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Investigating Which Elements of ECS Teaching Motivate Subsequent Computer Science Course Taking*

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Abstract

A key strategy for broadening computer science participation in a large urban school district has been the enactment of a high school computer science graduation requirement. The *Exploring Computer Science* (ECS) curriculum and professional development program serves as a core foundation for supporting the enactment of this policy. ECS seeks to foster broadening participation in computer science through activities designed to engage students in computer science inquiry connected to meaningful problems. Prior research has shown that student motivation is an important mediating factor for the impact of ECS on broadening participation in future CS coursework. The current study was undertaken to investigate which ECS teaching practices influence students' motivation to pursue additional high school computer science coursework. Researchers used the Danielson Framework for Teaching and the Tripod 7C as indicators of ECS teaching practices and expectancy-value-cost as a proxy for the likelihood of students taking additional coursework. Researchers collected and analyzed video observations and student surveys from one ECS lesson from 21 teachers. The results indicate that ECS teaching practices related to equity play a significant role in supporting inquiry around important computer science content. Those practices related to inquiry and computer science content were in turn correlated with student measures of motivation to enroll in future CS coursework. The results of this research provide evidence of the central role that equitable teaching practices play in broadening participation in computer science by increasing student motivation to enroll in future CS coursework.

Keywords: Exploring Computer Science, implementation research, Expectancy-Value-Cost, computer science pathways

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1 Introduction

A key strategy for broadening computer science participation in The Chicago Public Schools (CPS) has been the enactment of a high school computer science graduation requirement. The *Exploring Computer Science* (ECS) curriculum and professional development program serves as a core foundation for the implementation of this policy. In Spring 2020, more than fourteen thousand students from the CPS graduated with one year of computer science credit. More than three-fourths of those students identify as Black or Latinx. Prior research in the district has shown that students' performance on end-of-course ECS assessments is equivalent by gender and race/ethnicity [1]. Students who take ECS are more likely to take additional high school computer science coursework and succeed on the AP CS A exam, than students who take other CS coursework as their first course [2, 3]. Thus, ECS is an important strategy for CPS to support broadening participation in computer science.

A key mediating factor for the impact of ECS on future course taking is student motivation. The motivational construct of Expectancy-Value [4] has been shown to correlate with both success in ECS [1] and the probability of taking additional coursework [2]. However, there is variability in the extent to which ECS teachers are impacting student motivation. In order to better support improvements in ECS teaching, we need to better understand which aspects of ECS teaching are correlated with motivation so as to focus professional development efforts on improving those key areas of ECS teaching.

In this paper, we introduce the key elements of ECS teaching as described by the developers of ECS and how those are supported through professional development. We relate those elements of teaching to a standardized observational teaching framework (Charlotte Danielson Framework for Teaching) [5] and a related student survey (Tripod 7C) [6]. We validated the use of the observational framework and student survey through observations of the teaching of ECS lessons. For the analysis, we examined the correlation between the Tripod 7C dimensions and students' Expectancy-Value.

2 What are the Key Components of the Exploring Computer Science Curriculum?

The ECS curriculum focuses on making computer science concepts accessible through authentic opportunities to use computer science concepts in meaningful ways. Key to the design of the ECS curriculum is what Nasir and Hand [7] refer to as deep engagement within a community of practice. Nasir and Hand contrasted the experiences of high school boys during their participation on the basketball team versus the same boys' participation in mathematics class. The results of their analysis revealed the stark differences in access to the domain, ability to play an integral role in the community, and opportunity to express oneself, which are the foundations of deep engagement. ECS supports deep engagement through three strands: equity, inquiry, and computer science content [8]. The foundational strand is equity. It is not possible to be successful with the other two strands unless all students are fully engaged in the course. Inclusiveness is supported by focusing on ideas that are meaningful to students. Activities in the curriculum provide space for teachers to incorporate students' background and culture. In addition, many of the activities focus on real-life issues in the community. For example, students can make games that communicate messages about healthy eating or about the plight of undocumented students [8, p. 76]. Thus, the equity strand of ECS supports deep engagement by providing avenues for students to see themselves in the material and express themselves.

Building on the foundation of the equity strand are inquiry-based activities in which students are "expected and encouraged to help define the initial conditions of problems, utilize their prior knowledge, work collaboratively, make claims using their own words, and develop multiple representations of particular solutions." [8, p. 75] In other words, given the myriad of skills that are collectively required to successfully engage in inquiry, deep engagement is brought about through the unique and integral role that each student contributes to the group inquiry.

As teachers successfully bring about equitable inquiry through the first two strands, students gain access to the domain content of computer science, which is the third strand. The logic model for this research is that a high-quality ECS implementation is one in which deep engagement is achieved through presenting problems that tap students' desire to express their unique identity and providing them integral roles to inquire about and access important domain content. Furthermore, it is hypothesized that a high quality ECS implementation that successfully engages students in a deep way will increase students' desire to continue to engage in computer science and increase the likelihood that students will pursue further studies in computer science in high school and eventually in college.

3 How Does Professional Development Support Teachers in Translating the ECS Strands into Classroom Teaching?

The ECS curriculum materials and activities represent one component of the ECS program. Given the significant shift in the nature of computer science teaching required for the successful implementation of ECS, teachers need purposefully designed professional development opportunities to successfully implement ECS. Only about one-fourth of the new ECS teachers in CPS (26%) are certified to teach computer science [9]. Teachers of traditional high school computer science courses typically need to shift from foregrounding the content of computer science to now foregrounding the application of computer science concepts. They need to shift from presenting concepts for students to master towards supporting students in developing their own understanding of the concepts. They frequently also need to confront their own, often unconscious, biases about who can be successful in computer science.

Meanwhile, about three-fourths of the new ECS teachers in CPS have never taught computer science and are certified in other subjects [9]. The ECS professional development is imperative for this group as it serves to introduce them to computer science concepts as well as the inquiry-based approach of ECS. Given the prevalence of low expectations in urban settings regardless of the subject area [10], these teachers will also likely need to confront their own biases about students' abilities to learn computer science.

The ECS professional development program is designed to prepare teachers to implement the inquiry-based activities while also guiding teachers to build a classroom culture that is inclusive of all students [11]. The ECS professional development begins with a weeklong summer workshop prior to teaching ECS. During the school year, teachers participate in quarterly, daylong workshops. In the summer after implementing ECS, teachers return for a second weeklong summer workshop. The participation of teachers over long time spans is a key dimension of effective professional development [12].

The first key component is that teachers engage in inquiry through a Teacher-Learner-Observer model. Each small group is assigned a lesson that the the group co-plans and teaches to the rest of the participants, who play the role of learners. After the lesson, all the participants engage in a reflective discussion about the experience from the point of view of the three ECS strands (Equity, Inquiry, and CS Content). This component of ECS professional development is consistent with what Desimone and Garet [12] call active learning in professional development. They found that active learning influences changes in teacher practices.

The second key component of ECS professional development is explicit discussion and reflection on equitable practices. Research-based practices for supporting inclusivity are discussed in the context of specific lessons and as part of the lesson debriefs. These practices are essential for creating a culture of caring that helps students feel they have the space to express themselves. Teachers also read sections of *Stuck in the Shallow End* [13], which provides rich case study descriptions of the roots of inequity in computer science. Each cohort of teachers builds trust as they engage in tough, open discussions about equity and through open, honest feedback on lesson design and implementation.

The developers of the ECS curriculum have conducted some of the first investigations to systematically document the impact of professional development on ECS teaching practices. Through classroom observations and case studies, they developed initial characterizations of the nature of classroom teaching that has emerged from the combined ECS curriculum and professional development program in Los Angeles. They have highlighted the prevalence of a variety of ECS teaching practices that are hallmarks of the ECS approach [14].

Below is a description of the key ECS teaching practices. They are lettered here so as to refer to these practices in a later section when they are aligned to the observational framework. Under the equity strand, researchers found that teachers were able to (a) connect computer science learning to everyday issues and (b) foster the participation of all students by encouraging collaboration. Under the CS Content strand, teachers were able to (c) model specific computing skills or processes, (d) explain computer science vocabulary, and (e) use student-driven final projects to create meaningful performance goals. However, there was greater variability in the extent to which teachers were able to implement practices under the inquiry strand. Teachers were commonly able to (f) encourage exploration and (g) use guided inquiry one-on-one or in small groups. However, teachers were less likely to be observed (h) scaffolding learning by making explicit connections between lesson or units, (i) using journal writing for metacognitive reflection, and (j) differentiating instruction. There was also significant variability in the nature of questions teachers used to (k) facilitate students' higher order thinking. The most frequent type of question was related to checking for student understanding, which is at the lowest level of Bloom's taxonomy [15]. The least frequent type of question required students to evaluate the ideas of others, which is at the highest level of Bloom's taxonomy.

These findings related to the commonly observed ECS teaching practices in LA classrooms are consistent with the program model of ECS. The activities in the ECS curriculum provide explicit scaffolding for making connections to everyday issues. Also, during the professional development, the teachers have ample opportunities to engage in guided inquiry and collaborate in small groups, providing a model for how to implement those practices with their students.

On the other hand, there were important ECS teaching practices that were observed less often in the LA classrooms, at about one-third the rate of the most commonly observed teaching practices in LA classrooms. There are several plausible explanations for the lack of transfer of some of the practices from the workshops to the classroom. One explanation for the lack of making explicit connections between lessons may lie in the nature of the Teacher-Learner-Observer model. Only selected lessons are presented at the workshop, and each teacher only engages in planning and teaching a subset of them. Without planning for and teaching connected lessons, it may be difficult to make connections across lessons. On the other hand, it may be that an understanding of the underlying unit structure of ECS is something that only develops over time as teachers implement the course.

Journal writing is a key component of reflection in the professional development, so it is unclear why it did not translate as readily into classroom practice. It is possible that the practice of reflection in journals is something that the teachers are uncomfortable with and need more time to acclimate to before successfully supporting students to implement it. It is also possible that the below-grade-level writing abilities of many students made journal writing cumbersome for teachers to implement. The below-grade-level reading levels may also be related to the infrequent levels of differentiation. Teachers may need additional support in general strategies related to scaffolding and differentiating English Language Arts tasks in a computer science classroom.

These results provide evidence that, even in the flagship implementation of ECS, while high-quality aspects of implementation are evident in classrooms, there is also variability in the implementation of several of the important ECS teaching practices. That variability can be used as an independent variable to analyze the relationship with student motivation, which predicts the likelihood that students will pursue additional computer science coursework. In addition, these results point to the weakness of relying solely on emergent coding of teaching practices. Though it is useful for capturing many of the curriculum-specific practices, there are many other general teaching practices that are not captured but do have an influence on the quality of implementation. Therefore, it is important to use an observation system that captures both important ECS-specific classroom practices as well as important general classroom practices.

4 What is the Best Way to Measure Important ECS-Specific as well as Important General Classroom Practices?

Good teaching is hard to measure, given that it manifests in a variety of ways. Recognizing good teaching is metaphorically similar to recognizing the light in a well-lit room. We often do not notice the light but, rather, notice the illuminated objects. In fact, it is common for children to believe that color is an inherent property of objects, rather than the interaction of light with the physical objects [16]. Likewise, high quality teaching tends to shift the focus of attention to the students. It is not uncommon for a principal to enter a well-functioning, student-directed classroom for the purpose of observing the teacher and tell the teacher that they will come back later when the teacher is teaching. The importance of light is usually most noticeable in its absence. Likewise, it is usually in the absence of high-quality teaching that the focus shifts to what the teacher is doing. For any good measurement tool to capture high-quality teaching in the context of an equity-focused, inquiry-based classroom it should behave like a prism. In a well-lit room, a prism can highlight the role of light by breaking it up into its constituent wavelengths. The light beam can then be characterized by the relative strength of the different wavelengths of energy. However, it is important to keep in mind that it is the light beam in totality that illuminates, not the sum of the wavelengths.

The findings in the previous section indicate that while the ECS professional development is successful at imbuing teachers with many of the classroom practices that undergird the three strands, there may be more general pedagogical strategies that are necessary components for successful implementation of ECS. Therefore, it is essential to use an observations framework that captures general teaching practices while also capturing the nuances of ECS-specific strategies. In this project, we use the Charlotte Danielson Framework For Teaching (FfT) to code classroom practice [5].

Prior research showed that the quality of teaching as measured by the FfT is predictive of student growth in elementary reading and math assessments [17]. Students showed the greatest growth in test scores in classrooms where teachers received the highest Fft ratings. Conversely, students showed the least growth in test scores in the classrooms where teachers received the lowest ratings. The researchers found some systematic variation in the ratings by grade level and subject area.

These findings in the variability of ratings are consistent with other STEM initiatives [18]. Teachers in STEM subjects receive overall lower ratings on FfT than English Language Arts teachers. Teachers at the 9th grade level also receive lower ratings than teachers of 10th-12th grade students. In addition, novice teachers receive lower ratings than veteran teachers. Given that roughly three-fourths of the ECS teachers are new to computer science and are primarily teaching 9th grade students, these combined findings suggest that they will likely have overall lower ratings of the pedagogical practices.

To ensure that the FfT captures important dimensions of ECS teaching practices, we aligned the observed ECS teaching practices in LA classrooms [14] with the FfT dimensions. This alignment was validated with Gail Chapman, one of the ECS authors. Table 1 shows the results of that alignment, organized around the three strands of ECS. The first column represents the observable dimensions from the Classroom Environment and Instruction domains of the FfT. In parentheses we show the percentage of teachers in CPS who were rated as proficient or distinguished on that dimension [17]. The second column shows the corresponding components of ECS classroom practice that align to each of the dimensions of FfT.

The first FfT dimensions under the **CS Content strand** is *Establishing a culture of learning*. Within that dimension teachers are, among other things, expected to convey high expectations for what is to be learned and expect students to produce high quality work. This dimension is aligned with *Facilitates guided inquiry during the development of student-driven final projects* since that ECS practice require teachers

Table 1: Alignment of FfT with Important ECS Teaching Practices (Percentages Represent General Levels of Proficiency for CPS Teachers)

FfT Observable Dimensions	**Important ECS Teaching Practices**
CS Content	
2B. Establishing a culture of learning (76%)	(e) Facilitates guided inquiry during the development of student-driven final projects
3A. Communicating with students (78%)	(c) Models specific computing skills or processes (d) Explains computer science vocabulary
Inquiry	
3A. Communicating with students (78%)	(h) Scaffolds learning by making explicit connections between lessons or units
3B. Using questioning and discussion techniques (55%)	(k) Facilitates students' higher order thinking
3C. Engaging students in *inquiry* learning (57%)	(f) Encourages exploration (g) Uses guided inquiry in one-on-one or in small groups (j) Differentiates instruction
3D. Using assessment in instruction (67%)	(i) Uses journal writing for metacognitive reflection
Equity	
2A. Creating an environment of respect and rapport (78%)	(b) Encourages collaboration
3C. Engaging students in *meaningful* learning (57%)	(a) Connects computer science learning to equity and everyday issues
Classroom Management	
2C. Managing Classroom Procedures (75%) 2D. Managing Student Behavior (64%)	

to communicate meaningful performance expectations through the project requirements. The second FfT dimension under the CS Content strand is *Communicating with students.* The aspects of this dimension that fall under the CS Content strand are providing clear explanations of content without errors. This aspect of the dimension is aligned with the ECS practices of *Models specific computing skills or processes* and *Explains computer science vocabulary.*

The first FfT dimension under the **Inquiry strand** is *Communicating with students*, which requires teachers to explain the purpose of the lesson and provide clear directions. This dimension aligns with the ECS practice of *Making explicit connections between lessons.* The second dimension is *Using questioning and discussion techniques.* This dimension aligns with the ECS practice of *Facilitate students' higher order thinking.* Both the FfT dimension and the ECS practice require teachers to pose cognitively challenging questions with multiple answers and support all students to actively participate in the resulting discussions. The third dimension is *Engaging students in learning.* We have added the qualifier of *inquiry* to highlight the alignment to the Inquiry strand. The ECS practices aligned to this dimension are *Using guided inquiry and encourages exploration.* Also, the *Engaging students in learning* dimension requires that teachers differentiate instruction to meet the needs of all students. The fourth dimension under the Inquiry strand is *Using assessment in instruction*, which requires the teacher to collect evidence of student learning and use that evidence to guide further instruction. That dimension is aligned with the ECS practice of *Using journal writing for metacognitive reflection.*

The first FfT dimension under the **Equity strand** is *Creating an environment of respect and rapport*, which requires teachers to create an environment in which the teacher is respectful of students and students are respectful of others. Teachers also acknowledge students' backgrounds and home lives. The ECS practice that most closely aligns to this dimension is *Encourages collaboration*, which requires teachers to ensure students are respectful of each other. The second dimension repeats *Engaging students in learning*, but this time the emphasis is on the *meaningfulness* of the activities. This dimension is aligned to the ECS practice *Connects computer science learning to everyday issues.* In addition to these two ECS teaching practices, there is a belief among the ECS developers that more work needs to be done to capture the proactive ways in which ECS teachers should support the Equity dimension [19].

The last two dimensions of the Classroom Environment domain of FfT are *Managing classroom procedures* and *Managing student behavior.* There are no corresponding ECS practices directly related to these dimensions. These are general teaching practices that do not have unique elements of ECS practice. However, they are foundational for all of the other practices. If teachers are not able to manage classroom procedures and student behavior, it is very unlikely that they will be able to successfully implement any of the other practices [18]. On the flip side, however, the ECS curriculum is designed to build a student-centered learning community. It is possible that if ECS teachers focus on the equity and inquiry practices, it will also support these classroom management dimensions. Overall, the alignment represented in Table 1 provides a conceptual validation that FfT captures the ECS-specific teaching strategies while also aligning to important general teacher practices.

5 How are the ECS Curriculum Components and ECS Teaching Practices Perceived by Students?

The Tripod 7C [6] is a survey of student course experiences that was empirically validated with the FfT as part of the Gates Foundation-funded Measurement of Effective Teaching project [20]. Teachers from a variety of subject areas and grade levels were observed and scored using FfT. Their students were surveyed about their course experiences with the teacher using the Tripod 7C survey. Ferguson and Danielson examined the relationship between dimensions of the Tripod 7C and the dimensions on FfT to validate the ways in which students experience the various dimensions of FfT.

Table 2: Alignment of FfT Dimensions with the Tripod 7C Dimensions

FfT Observable Dimensions	**Tripod 7C**
CS Content	
2B. Establishing a culture of learning	• Challenge
3A. Communicating with students	• Clarify
Inquiry	
3A. Communicating with students	• Confer
3B. Using questioning and discussion techniques	• Confer • Consolidate
3C. Engaging students in *inquiry* learning	• Challenge
3D. Using assessment in instruction	• Consolidate • Clarify
Equity	
2A. Creating an environment of respect and rapport	• Care
3C. Engaging students in *meaningful* learning	• Captivate
Classroom Management	
2C. Managing Classroom Procedures 2D. Managing Student Behavior	• Control

Table 2 shows the empirical alignment of dimensions of the FfT to the dimensions of the Tripod 7C survey [6], organized around the three strands of ECS. The first column represents dimensions from the Classroom Environment and Instruction domains of the FfT. The second column shows the corresponding components of the Tripod 7C survey that were correlated to each of the dimensions of FfT.

Under the **CS Content strand** there are two Tripod dimensions that were correlated to FfT dimensions. *Challenge* refers to the extent to which the students acknowledge that the teacher places high expectations for rigor and performance. *Challenge* was correlated with *Establishing a culture of learning*. *Clarify* refers to the extent to which students feel that the teacher explains concepts well. *Clarify* is correlated to the CS Content part of the *Communicating with students* dimension.

Under the **Inquiry strand** there are four Tripod 7C dimensions that are correlated to Fft dimensions: *Challenge* and *Clarify* as discussed above and two others. *Confer* refers to the extent to which the teacher elicits ideas from students and supports student discussion. This 7C dimension is correlated to both the *Using questioning and discussion techniques* and the *Communicating with students* dimensions. *Consolidate* refers to the extent to which the teacher makes the learning experiences coherent for the students, giving feedback, and checking for understanding. The *Consolidate* dimension is correlated to *Using questioning and discussion techniques* and *Using assessments in instruction*. The *Challenge* dimension is correlated to the inquiry aspect of *Engaging students in learning*, and the *Clarify* dimension is correlated to *Using assessment in instruction*.

Under the **Equity strand** there are two Tripod 7C dimensions correlated to FfT dimensions. *Care* relates to whether the teacher develops supportive relationships with students and is attentive to their feelings. This dimension is correlated to *Creating an environment of respect and rapport*. *Captivate* refers to the extent to which the teacher stimulates interest in the lessons. This 7C dimension is correlated to the meaningfulness aspect of *Engaging students in learning* in ECS.

The last dimension of the Tripod 7C survey falls under classroom management. *Control* is related to the degree to which the class is well-behaved and the teacher is able to manage the class so that learning can occur. This dimension is empirically correlated to the *Managing Classroom Procedures* and *Managing Student Behavior* dimensions of FfT.

6 How do Students' Experiences in the Course Inspire them to Pursue Future Coursework?

The Expectancy-Value-Cost model [21] was used as a mediator for predicting the probability that students will take another computer science course after ECS. The Expectancy-Value model is based on decades of research on college students' choices about majors [4]. The basic premise is that students' choice of major is dependent on how much value they put on the field as well as their expectation that they will be successful. Eccles' research has shown that people's expectations for success develops over time based on experiences with the relevant school subjects and individuals' subjective interpretation of those experiences. Eccles' research has also shown that the value that people place on a particular field develops over time and is influenced by a number of social factors, such as enjoyment, perceptions of whether the major will meet personal goals, as well as family, friends, and educators' opinions.

The Expectancy-Value model has been widely used in a variety of areas to predict future choices and behavior. For example, Eccles [22] conducted a longitudinal study of around 1,000 adolescents from south-eastern Michigan. The study began when the adolescents were seniors in high school. Eccles and her colleagues surveyed the students' occupational aspirations as well as dimensions of the Expectancy-Value model as it relates to a wide variety of occupations. They analyzed the relationship between the ratings for various occupational fields and the resulting occupational choices. Over time, the adolescents' eventual job choices were strongly predicted by Expectancy-Value, not only in terms of which occupations were chosen, but also in which choices were not selected. When Expectancy and Value were high for a given field, it was likely the career choice of that adolescent. Conversely, if either Expectancy or Value were low for a given field, it was unlikely to be the career choice of that adolescent.

Of the corpus of research on the link between Expectancy-Value and future aspirations, there are two studies in particular that are directly related to this project. The first is a study of the pedagogical approaches that support growth in Expectancy-Value [23]. The study took place at three middle schools in Greece where students were just finishing their first year of instruction in information technology. The students were surveyed on their Expectancy-Value as it relates to information technology. They were also surveyed on the extent to which their teachers used practices that made meaningful connections to the real-world and that involve active learning. These practices are similar to the Equity and Inquiry strands of ECS. The results indicate that exposure to meaningful experiences significantly predicted growth in the value dimension. However, the extent to which students engaged in active learning did not predict changes in the expectancy dimension. Since there was no characterization of the extent to which teachers actually engaged students in active learning, it is hard to draw firm conclusions about active learning. This study provides evidence for the hypothesis that a high quality implementation of the ECS curriculum could increase the value students place on computer science by engaging them in meaningful tasks.

In a second study of interest, Dickhäuser and Stiensmeier-Pelster [24] examined computer science course selection at five middle schools in Germany. Students were free to select computer science as one of their elective choices. The Expectancy-Value model was used to predict course selection among boys and girls. Boys and girls with high Expectancy-Value were equally likely to select a computer science course. However, Expectancy-Value was significantly different between girls and boys, which explained a significant amount of variation in course selection between boys and girls. Boys were higher in both expectancy and value.

In this project, we used a validated shortened version of the Expectancy-Value-Cost survey. Barron and Hulleman [21] created separate versions of the survey questions specific to middle school and to high school. They conducted an extensive factor analysis to pare down the survey length to the shortest possible length that still provides high levels of reliability and construct invariance. In doing so, they discovered that the best factor structure treats Cost as a separate construct rather than as a negative valence within the Value dimension. The resulting survey instrument takes less than 10 minutes to administer, so it can be administered more frequently.

Prior research on Tripod 7C has shown that the *Challenge* and *Control* dimensions, which Ferguson and Danielson refer to as *Academic Press*, are the best predictors of academic performance. These dimensions are related to the *Expectancy* dimension. The remaining five dimensions relate to supporting students' well-being in the classroom and their future aspirations, which is related to the *Value* dimension. Given the recentness with which Cost has been treated as a separate dimension, there is no research on the interrelationship of the construct with other dimension. However, we hypothesize that a lack of rapport and a lack of classroom management will likely increase the perceived costs of computer science.

7 Research Design

ECS teachers in CPS were invited to participate in the research in school years 2015–16 through 2017–18. Researchers visited the ECS summer workshops to invite new teachers to participate. In addition, researchers sent email invitations to active veteran ECS teachers who were no longer participating in the workshops. There were 21 ECS teachers who accepted the invitation and opened their classrooms to observations by researchers.

Teachers were observed from 1 to 4 times for a total of 48 lessons observed. Lessons were sampled across the range of ECS units and scheduled at the convenience of the teacher. Given that the teachers could choose which lessons for researchers to observe, it is likely that teachers selected lessons they were most comfortable teaching. Prior to the observation, researchers conducted a phone conference with the teacher to discuss what lesson the students would be working on so as to plan out the best vantage point for capturing the crux of the lesson. In addition, teachers were informed of which students had not given permission to be on camera. Teachers were able to rearrange the seating so that all of the students without permission were grouped together, which helped us to minimize their appearance on the recording. Those students who appeared on the recording without permission were blurred so that they were unrecognizable.

For the video recording, researchers used an iPad mini mounted on a Swivl robot. The Swivl comes with a separate Bluetooth microphone and tracking device worn around the teachers' neck. The audio is transmitted from the tracking device to the Swivl and recorded on the iPad. The Swivl base tracks the movement of the teacher so that the iPad camera remains focused on the teacher. Researchers used a second Swivl robot to focus on a specific group in the classroom. The Swivl allowed up to five microphones to be connected to the same base in order to capture individual student comments during the group discussions. Researchers used the Swivl Cloud service for uploading the videos from the iPad.

At the end of the lesson, students completed a short survey on expectancy-value-cost [21] and the Tripod 7C [6].

7.1 Scoring

Four researchers successfully completed the official Fft certification process conducted through TeachScape, which is the official state certifier for school administrators to be endorsed to conduct teacher evaluations. All four scorers rated the same two initial videos for each of the eight observable FfT dimensions. To reinforce inter-rater reliability, the scorers discussed discrepancies and came to a consensus on the scores for the first two videos. The remaining videos were scored independently by the scorers. For teachers with multiple videos, researchers sampled one video to include in the analyses so that teachers with multiple videos would not be over sampled in comparison to teachers who only had one video. This resulted in a sample of 21 lessons.

Table 3: Percent Proficiency on Charlotte Danielson Dimensions for CPS Teachers as a Whole and ECS Teachers

FfT Observable Dimensions	**CPS**	**ECS**
2A. Respect and Rapport	78%	81%
2B. Culture of Learning	76%	67%
2C. Manage Classroom Procedures	75%	71%
2D. Manage Student Behavior	64%	81%
3A. Communicating with Students	78%	86%
3B. Using Questioning and Discussion Techniques	55%	43%
3C. Engaging students in learning	57%	81%
3D. Using assessment in Instruction	67%	71%

8 Results

Table 3 shows the percentage of CPS teachers in general and ECS teachers in the study demonstrating proficiency in each of the FfT dimensions during the observed lesson. Both the district and ECS teachers are least proficient at *Using Questioning and Discussion Techniques* (3B). On *Engaging Students in Learning* (3C), fewer CPS teachers demonstrated proficiency (57%) in comparison to ECS teachers who had a higher percentage of teachers who demonstrated proficiency (81%). For the other FfT dimensions, the percentage of district teachers demonstrating proficiency was within 10% of the percentage of ECS teachers demonstrating proficiency, with the exception of *Managing student behavior* (3A), where 17% more ECS teachers demonstrated proficiency than CPS teachers. This difference in *Managing student behavior* may indicate a selection bias in that teachers who have well-managed classrooms may have been more likely to have allowed the researchers to observe their classes.

Researchers examined the relationship between the FfT dimensions and the Tripod 7C. Given that the FfT and Tripod 7C data are ordinal, researchers used the Kendall Tau rank correlation. Table 4 provides the Kendall Tau correlation table between the FfT dimensions and the 7C scales. The boxes highlighted in green represent statistically significant correlations. The results indicate that the 7C *Confer* dimension is a key dimension as it is statistically correlated with all of the FfT dimensions. The *Confer* scale measures the extent to which the teachers give students time to explain their ideas and the teachers respect the ideas that students share. This construct is also a core value of the ECS Equity strand.

The results also indicate that the FfT dimension of *Create an environment of Respect and rapport* (2A) is a key dimension. It is aligned to the ECS Equity strand. In turn, it correlates with one Tripod 7C dimension in the ECS Inquiry strand (*Confer*) and one Tripod 7C dimension in the CS Content strand (*Clarify*). It also correlates with classroom management (*Control*). These results provide evidence that equity is the foundational one of the ECS strands.

It is notable that none of the FfT dimensions are correlated with *Captivate* and only one FfT dimension is correlated with *Challenge*. In the METS study [6], *Engaging students in learning* was correlated with *Challenge* and *Captivate*. In our research, ECS teachers had a higher rate of proficiency on *Engaging students in learning* than the district teachers. It is possible that the ECS curriculum materials themselves are the source of challenge and captivation. This warrants further study.

Several of the FfT dimensions were negatively correlated with the *Consolidate* dimension. These results are not consistent with prior research on the relationship between 7C and FfT [6], which warrants further investigation.

Researchers examined the correlation between the 7C dimensions and Expectancy-Value-Cost (Table 5). Prior research has shown that the Expectancy, Value, and Cost dimensions predict ECS learning outcomes and the likelihood of pursuing additional CS coursework in high school [1]. All three of the dimensions

Table 4: Correlations Between Charlotte Danielson Framework for Teaching Dimensions and Tripod 7C Scales

FfT Observable Dimensions	**Care**	**Captivate**	**Confer**	**Challenge**	**Consolidate**	**Control**	**Clarify**
2A. Respect and Rapport	0.07	0.25	0.31	0.17	-0.06	0.36	0.29
2B. Culture of Learning	-0.02	0.10	0.41	0.11	-0.33	0.17	0.14
2C. Manage Classroom Procedures	0.00	0.08	0.40	0.19	-0.33	0.36	0.23
2D. Manage Student Behavior	0.05	0.13	0.31	0.00	-0.27	0.37	0.11
3A. Communicating with Students	-0.14	0.19	0.30	-0.31	-0.34	0.07	-0.10
3B. Using Questioning & Discussion Techniques	0.03	0.25	0.33	-0.03	-0.25	0.09	0.03
3C. Engaging students in learning	-0.16	0.26	0.35	0.10	-0.22	0.20	0.06
3D. Using assessment in Instruction	0.06	0.01	0.28	-0.01	-0.18	0.22	0.09

Table 5: Correlations Between Tripod 7C Scales and Expectancy-Value-Cost Scales

Tripod 7C	**Expectancy**	**Value**	**Cost**
Care	0.140	0.098	-0.209
Captivate	0.097	0.061	-0.049
Confer	0.456	0.277	-0.422
Challenge	0.304	0.393	-0.267
Consolidate	0.089	0.168	0.020
Control	0.445	0.462	-0.400
Clarify	0.445	0.473	-0.359

that correlate with *Create an environment of respect and rapport* are also correlated with all three scales of Expectancy-Value-Cost. The only other dimension that is correlated with all three scales is *Challenge*, which is correlated with only one of the FfT dimensions.

9 Conclusion

In this research, we sought to understand which ECS teaching practices are correlated with student motivation, which predicts the likelihood of students pursuing additional computer science coursework. The results provide evidence of the central role of the ECS Equity strand. One of the ways that the ECS Equity strand was operationalized in this research was *Creating an environment of respect and rapport*. Danielson [5] describes the importance of this dimension as, "In a respectful environment, all students feel valued, safe, and comfortable taking intellectual risks." (p. 33) Such an environment correlates with students' feelings that their voice is valued during inquiry (*Confer*), their teachers provided good explanations of CS Content (*Clarify*), and their teachers maintained control of the classroom (*Control*). All three of these dimensions are correlated with Expectancy-Value-Cost, which are all measures of motivation, which is a key factor in broadening participation.

Research that relates classroom practices to student motivation to pursue additional computer science can provide strategic guidance on how teachers can improve their practice to better support broadening participation. In this research, ECS teachers were least proficient in *Using questioning and discussion techniques*, which is conceptually most closely aligned with the *Confer* dimensions of 7C. A core pedagogical strategy for supporting student discussion is the Think-Pair-Share routine associated with ECS journal reflections, which researchers in LA also found was a less prevalent ECS practice [14]. CPS is exploring instructional coaching as a supplement to the ECS workshops to help teachers with translating what they learn in the workshops into classroom practice. This research has guided the coaches to focus on support for student discussion knowing that it plays a central role in broadening CS participation by increasing student motivation to enroll in future CS coursework.

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