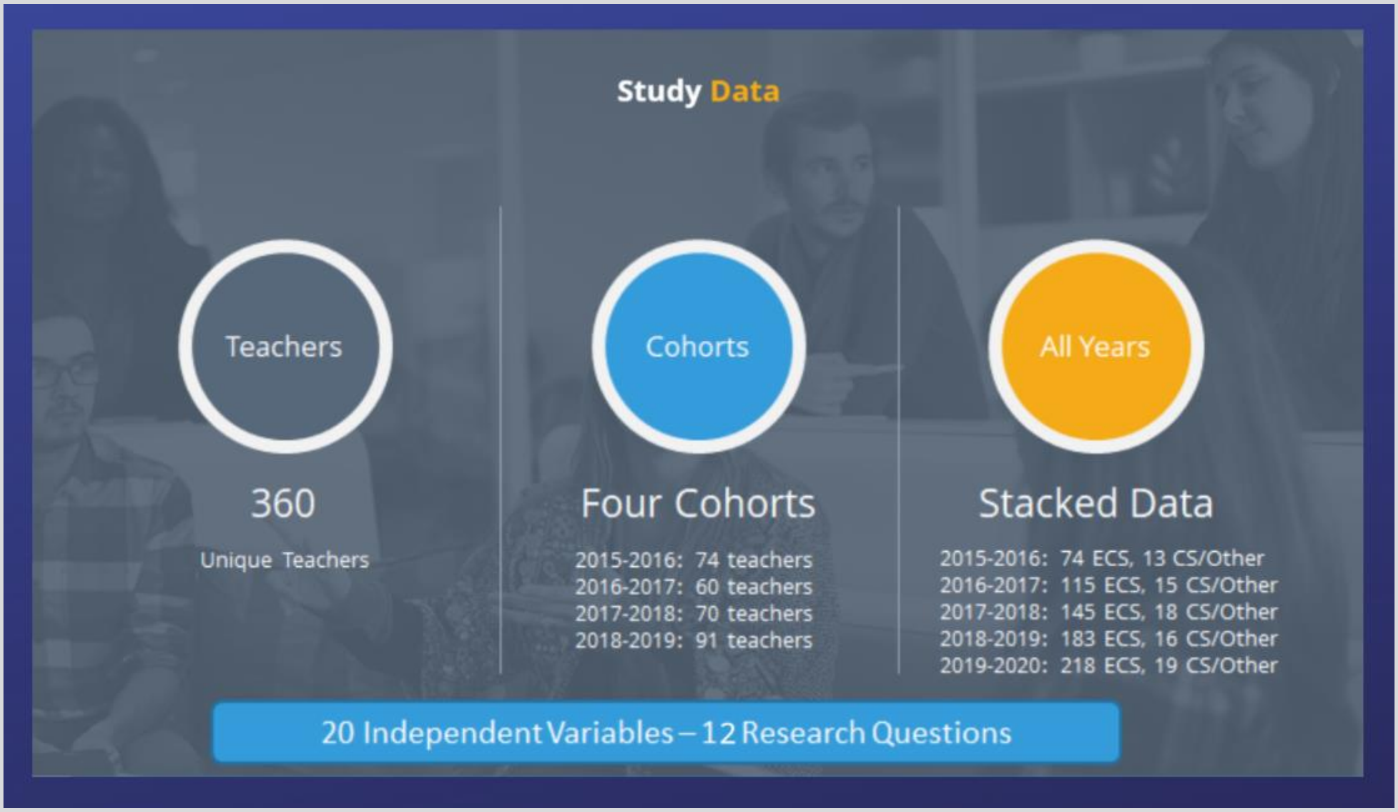


Figure 5. Study Set

Methods

We began our study by using descriptive statistics to help CAFÉCS understand the scope of ECS teacher attrition and persistence in Chicago Public Schools. Ingersoll's (2001) seminal research on teacher turnover guided our approach to our quantitative research method. We chose this method in part because it is cited more than 4,800 times in other related research and is often looked to as influential in subsequent research about teacher turnover (mobility), attrition, and retention. Second, Ingersoll's (2001) study also looked at secondary data and addressed a similar problem of practice, which led us to adopt the same multi-model, logistic regression method to look at the relationship between ECS teacher persistence and school, teacher, and student variables.

We first explored the prevalence of ECS teachers who discontinue teaching ECS to establish the scope of ECS teacher persistence as a problem of practice. Three approaches were used to corroborate the results, all of which are found in the data analysis section of this paper.

In the second phase of the study, we ran a series of logistic regression models to determine how the independent variables related to ECS teacher persistence and to determine which of those variables had a statistically significant relationship to persistence, either positive or negative (See Appendix A). The logistic regressions provide a holistic picture of the effects of the independent variables. They provided a balanced look and helped identify collinearity.

We ran seven models to determine which would be the most predictive of ECS teachers continuing to teach ECS. Models 1, 2, 3 were run as controls. The first model consisted of teacher characteristics such as race, degree, gender, and the number of years teaching ECS. In the second model we added student achievement, and we also added average student ECS class grade as an additional control. The third model added school characteristics as controls. Those included Average composite SAT scores, the number of ECS teachers at a given school, the percent special education students, the percent of bilingual students, the percent of underrepresented students in ECS (minority students), the percent of students qualifying for free/reduced lunch, two levels of SQRP status, Intensive and Provisional support, and school size.

We then created three additional models, each adding one independent variable of interest. Model four added the percent of participation in the ECS Professional Development workshops to the previously included controls. Model five added teacher endorsement (computer science or not), and model six added the 5Essential® scores.

Model seven included the controls and variables from the previous six models (see Table 2). We looked to the AIC* score to determine the most predictive model, which was model 7, with an AIC of 365. The next closest was model 6 with an AIC score of 420. Model seven was the most predictive and most clearly explained the relationships between the various controls and variables, and ECS Teachers continuing to teach ECS.

*Akaike's Information Criterion (AIC) compares a series of statistical models to determine which one is the highest quality. It ranks models exploring the effects of different independent variables on a dependent variable from the least predictive to the most predictive. The lowest AIC score is the best model of the series. However, it does not address overall quality of the hypothesis, only the relative quality between the models created to determine a relationsip.(https://www.statisticshowto.com/akaikes-information-criterion/)

```
Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.4642  -0.7702   0.5021   0.7614   1.7694

Coefficients:
                                              Estimate Std. Error z value Pr(>|z|)
(Intercept)                                  0.2882826  4.5580363   0.063  0.94957
TeacherMinority                              0.2516118  0.3130175   0.804  0.42150
CSdegree                                     0.7410513  0.5475192   1.353  0.17591
GenderMale                                   0.1904200  0.2920233   0.652  0.51436
YrsTchECSb4                                  0.2829642  0.1081739   2.616  0.00890 **
AvgGrade                                    -0.2389285  0.2758475  -0.866  0.38640
SAT_AvgComp                                  0.0023039  0.0033343   0.691  0.48959
ECStchrs                                    -0.0765018  0.0996225  -0.768  0.44254
Sch_SpED                                    -5.3278733  3.5179952  -1.514  0.12991
Sch_Bilingual                               -2.4186757  1.8712212  -1.293  0.19616
Sch_Minority                                -8.9284985  2.9852400  -2.991  0.00278 **
Sch_FRL                                      7.8836611  3.2231812   2.446  0.01445 *
SQRP_AccountabilityStatusIntensive Support   0.5667635  0.5547736   1.022  0.30696
SQRP_AccountabilityStatusProvisional Support -0.0397533 0.5407472  -0.074  0.94140
Sch_Size                                    -0.0002631  0.0002758  -0.954  0.34014
PartPercent                                  2.2881045  0.5279866   4.334 1.47e-05 ***
CSEndorse3CS Adjacent                        0.1590929  0.5055820   0.315  0.75301
CSEndorse3CS Endorsement                    -0.0894562  0.3608020  -0.248  0.80418
Five_Es_Environment                         -0.0425523  0.0260246  -1.635  0.10203
Five_Es_Families                            -0.0012961  0.0176878  -0.073  0.94159
Five_Es_Instruction                          0.0499017  0.0233002   2.142  0.03222 *
Five_Es_Leaders                              0.0329228  0.0252721   1.303  0.19266
Five_Es_Teachers                            -0.0405285  0.0283381  -1.430  0.15267
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 374.47  on 319  degrees of freedom
Residual deviance: 319.07  on 297  degrees of freedom
  (119 observations deleted due to missingness)
AIC: 365.07

Number of Fisher Scoring iterations: 5
```

Table 2. Logistic Regression of the Likelihood of ECS Teacher Persistence

P-values were compared to levels of significance ranging from .001 to .1 to determine the presence of significance and whether there was a positive or negative relationship.

Data Analysis and Findings

Data analysis brought us to Step 4 of the CAFÉCS problem-solving cycle (Henrick et al., 2021). Implementing our study design resulted in findings that helped clarify the ECS teacher persistence problem and guided our next steps.

Teacher Persistence and Mobility

How does ECS teacher retention compare to CPS and Illinois overall teacher retention?

Chicago Public Schools and the State of Illinois had better teacher retention rates than CPS ECS teachers (see Figure 6). CPS ECS teacher retention rate was 68% in 2019, the CPS district overall teacher retention rate was 82%, and state-wide data showed an overall teacher retention rate of 86%.

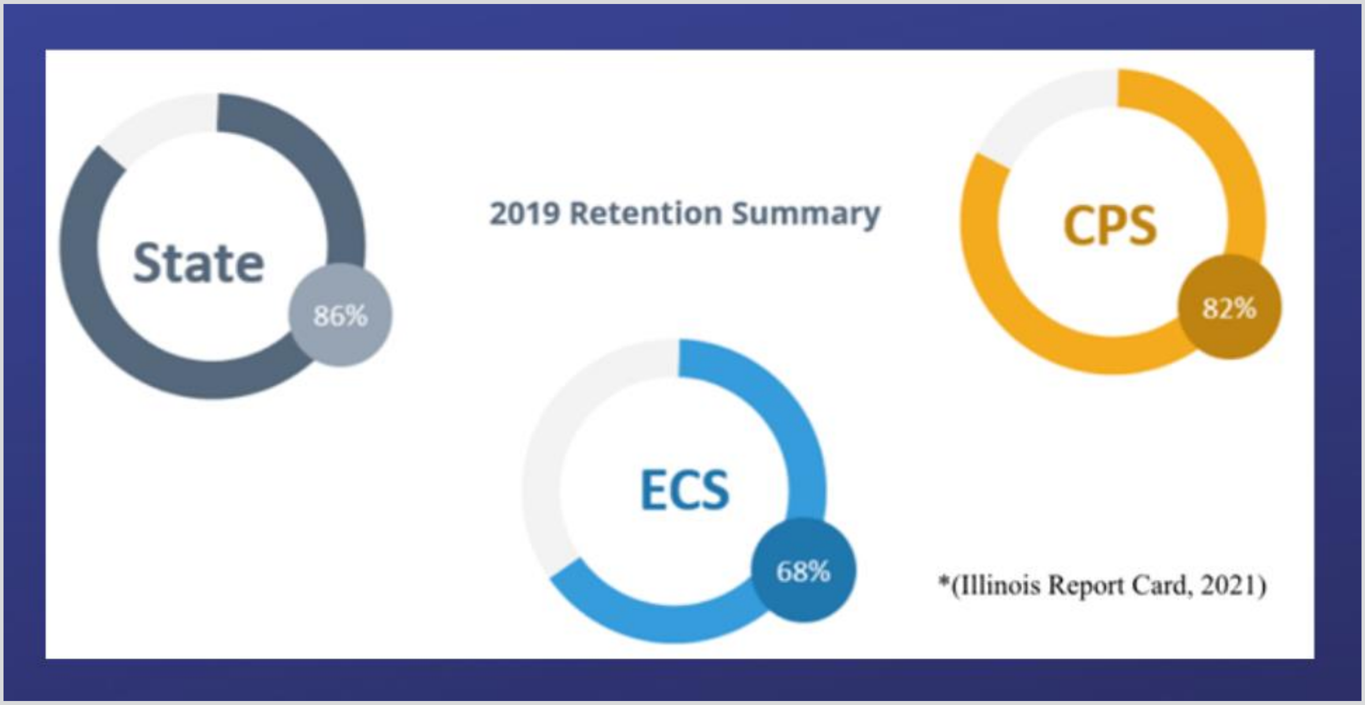


Figure 6. 2019 Illinois, CPS, and CPS ECS Teacher Retention Summary

What are the ECS attrition rates by cohort for the past four years for CPS?

Of the 74 ECS teachers who started in school year 2015-2016, 26% had ceased teaching ECS by the next year (Table 3). Of the 60 in cohort 2016-2017, 40% had discontinued teaching ECS within one year, and half the 2017-2018 cohort had stopped teaching ECS by the next year (50%). The 2018-2019 cohort had a slightly lower percent who discontinued teaching ECS after one year at 32%. The percentages for each cohort continue to increase each year and by the end of four years of teaching ECS, 71% of the 2015-2016 cohort had discontinued teaching ECS.

	After teaching ECS for 1 year	After teaching ECS for 2 years	After teaching ECS for 3 years	After teaching ECS for 4 years
2015-2016 Cohort n=74	26%	47%	64%	71%
2016-2017 Cohort n=60	40%	50%	53%	N/A
2017-2018 Cohort n=70	50%	62%	N/A	N/A
2018-2019 Cohort n=91	32%	N/A	N/A	N/A

Table 3. ECS Teacher Attrition by Cohort

Are ECS teachers changing CPS schools?

ECS teachers are not changing schools as shown in Table 4, which represents a raw count of the teachers who left teaching ECS during the study period by year and persistence category. The first column lists the school year and the subsequent comparison year. The second column is the number of teachers who taught ECS during the study year, 74 teachers in the school year 2015-2016. When looking at the teaching status for those teachers in the next school year we found that six left teaching ECS but continued to teach another computer science class at the same school (ECS_Leaver_Same). Thirteen discontinued teaching ECS and they dropped from the data set because they did not teach another computer science class (ECS_Leaver-Unknown). There were no teachers who stopped teaching ECS and went to another school to teach (ECS_Leaver_Dif). Five teachers continued to teach ECS the next year, but at a different school (ECS_Stayer_Dif), and 50 continued to teach ECS at the same school (ECS_Stayer Same).

Results from the other three years of the study are shown in the other rows of the table. Of note was the persistence category ECS_Leaver_Unknown. Our data did not indicate the status of those teachers in the following year. They may have taught a non-computer science class, left the district, or left teaching. Another observation of note was the number of teachers who continued to teach at the same school. The CAFÉCS staff were interested in teacher mobility (teachers moving to a different school to teach in a subsequent year) and those numbers were much smaller than anticipated. Only 25 teachers were known to go to another school to teach during the study period.

Of the 74 ECS teachers who taught in school year 2015-2016, 55 continued to teach ECS the next year and 19 discontinued teaching ECS. Of the 115 who taught ECS in school year 2016-2017, 75 taught ECS the next year. Ninety two of the 145 teachers who taught ECS in 2017-2018 taught ECS the next year, and 139 of the 183 teachers who taught ECS in the school year ending 2019 taught ECS the next year.

	No. of teachers	Leaver_ Same	Leaver_ Unknown	Leaver_ Dif	Stayer_ Dif	Stayer_ Same
2015-2016 to 2016-2017	74	6	13	0	5	50
2016-2017 to 2017-2018	115	5	33	2	6	69
2017-2018 to 2018-2019	145	9	44	0	5	87
2018-2019 to 2019-2020	183	6	38	0	7	132

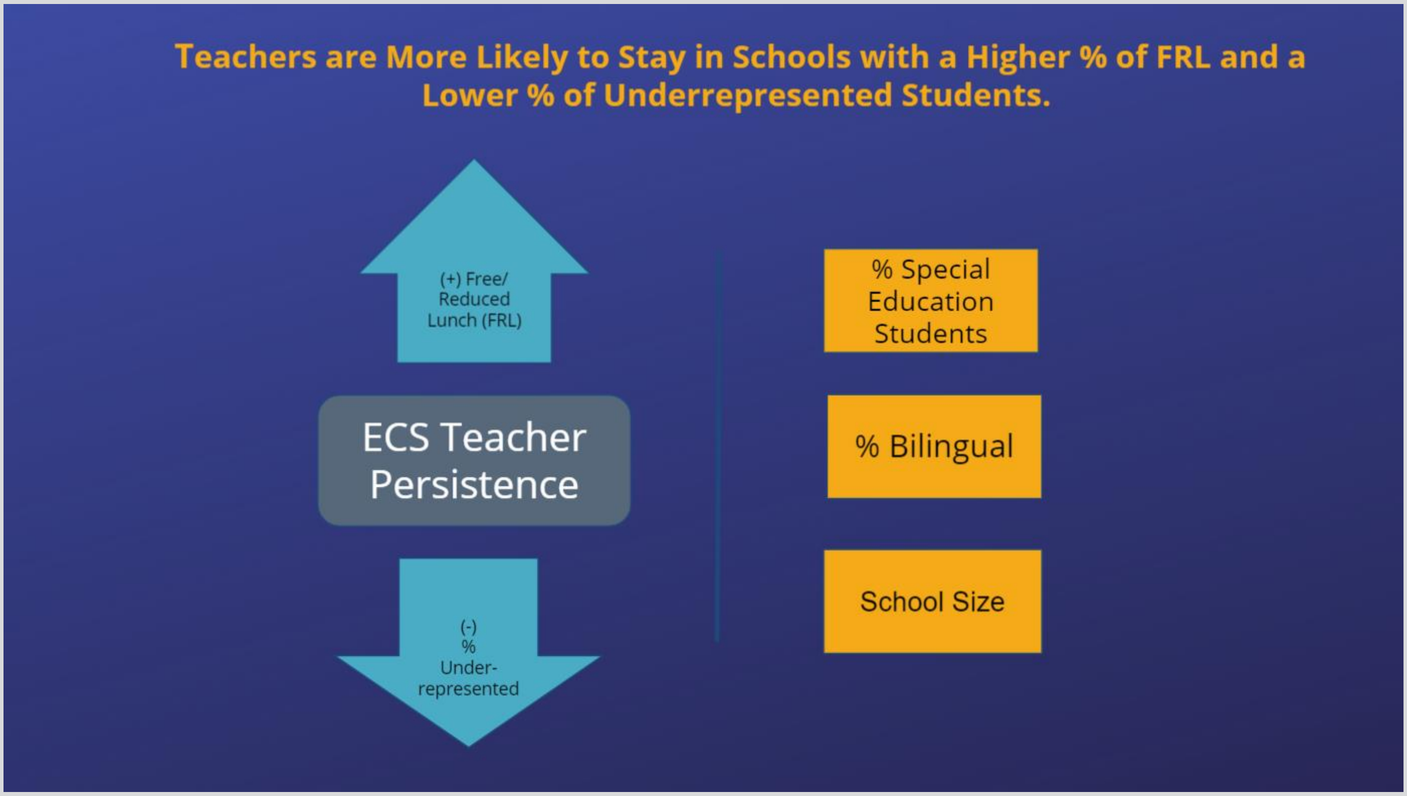
Table 4. ECS Teacher Persistence Raw Count

School Demographics and Organizational Conditions

Is there a relationship between school demographics and ECS teacher persistence?

Two school demographics had a statistically significant relationship with ECS teacher persistence. First, as the percent of students who qualify for **free/reduced lunch** increases, ECS teachers are more likely to continue teaching ECS. Free/Reduced Lunch was statistically significant at a 95% level of confidence. As the **percent of minority students** increases in a school, ECS teachers are less likely to continue teaching ECS. The percent of minority students was statistically significant at the 99% confidence level.

The following three demographics did not have statistically significant relationships with ECS teacher persistence: **percent of bilingual students**, **percent of special education students**, and **school size**.



Is there a relationship between SQRP ratings and ECS teacher persistence?

There is no significant relationship between SQRP ratings and ECS teacher persistence. Table 5 shows that a higher proportion of ECS teachers who taught at more highly rated schools (Good Standing) continued teaching ECS, but those results were not statistically significant.

Teachers who taught at schools receiving Provisional Support had a lower proportion of ECS teachers continuing to teach ECS, and schools receiving Intensive Support had the lowest proportion of teachers continuing to teach ECS, although it was not much lower than the schools receiving Provisional Support. Teachers in schools in Good Standing have a probability to continue to teach ECS of 73%. ECS teachers in schools receiving Provisional Support have a probability to continue to teach ECS of 63%, and ECS teachers in schools needing Intensive Support have a 59% likelihood of continuing to teach ECS.

	Good Standing	Provisional Support	Intensive Support
% Discontinuing to teach ECS	27%	37%	41%
% Continuing to teach ECS	73%	63%	59%

Table 5. School SQRP Rating and Percent ECS Teacher Attrition and Persistence

Does the number of ECS teachers at a school relate to teacher persistence?

The number of ECS teachers assigned to a school does not have a significant relationship with ECS teacher persistence. Table 6 shows inconsistent results regarding the likelihood teachers will continue teaching ECS as the number of ECS teachers in a school change.

	1	2	3	4	5	6	7	9
% Discontinuing to Teach ECS	25%	32%	22%	40%	36%	28%	24%	55%
% Continuing to Teach ECS	75%	68%	78%	60%	64%	72%	76%	45%

Table 6. ECS Teacher Persistence by Number of ECS Teachers at a School

How do the 5Essentials® scores relate to ECS teacher persistence?

Only the 5Essentials® score for Ambitious Instruction had a statistically significant relationship to ECS teacher persistence at a confidence level of 95%. As the score for Ambitious

Instruction increased the likelihood that an ECS teacher would continue to teach ECS increased. This determination was surprising since the Instruction score relates to English and Math instruction and not computer science. There was no significant relationship between the other four Essentials, Environment, Families, Leaders, and Teachers, and ECS teacher persistence.

Relative to 5Essentials® scores, strong schools are those with at least three Essentials with scores over 60. Weak schools are defined as those that have three Essentials with scores below 60. Our findings in Table 7 did not show any difference in the likelihood of ECS teachers continuing to teach ECS relative to Strong or Weak schools. Seventy percent of ECS teachers from strong schools continued to teach ECS and 69% from weak schools continued to teach ECS.

	Strong Schools	Weak Schools
% Discontinuing to Teach ECS	30%	31%
% Continuing to Teach ECS	70%	69%

Table 7. ECS Teacher Persistence by 5Essentials® rating.

Teacher Demographics, Experience, Preparation, and Support Student Achievement

How do teacher race and gender relate to ECS teacher persistence?

There is no relationship between teacher race or gender and ECS teacher persistence. Table 8 below shows very little variation between ECS teachers continuing or discontinuing teaching ECS based on Race or Gender.

	Black/African American	Hispanic/Latino	White	Female	Male
% Discontinuing to Teach ECS	26%	29%	32%	30%	31%
% Continuing to Teach ECS	74%	71%	68%	70%	69%

Table 8. ECS Teacher Persistence by Teacher Race and Gender

Is there a relationship between education and type of endorsement with ECS teacher persistence?

Teacher education and endorsement did not have a significant relationship with ECS teacher persistence. As Figure 7 shows, the proportion of ECS teachers continuing and discontinuing to teach ECS was similar regardless of the type of teacher endorsement. Teachers with a computer science endorsement had a probability to continue teaching ECS of 67%. Teachers with a CS adjacent endorsement were likely to continue teaching ECS at a rate of 78%, and teachers with another endorsement were likely to continue teaching ECS at a rate of 76%.

Teachers with a computer science degree were more likely to continue teaching ECS, with an 82% probability, compared to teachers with a non-STEM degree at 73%, and teachers with a STEM degree were likely to continue teaching ECS at a rate of 65%. Despite these differences our regressions found that there is no significant relationship between teacher degree and ECS teacher persistence.

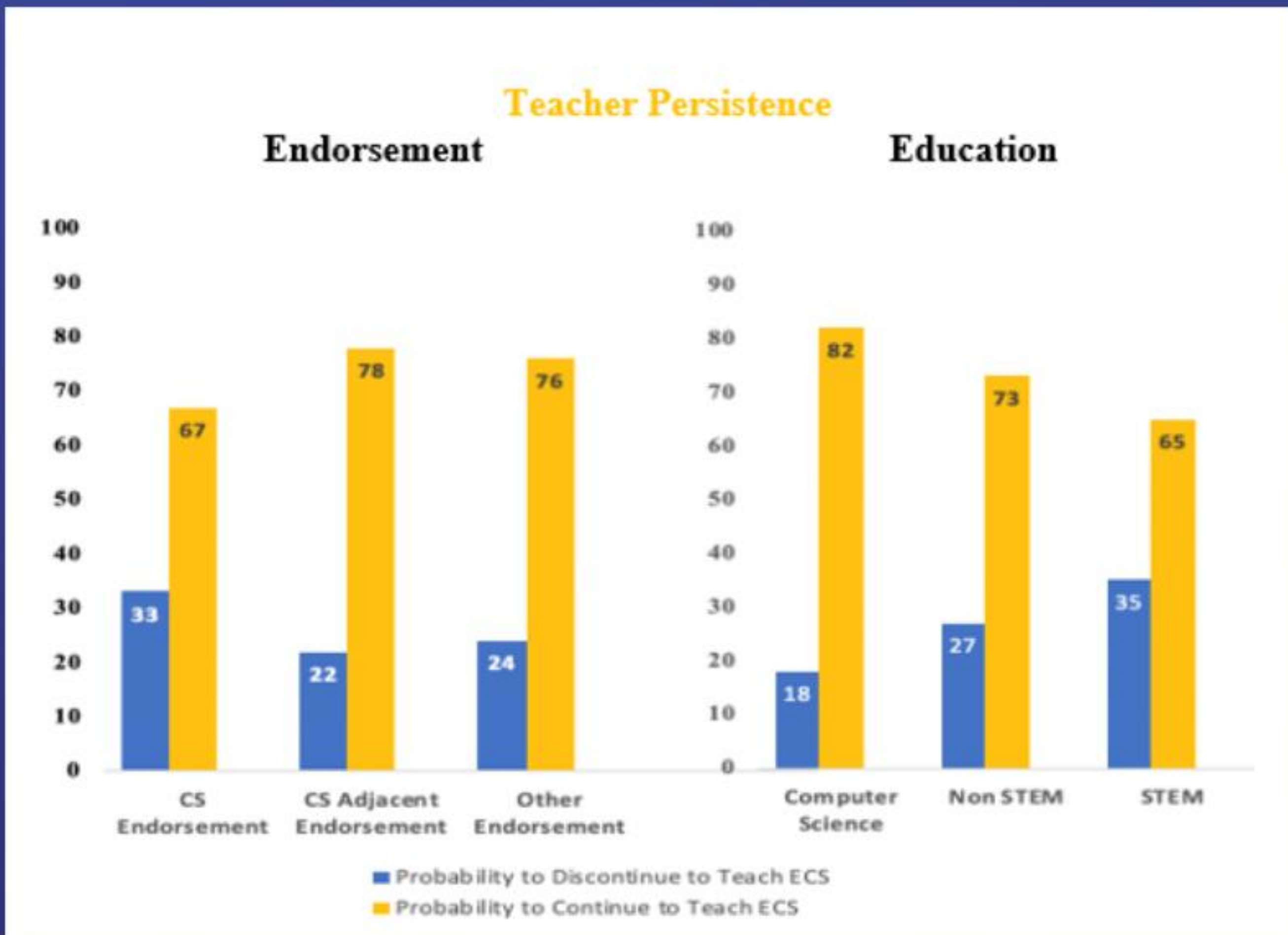


Figure 7. ECS Teacher Persistence by Endorsement and Education

Does teacher experience teaching ECS relate to ECS teacher persistence?

There is a statistically significant relationship between the number of years an ECS teacher has taught ECS and ECS teacher persistence. Years teaching ECS before the study year had the second most significant relationship to persistence identified by the logistic regression at a confidence level of 99%. The more years of experience teaching ECS an ECS teacher has, the greater the probability he or she will continue to teach ECS.

Table 9 shows the significant relationship identified in the regression model. As the number of years teaching ECS increases from no prior experience to four years prior experience, the percent of teachers who continue teaching ECS increases from 60% to 91%.

Years ECS Experience	0	1	2	3	4	5	6	7
% Discontinuing to Teach ECS	40%	26%	21%	24%	9%	24%	0%	33%
% Continuing to Teach ECS	60%	74%	79%	76%	91%	76%	100%	67%

Table 9. ECS Teacher Persistence by Years Teaching ECS

Does ECS Professional Development participation level relate to ECS teacher persistence?

The percent participation in ECS Professional Development workshops was the variable most significantly related to ECS teacher persistence. It was statistically significant at a level of confidence of 99.9%. Teachers with a higher percentage of participation in the six ECS professional development mandatory sessions are much more likely to continue teaching (See Figure 8). This density plot shows a steady increase in the likelihood that an ECS teacher will continue to teach ECS as the percentage of workshop attendance increases. We found that teachers who continued teaching ECS had a range of workshop attendance between 67% and 78% and those who stopped teaching ECS had a range of workshop attendance between 54% and 63% during the study years.

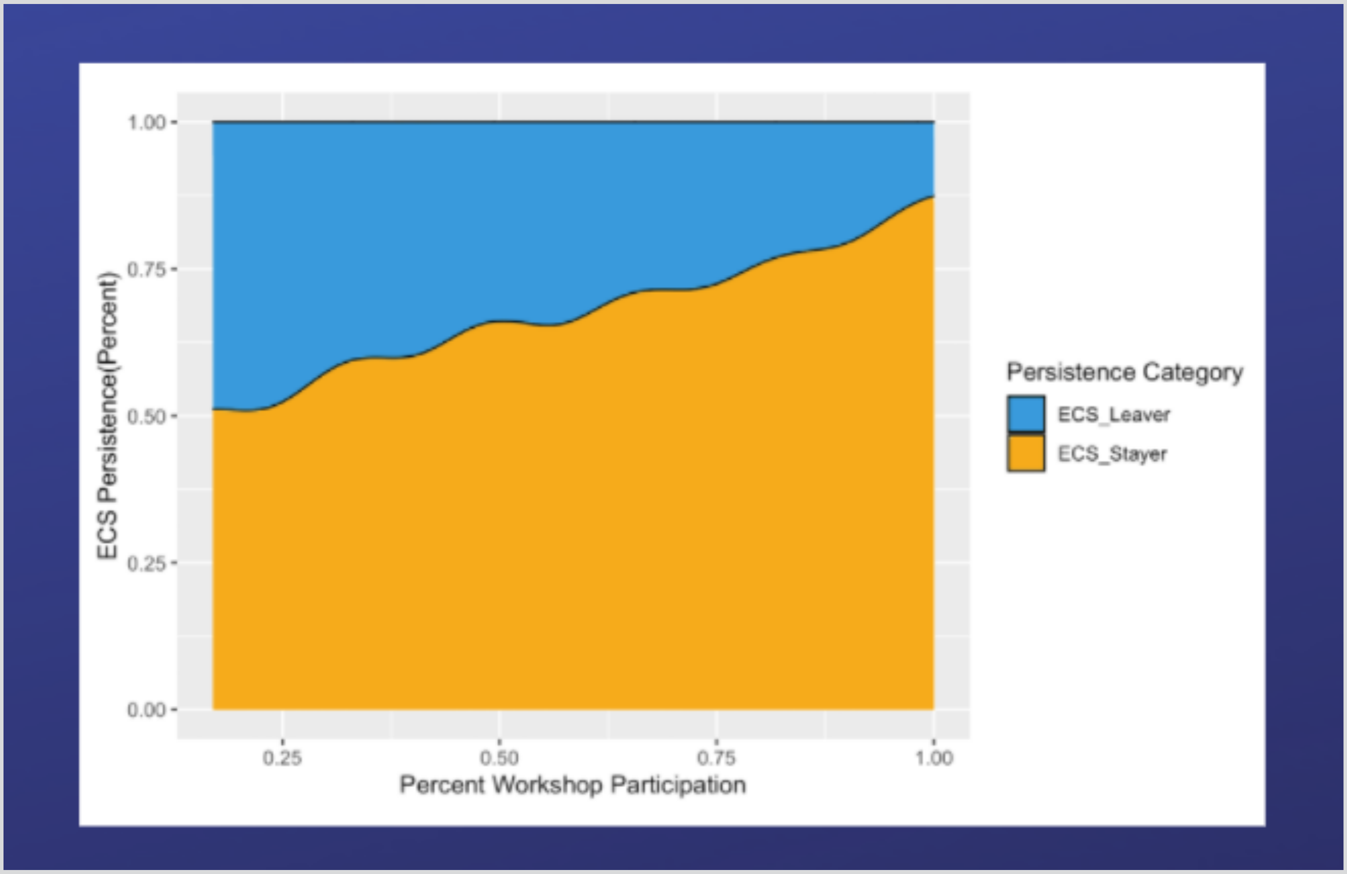


Figure 8. ECS Teacher Persistence by Percent ECS PD Participation

Student Achievement

How does cumulative GPA and student performance in ECS course relate to ECS teacher persistence?

There was no significant relationship between student GPA or ECS course performance and ECS teacher persistence according to our regression model.

The average grade of students in an ECS class did not show a consistent pattern. The results were varied, but somewhat counter-intuitive to the literature (Nguyen, T. D., Pham, L., Springer, M., & Crouch, M., 2019). Over the four years of the study the average class grade of students of teachers who discontinued teaching ECS ranged from 1.5 to 3.4. The average class grade of teachers who continued to teach ECS ranged from 2.4 to 2.9.

The mean annual student GPA of students in classes taught by teachers who continued and discontinued teaching ECS were equally as varied. There was no clear pattern of relationship between GPA and ECS Teacher Persistence. Figure 9 shows these irregularities.

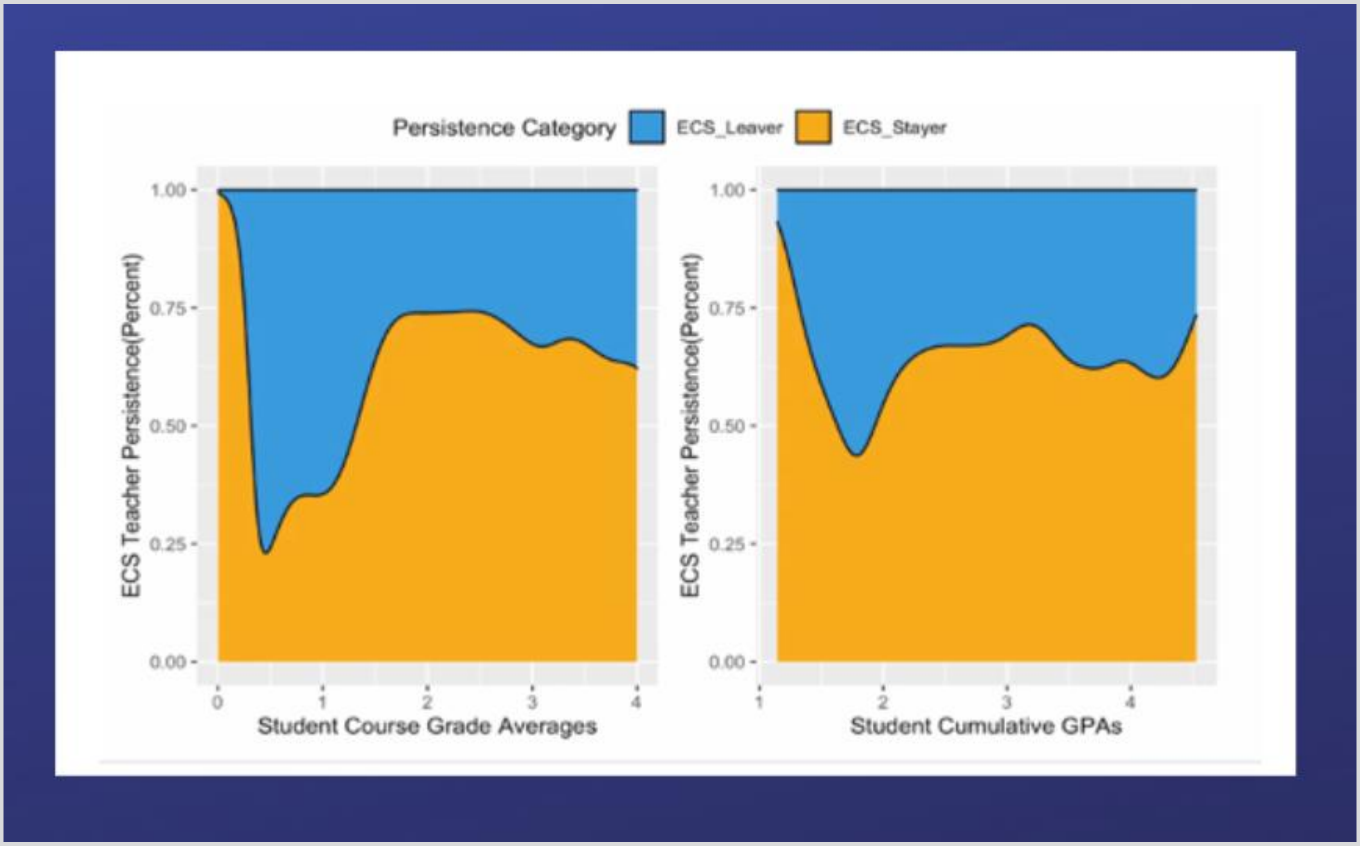


Figure 9. ECS Persistence by Student Course Grade and Student Cumulative GPA Averages

Discussion

In keeping with the fifth step in the CAFECS problem solving cycle (Henrick et al., 2021), we shared and discussed our findings. First, in a meeting with CAFECS and then in a meeting with CAFECS, the CPS research team, and representatives of the CPS Computer Science Department.

CPS ECS Teacher Attrition

The rate of ECS teachers discontinuing teaching ECS was as prevalent as CAFÉCS had suspected. For each cohort in the study, approximately 50% of teachers had stopped teaching ECS within two years of starting. According to the literature, this level of attrition may result in instability at the school and program level, and may decrease student opportunities to achieve (Boyd, D., Grossman, P. Lankford, H., Loeb, S., & Wycoff, J., 2008).

The average rate of ECS teacher attrition for the cohorts 2015-2016, 2016-2017, and 2017-2018 of our study for the first year was 38% and approximately 50% after two years. This level of attrition resulted in a consistently high number of first-year ECS teachers. First-year teachers see the work environment more negatively, which means support and community is very important

(Pederson & West, 2017). The results of our study indicate a need to address attrition in the first years of teaching ECS.

More Years Teaching ECS has a Relationship with ECS Teacher Persistence

The number of years teaching ECS before the study year had the second most significant relationship to ECS teacher persistence of all the independent variables, according to the regression model. Further, when a logistic regression was run to explore the relationship between first-year ECS teachers and retention, we found a very strong relationship with ECS teachers discontinuing teaching ECS. Our interpretation, which was supported by the cohort attrition data, was that beginning ECS teachers are highly likely to stop teaching ECS. The likelihood of leaving drops noticeably after 3 to 5 years of teaching ECS.

The reason for the quick attrition is uncertain, but research suggests it could be connected to professional development, access to a coach, and teaching with a supportive community (Goode et al., 2014). Teacher effectiveness, as demonstrated by student achievement, also leads to teacher retention (McGee et al., 2018; Skaalvik & Skaalvik, 2011; Swars et al., 2009). As mentioned previously, focusing on encouraging new teachers to continue teaching ECS past the first year significantly increases the chance they will continue to teach ECS for the long term.

Participation in Professional Development has a Positive Relationship with ECS Teacher Persistence

Participation in ECS Professional Development had the strongest significant relationship with ECS teachers continuing to teach ECS of all the independent variables. The higher the percentage of participation in PD, the more likely an ECS teacher was to continue teaching ECS. The ECS PD program is designed to foster community and inclusion. It is active, participatory, and engaged learning. It is not about having the right answer, but about thinking and processing. In a study about ECS PD effectiveness conducted in the Las Angeles School District in the 2012-2013 school year, 91% of the ECS teacher participants categorized it as very useful (Goode, et al., 2014).

Our study data showed a higher range (67% to 78%) of workshop participation for those continuing to teach ECS. Those who stopped teaching ECS had a lower participation range (54% to 63%). Passing a threshold of 65% participation may result in increased retention.

Professional development is linked to teacher effectiveness and efficacy and teachers' ability to meet student achievement and classroom climate goals, which lead to teacher retention (McGee et al., 2018; Skaalvik & Slalvik, 2011; Swars et al., 2009). Seven features of professional development encourage teacher participation: an active learning component, modeling best practices, providing support and coaching, incorporating hands-on learning, offering feedback, allowing time for reflection, and facilitating collaboration (Darling-Hammond et al., 2017). ECS professional development includes all seven (Goode et al., 2014). Access to coaches for ECS teachers provides a sense of collaboration, improved pedagogy, and improved content knowledge (Margolis et al., 2017). The CPS ECS professional development program also offers mentoring through the Accelerate ECS4All coaching program. Early findings suggest that teachers had a positive experience with the program and that efficacy in delivering content was found to be a clear benefit of having a coach (Wachen et al., 2021). The data from this study was not part of our data agreement. A connection of this data with the ECS persistence data would have been an enhancement to our study and will benefit future studies.

Community of Practice

We looked at the number of ECS teachers assigned to a school and found that the numbers, which ranged from 1 to 9 ECS teachers, had no relationship to ECS teacher persistence. Initially we thought this could be a loosely based proxy for elements of a community of practice. These results convinced us otherwise. We determined the number of individuals was not the important aspect of a community of practice; rather, support and the facilitation of identity and learning opportunities make the community important to teacher persistence (Ni & Guzdial, 2012).

The environment and organizational climate are integral to teacher satisfaction and effectiveness (Pedersen & West, 2017). A community of practice where a teacher can find support, collaboration, learning and an appreciation for funds of knowledge would facilitate ECS teacher efficacy and confidence. We did not have data to examine the presence, frequency of participation, or quality of communities of practice within CPS.

Teacher Mobility

A concern that emerged in steps one and two of the CAFÉCS problem-solving cycle (Henrick et al., 2021) was the possibility of excessive ECS teacher mobility. ECS teacher mobility proved not to be an issue for the teachers in our study, despite the research's indication (Feng & Sass, 2017) that teachers are more likely to leave lower-performing schools to teach at higher-performing schools. In the four-year study period only 25 teachers changed schools, a mobility rate of about 5%. Twenty-three of those teachers continued teaching ECS after the move and only two did not. Finding that SQRP ratings and school strength were not significantly related to ECS teacher persistence further discounted the assumption that CPS ECS teachers leave to seek higher-performing schools, as high scores on both would indicate higher-performing schools. There is little research specifically related to CS and STEM teacher persistence.

School Demographics

Across our logistic regression models, school characteristics of percent of free and reduced lunch (FRL) and percent minority students had significant relationships with ECS teacher persistence. Unexpectedly, an increase in free/reduced lunch was related to an increase in ECS teacher persistence, whereas typically there would be a negative relationship (Allensworth, Ponsiciak, Mazzeo, 2009). However, in another study free and reduced lunch was found insignificant relative to teacher persistence (Nguyen, et al., 2019). As expected, an increase in the percent of minority students resulted in a greater probability that ECS teachers would discontinue teaching ECS. Because CPS does not have the ability to change the percentage of typically under-represented students or overall percentage of FRL, this demographic data may not be useful to guide policy.

There was also a lack of information about school size other than the fact that student population ranged from 32 to over 4,000. We speculate that school size also relates to school type such as charter, magnate, and private. Looking at the effect of the study variables according to school type could be revealing.

Organizational Factors

Our study focused primarily on teacher, student, and school demographics, which we also found to be the case in many previous studies included in our literature review. However, a significant catalog of literature, which are discussed in this paper, move from examining demographics to organizational factors and work conditions. These factors, if understood in the context of CPS, could lead to more thoroughly understanding ECS teacher persistence.

We did not have access to data about the many sociocultural factors that have emerged as important to teacher retention. Teacher relations and collaboration is strongly supported in the literature as important to teacher attrition (Allensworth et al., 2009: Boyd et al., 2011; Darling-Hammond et al., 2017; Hughes, 2012; Ingersoll, 2011; Skaalvik & Skaalvik, 2011; Swars et al., 2009; Pedersen & West, 2017). Also strongly supported in the literature as important to teacher attrition are: improving instructional rigor and quality (Allensworth et al., 2009; Moore et al., 2018), inclusive leadership (Allensworth et al., 2009; Dixon et al., 2019), opportunities for growth and teacher leadership (Allensworth et al., 2009; Boyd et al., 2011; Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006), competitive compensation (Carver-Thomas & Darling-Hammond, 2017; Guarino et al., 2006; Hughes, 2012 Ingersoll, 2000; Ingersoll, 2001), teacher agency and influence over decision making (Boyd et al., 2011; Dixon et al., 2019; Guarino et al., 2006; Ingersoll, 2000; Ingersoll, 2001), and the school’s provision of effective professional development and support (Boyd et al., 2011; Darling-Hammond et al., 2017; Minarik et al., 2003; Moore et al., 2018; Neutens and Wyffels, 2018; Smith & Ingersoll, 2014; Pedersen & West, 2017).

Accessing existing data that addresses these factors or collecting such data via qualitative methods would result in a richer study and an opportunity to identify additional significant relationships related to ECS teacher retention. This would require qualitative data acquisition and a change to the existing data sharing agreement between CPS and CAFÉCS.

5Essentials®

In our study, we found that the scores of the Instruction category in the 5Essentials® were significantly related to ECS teacher persistence. Scores in the categories Environment, Families, Leaders and Teachers were not significantly related to ECS teacher persistence. The 5E category, Instruction, pertains to English and Math instruction and not computer science or ECS, but does relate to rigorous instruction, which may translate to computer science. Improving instructional rigor and quality is a factor that influences teacher persistence (Allensworth et al., 2009).

The multi-collinearity of the 5E's should also be considered. Testing revealed they are highly colinear (aligned with one another). Considering them in the aggregate may be more meaningful than doing so individually. Therefore, the significance of the relationship between Instruction and teacher persistence could have been influenced by the other 5E's. There are elements of the 5E's that would seem to address the sociocultural factors that have emerged as important to persistence such as agency and impact on school level decisions, but the 5E's are specifically designed to create a supportive environment for students and not teachers.

Leaver_Unknowns

A sizeable and unexpected number of teachers stopped teaching ECS and were no longer in the data set. Whether they taught another non-CS class in the same or a different school, left the district, or left teaching was undetermined. These teachers represented 25% of the teachers in the four cohorts of this study. This percentage is large enough to change or further support our findings. Access to this data will be important to future persistence studies.

Limitations

Due to COVID-19 restrictions we were not able to implement a mixed-methods research design that would have allowed us to interview and survey ECS teachers, PD instructors, and ECS coaches. That qualitative information could have provided additional insight into the ECS Teacher persistence problem. There were some fields in the dataset that were missing data, which makes the findings less reliable. In addition, a significant number of teachers dropped from the database, which means they stopped teaching ECS and any other computer science course in CPS. They may have begun teaching non-CS courses, left the district or left the industry. Data about their movement could affect our study's results. These and other study limitations are listed below and are considered in our recommendations regarding further research.

- Lack of qualitative data from current and former ECS teachers about their persistence.
- Lack of qualitative data from ECS PD instructors and coaches.
- Lack of Qualitative data from school administrators.
- Lack of information about PD policy – is it required by the principal?
- Lack of information about the impetus for teachers to teach ECS – mandatory or volunteer?
- Lack of information about teachers' future plans for teaching when accepting an ECS teacher position.
- Lack of information about the status and whereabouts of the Leaver Unknown teachers.
- Missing data – some data fields were incomplete.
- Lack of information about school size and type.

Recommendations

The 6th step of the CAFÉCS problem solving cycle involves using the study findings to inform CS department decision-making and next steps for ongoing research. Based on the above findings along with a thorough review of the relevant literature, we have two recommendations to support CPS ECS teacher persistence and six recommendations for the CAFÉCS research agenda.

Action Items

Strengthen the CPS Computer Science Teacher Community of Practice

When a teacher is new to teaching computer science, student outcomes suffer unless the teacher has support from other experienced teachers (Boyd et al., 2008; Yadav et al., 2016). Yadav (2016) reported that schools with only one computer science teacher are vulnerable to that teacher leaving. In CPS, ECS teachers on average have taught less than two years due to attrition. In fact, 40% of ECS teachers leave after their first year of teaching. There have been studies showing the benefit of active computer science teacher communities of practice within districts, which have served to empower and give agency to those teaching CS classes (Goode et al., 2020; Hu, et al., 2017; Ni et al., 2011) Ni and Guzdial (2012) identified the need in CS education of a presence of a CS community and reported that such a community positively influenced teachers' identity as a CS teacher. A study in Georgia with two cohorts of ECS teachers from diverse geographic and demographic settings found that the ECS PD and further connection to the CS education community resulted in improved teacher effectiveness and efficacy (Goode et al., 2020). A lack of a community of practice prohibited learning opportunities, which resulted in teachers having a poor sense of belonging at the school and led to higher rates of attrition. In addition, a strong community of practice where teachers build relationships and learn together may incentivize teachers to attend more of the ECS professional development to be with and learn with their colleagues. As we have learned, attending more of the ECS PD has a strong relationship with teacher retention. Therefore, it is recommended that ECS create an active Community of Practice to facilitate ongoing collaboration and connection.

District Communication Plan: Disseminate Research Data about Impact of ECS PD and ECS4All Coaching

Our study found that participation in the ECS professional development has a significant positive relationship with ECS teacher retention. Other studies have also shown that CS, and specifically ECS, teachers need robust professional development (McGee et al., 2018; Neutens & Wyffels, 2018) to increase student achievement and to lower student failure rates. Other studies have also shown that the school's provision of effective professional development and support directly and positively affects retention (Boyd et al., 2011; Darling-Hammond et al., 2017; Minarik et al., 2003; Moore et al., 2018; Neutens and Wyffels, 2018; Smith & Ingersoll, 2014; Pedersen & West, 2017). In addition, professional development that provides support and coaching are more effective. In other words, teacher participation results in improved teaching effectiveness, which leads to improved efficacy and student growth (Darling-Hammond et al., 2017; Donohoo, 2018). Early findings of CPS's ESC4All coaching program suggest that teachers had a positive experience with the program and that efficacy in their ability to deliver content was found to be a clear benefit of having a coach (Wachen et al., 2021). Therefore, a district-wide communication plan to help administrators understand the impact of coaching and ECS Professional Development on student achievement and teacher persistence is recommended. The goal of this plan would be to promote and increase participation in both ECS professional development and the ECS4All coaching program.

Further Research

Although we were better able to understand the role professional development and years of experience play in teacher retention, we were limited by the COVID-19 pandemic in that we were unable to reach out to teachers, coaches, and administrators to study working conditions and organizational characteristics. Better understanding the organizational factors that have been linked to retention specifically for ECS teachers would likely lead to meaningful ways to impact policy to remediate high attrition. Sociocultural factors such as teacher relations and collaboration, improving instructional rigor, quality-inclusive leadership, opportunities for growth and teacher leadership, competitive compensation, teacher agency and influence over decision making, and a school's provision of effective professional development and support are important factors influencing teacher attrition. The 5Essentials® measure some of these factors, but the measurement does not provide sufficiently comprehensive information about the sociocultural aspects of the experience of ECS teachers from the 5Essentials® to inform recommendations.

In addition, our study revealed a high rate of teachers in the category called Leaver-Unknown. 24.7% of ECS teachers in the study discontinued teaching ECS and subsequently dropped from the data set. Their destinations and employment endeavors were unknown. Obtaining this information could impact our ECS teacher persistence story and change the results of our statistical analysis.

Further, the strongest statistical relationship to ECS teachers continuing to teach ECS was participation in PD. The data did not tell us about school-level expectation for participation. Examining persistence in relation to expectations could further inform actions and strategies. There is also evidence regarding the importance of an effective coaching program to teachers' individual and group efficacy and teacher retention. It would be helpful to connect the data from the ECS4All Coaching Program to the ECS teacher persistence data to see if there is a relationship between participating in coaching and continuing to teach ECS.

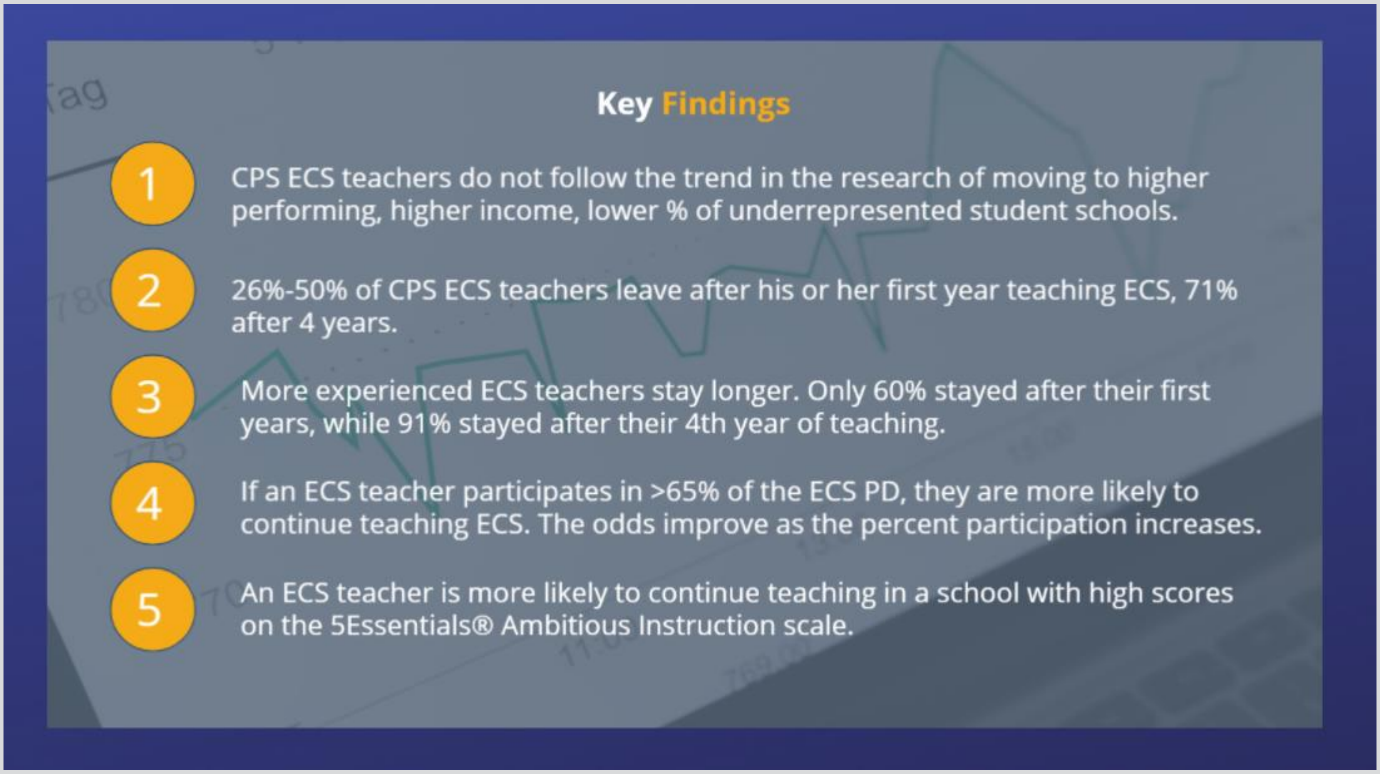
Our recommendations for further research are outlined below in Figure 10.

Figure 10. Recommendations for CAFÉCS Research

Conclusion

CAFÉCS, formalized in 2017, has been involved in the implementation and research of the Exploring Computer Science Curriculum and its associated professional development and ECS4All coaching program. Early results have shown ECS to accomplish the goals of increasing student interest in taking more high school level computer science courses and proclaiming interest in majoring in the subject in college. In addition, participation in the professional development program has shown promise in improving teacher efficacy and decreasing student failure rates. Also, the longer the ECS teacher is an instructor for the subject, the greater the student achievement. Further, a recent study of a small subset of teachers who participate in the ECS4All coaching program reported improving confidence in the content areas they must teach.

Unfortunately, a significant number of ECS teachers are leaving after one to two years of teaching, creating instability for the program, and possibly masking impact. Through the CAFÉCS problem-solving cycle (Henrick et al., 2021), CAFÉCS, in collaboration with the CPS CS Department, was interested in finding out the state of attrition and mobility of ECS teachers and whether any of the data they have collected would yield any insight into the problem. Our findings suggest that, on average, the teacher cohorts for the school years ending 2016, 2017, and 2018 lost 38% of the teachers in the cohort, and, by the end of the second year, an average of 53% had stopped teaching ECS. It was also of interest that ECS teachers are leaving at a 26-40% attrition rate during their first year of teaching. A logistic regression model looking at the relationship between ECS teacher persistence and student achievement, teacher demographics, school demographics, computer science degrees, computer science endorsements, participation in the ECS professional development, and years teaching found a significant positive relationship between participation in professional development, years teaching ECS, and school percentages of Free and Reduced Lunch and ECS teacher persistence. Other variables that had a significant, negative relationship to ECS teacher persistence were school percentages of underrepresented races, percentages of bilingual students, and percentages of students participating in the special education program.



Based on our findings, we make the following recommendations, which are supported in the literature. Strengthen the CPS CS Community of Practice, develop district communication plan to disseminate research data about impact of ECS PD and ECS4All Coaching, broaden the data sharing agreement to follow ECS teachers throughout CPS, conduct further research to understand more fully the work conditions affecting ECS teacher persistence, explore expectations for ECS PD attendance at the school level, connect ECS4ALL coaching program data to ECS persistence data from this study, and gather qualitative information from teachers, administrators, ECS PD instructors, and ECS coaches.

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Appendix A

Multi-Model Logistic Regression

	Dependent variable:						
	ECS Teacher Retention						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Minority Teacher: Yes	0.139	0.120	0.246	0.266	0.272	0.235	0.252
	(0.217)	(0.222)	(0.272)	(0.296)	(0.275)	(0.286)	(0.313)
CS Degree: Yes	0.276	0.302	0.213	0.651	0.388	0.245	0.741
	(0.368)	(0.369)	(0.447)	(0.481)	(0.500)	(0.462)	(0.548)
Gender: Male	0.085	0.098	0.155	0.046	0.179	0.255	0.190
	(0.219)	(0.221)	(0.257)	(0.279)	(0.259)	(0.267)	(0.292)
# Years Teaching ECS	0.299***	0.292***	0.240**	0.208**	0.253***	0.326***	0.283***
	(0.083)	(0.083)	(0.094)	(0.096)	(0.096)	(0.103)	(0.108)
Avg Student Grade		-0.060	-0.319	-0.198	-0.321	-0.398	-0.239
		(0.171)	(0.240)	(0.257)	(0.241)	(0.257)	(0.276)
Avg Composite SAT			-0.0001	0.0001	0.00003	0.002	0.002
			(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
# ECS Teachers			-0.122	-0.065	-0.120	-0.127	-0.077
			(0.092)	(0.097)	(0.093)	(0.095)	(0.100)
% Special Ed			-7.051**	-7.422**	-6.813**	-5.297	-5.328
			(3.086)	(3.268)	(3.093)	(3.327)	(3.518)
% Bilingual			-3.409**	-3.742**	-3.503**	-2.206	-2.419
			(1.567)	(1.736)	(1.570)	(1.697)	(1.871)
% Minority			-6.103**	-6.458**	-6.084**	-8.714***	-8.928***
			(2.540)	(2.653)	(2.544)	(2.875)	(2.985)
% Free and Reduced Lunch			4.867*	6.103**	4.988*	6.631**	7.884**
			(2.764)	(2.909)	(2.776)	(3.113)	(3.223)
SQRP Status: Intensive Support			0.095	0.729	0.048	0.006	0.567
			(0.455)	(0.526)	(0.458)	(0.477)	(0.555)
SQRP Status: Provisional Support			0.087	0.312	0.060	-0.193	-0.040
			(0.480)	(0.516)	(0.481)	(0.504)	(0.541)
School Size			-0.0001	-0.0001	-0.0001	-0.0003	-0.0003
			(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0003)
% Workshop Participation				2.387***			2.288***
				(0.505)			(0.528)
CS Adjacent Endorsement					-0.131		0.159
					(0.452)		(0.506)
CS Endorsement					-0.276		-0.089
					(0.328)		(0.361)

Five E - Environment						-0.031	-0.043
						(0.024)	(0.026)
Five E - Families						-0.001	-0.001
						(0.017)	(0.018)
Five E - Instruction						0.043**	0.050**
						(0.021)	(0.023)
Five E - Leaders						0.039	0.033
						(0.024)	(0.025)
Five E - Teachers						-0.041	-0.041
						(0.026)	(0.028)
Constant	0.448**	0.606	4.810	1.816	4.559	3.408	0.288
	(0.218)	(0.506)	(3.854)	(4.037)	(3.866)	(4.373)	(4.558)
Observations	439	436	351	331	351	340	320
Log Likelihood	-251.070	-250.315	-193.494	-169.261	-193.136	-181.217	-159.535
Akaike Inf. Crit.	512.139	512.630	416.987	370.522	420.273	402.434	365.071
Note:					*p<0.1; **p<0.05; ***p<0.01		