Does Exploring Computer Science Increase Computer Science Enrollment?

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Abstract

This study investigated the impact of the Exploring Computer Science (ECS) program on the likelihood that students of all races and gender would pursue further computer science coursework in high school. ECS is designed to foster deep engagement through equitable inquiry around computer science concepts. The results indicate that students who pursued ECS as their first course were more likely to pursue another course relative to taking a traditional course as the first course.

Keywords—high school computer science, Exploring Computer Science

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I. Objective

Exploring Computer Science (ECS) is a curriculum and professional development program that was developed at the University of California at Los Angeles (UCLA) with the goal of contributing to the broadening of participation of and increasing equity for women and minorities in the field of computer science (Margolis et al., 2012). The ECS curriculum seeks to accomplish the goal of broadening participation by introducing students to the field of computer science and computational practices in a way that makes the field relevant, engaging, and stimulating for a diverse population of students. The ECS curriculum is composed of activities that are designed to engage students in computer science inquiry around meaningful problems. 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. Prior studies have successfully documented the impact of the professional development on the quality of ECS implementation (e.g., Goode, Margolis, & Chapman, 2014; Margolis & Bernier, 2011).

With continued support from the National Science Foundation, a variety of university-based and community-based organizations are adopting the ECS program and rapidly expanding its reach to cities across the United States (Exploring Computer Science, 2017). This study takes place in the Chicago Public Schools, which has adopted ECS as a foundation for broadening participation in computer science, starting with a pilot during the 2011–12 school year. Our previous research found that students perceived the ECS course to be relevant and engaging and, as a consequence, increased both their interest in taking another computer science course in high school as well as the probability of actually taking another computer science course. (Dettori, Greenberg, McGee, & Reed, 2016; McGee et al., 2017). Although increasing enrollment in further computer science is not a central goal for the ECS developers, it can be a valuable consequence of providing students with meaningful experiences in computer science. In this research, we seek to extend our prior work to investigate the extent to which successful completion of the ECS course predicts the likelihood that students will take another computer science course in high school in comparison to taking a traditional computer science first. Our research is guided by the following research question:

> *Does successful completion of an ECS course influence the probability that students will take additional computer science coursework in high school relative to successful completion of other computer science courses?*

Subsequent to completing ECS, students in this district have a variety of options for taking other high school computer science courses at their schools, such as game design, web development, and database programming, in addition to AP computer science. Therefore, students who complete an ECS course have a range of options to take another computer science course. The availability of a variety of computer science courses at the schools in this study allows us to use students' actual decisions about taking another computer science course as the outcome measure of interest. Given the significant number of women and minority students who have participated in ECS courses in this district, the conclusions from this research will be directly applicable to informing efforts to use ECS as a means to broaden participation in computer science.

II. THEORETICAL FRAMEWORK

Key to the design of the ECS curriculum is what Nasir and Hand (2008) 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. When computer science is taught as an abstract academic subject, it privileges access to computer science to mostly Caucasian, male students (Margolis, Estrella, Goode, Holme, & Nao, 2010). In order to play an integral role in such classrooms, students must master abstract programming for programming's sake. Therefore, the opportunity to express oneself is limited to narrow abstract programming ideas. Typically, computer science courses in both high school and college have been taught in this abstract way (Margolis & Fisher, 2002). For non-Caucasian students in low-income neighborhoods, computer instruction has tended to focus on computer applications and tends to lack opportunities for engaging in collaborative inquiry (Margolis et al., 2010; Reich, Murnane, & Willett, 2012).

The ECS curriculum is designed to engender deep engagement with important computer science concepts by mimicking important features of communities in which youth participate outside of the classroom. General technology use outside of school by youth of all races and genders tends to revolve around making social connections and working on practical problems (Ito et al., 2008). Thus, access to technology outside of school is broad and students have opportunities to play an integral role within their community. In addition, students have opportunities to express themselves. Reorienting computer science instruction around problem-solving experiences that are meaningful to students has the potential to increase access to computer science content, provide students with integral roles, and create opportunities for students to express themselves (Christensen, Knezek, & Overall, 2005; King, Bond, & Blandford, 2002). At the college level, computer scientists at Carnegie Mellon made progress at increasing the representation of women in their computer science program by making such changes to the nature of instruction in their introductory courses. Faculty significantly changed the course assignments to highlight problem-solving as a primary component. Students develop technical fluency through solving problems of interest (Margolis & Fisher, 2002).

Likewise, the high school ECS curriculum focuses on making computer science concepts accessible through opportunities to use computer science concepts in meaningful ways. The curriculum supports deep engagement through three strands (equity, inquiry, and CS content) (Margolis et al., 2012). The foundational strand is equity. 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 (Margolis et al., 2012, p. 76). Thus, the equity component of ECS supports deep engagement by providing avenues for students to express themselves.

Resting upon equity 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." (Margolis et al., 2012, 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. If 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.

III. ECS Professional Development

Curriculum materials and activities represent one component of the ECS program. Given the significant shift in the nature of computer science teaching required for successful implementation of ECS, teachers need extended professional development to successfully adapt to the ECS model of teaching (Goode et al., 2014). The ECS professional development program is intentionally designed to prepare teachers to implement the inquiry-based activities while also guiding them to build a classroom culture that's inclusive of all students (Goode et al., 2014). Professional development begins with a weeklong summer workshop prior to implementing ECS. There are five key components of the ECS professional development model, the first being that teachers engage in the process of collaborative inquiry in small groups in the same way that students will engage in inquiry. The second component is that, throughout the first week, teachers participate in inquiry specifically through a teacher-learner-observer model. Each small group is assigned a lesson in which the group co-plans and teaches the lesson to the rest of the participants, who experience the lesson as learners. After the lesson, all the participants engage in reflective discussion about the experience from the point of view of the three ECS teaching strands (equity, inquiry, and CS content). These first two components of ECS professional development are consistent with what Desimone and Garet (2015) all active learning in professional development. Their review of professional development found that active learning was an important component of professional development as it significantly influenced changes in teacher practices.

The third component of ECS professional development is explicit discussion and reflection on equitable practices. During the workshop, the teachers read sections of *Stuck in the Shallow End* (Margolis et al., 2010), which provides rich case study descriptions of the roots of inequity in computer science. The fourth and fifth components of ECS professional development are meant to sustain teacher development over long time spans, which is another key dimension of effective professional development (Desimone & Garet, 2015). The fourth component is ongoing professional development during the school year and a second weeklong workshop the summer after their first year of implementation. The fifth component of ECS professional development is the development of a professional learning community. It begins in the summer workshop through the formation of small groups that engage in collaborative inquiry. It's also built up through the trust that teachers develop as they engage in tough, open discussions about equity as well as through open, honest feedback on lesson design and implementation during the workshops.

IV. Methods/Data

A. *CPS District Data*

Through a data sharing agreement with the district, we were provided with data about the students in this sample. The district provided the students' cumulative GPA for the year they completed an ECS or CS course, their course grade, grade level and demographic information about race, gender, and designation as special education, English Language Learner, and/or free or reduced lunch participation. The district also provided information about any subsequent computer science courses students completed in the years after completing ECS or their first CS course. This last variable will be the dependent variable for the study to provide evidence on

TABLE I: DEMOGRAPHIC INFORMATION ABOUT STUDENTS WHO COMPLETED ECS OR CS AS THEIR FIRST CS COURSE RELATIVE TO CPS AS A WHOLE

Demographic Information	ECS	CS	District
% Hispanic	44%	46%	43%
% African American	39%	33%	43%
% Caucasian	10%	12%	8%
% Asian	5%	7%	3%
% Female	45%	43%	-
% Free or Reduced Lunch	86%	82%	85%
% Special Education	14%	10%	15%
% ELL	6%	3%	6%
% taking another CS course	43%	26%	-

whether students' experiences in ECS predict future course taking.

B. *Population*

This study took place during the 2011–12 through 2015–16 school years. At the time of the study, ECS was an elective course for students; therefore, students in the district typically opted in to take computer science. There were 8,926 students who took an ECS course and 17,465 students who took another course as their first computer science course. For the sake of comparison, we limited the analyses to those schools that offered both ECS and other CS courses. We also eliminated students who took their first course in senior year since they would not have an opportunity to take another course. There were 14,916 students who completed an initial computer science course at a school that offered both ECS and other CS courses. There were 6,663 students who completed ECS as their first CS course and 8,253 who completed another course as their first CS course. Table I shows the demographic information for students who took ECS as their first course versus another course as their first computer science course at schools that offered both. The demographics for these two populations are very similar and are consistent with the overall population for the school district. Almost twice as a many ECS students went on to take another CS course as did students who took another course as their first CS class.

V. RESULTS

Since students were nested within classes, we conducted hierarchical linear modeling on the probability of taking another CS course using *WHLM* software version 7.24q. Since the probability of taking another CS course is a dichotomous variable, we used logistic regression. In the equation below, η_{ijk} represents a logit score, which is the log of the odds that a student will take another CS course. Taking the exponential of the logit gives the odds, or the probability of taking another CS course divided by the probability of not taking another CS course. The predicted probability can be calculated by dividing the odds by 1 plus the odds. Positive numbers indicate that the variable increases the probability that students will take another CS course, and negative numbers indicate that the variable decreases the probability that students will take another CS course.

TABLE II: RESULTS OF LOGISTIC REGRESSION PREDICTING WHETHER STUDENTS TOOK ANOTHER COMPUTER SCIENCE COURSE

Probability of Taking Another CS Course	**Coefficient**	**Standard Error**	**t-ratio**	**p value**
Average	**-1.40**	**0.22**	**t(29) = -6.27**	**p<0.001**
ECS Class	**0.93**	**0.04**	**t(14,876) = 20.81**	**p<0.001**
Student Characteristics				
Cumulative GPA	**0.12**	**0.03**	**t(14,876) = 3.58**	**p<0.001**
Course Grade	**0.23**	**0.03**	**t(14,876) = 9.25**	**p<0.001**
Junior	**0.36**	**0.05**	**t(14,786) = 7.23**	**p<0.001**
Male	**0.46**	**0.04**	**t(14,786) = 12.00**	**p<0.001**
Hispanic	**-0.12**	**0.06**	**t(14,786) = -2.22**	**p=0.026**
African-American	-0.11	0.08	t(14,786) = -1.42	p=0.155
Special Education	-0.05	0.06	t(14,786) = -0.93	p=0.353
Free and Reduced Lunch	0.02	0.03	t(14,786) = 0.71	p=0.480
ELL	**-0.25**	**0.09**	**t(14,786) = -2.83**	**P=0.005**

There were two levels to the HLM model. At the first level were the student characteristics, which included the cumulative GPA in the year in which the student completed their first CS course, the annual grade received in the first CS course, whether the student was a junior, male, African American or Hispanic in comparison to other races, in special education, participated in free or reduced lunch program (FRL) or participated in the English language learning program (ELL). All of these factors were fixed effects. Cumulative GPA and course grade were group mean centered. There were no course variables included in model at level 2.

$$\eta_{ti} = \pi_{0i} + \pi_{1i}*(ECS\_CLAS_{ti}) + \pi_{2i}*(MALE_{ti}) + \pi_{3i}*(AFRICAN\ AMERICAN_{ti}) + \pi_{4i}*(HISPANIC_{ti}) + \pi_{5i}*(JUNIOR_{ti}) + \pi_{6i}*(SPECED_{ti}) + \pi_{7i}*(FRL_{ti}) + \pi_{8i}*(ELL_{ti}) + \pi_{9i}*(GPA_{ti}) + \pi_{10i}*(CS\_GRADE_{ti})$$

The results are in Table II. The statistically significant variables are bolded. Students with higher cumulative GPA's and higher course grades were more likely to take additional CS courses. The probability of a male students taking another CS course is about 10% higher than female students. Juniors are about 8% more likely to take another CS course than freshman and sophomores. Hispanic students and students participating in the ELL program had a lower probability of taking another CS course. After controlling for prior achievement and these demographic variables, students who took an ECS class were more likely to pursue another computer science course than students who started with a traditional computer science course. For example, a female, Hispanic student with an average GPA who took ECS and received an average grade in the class has a 36% probability of taking another CS course in comparison to a female, Hispanic student with an average GPA who took another CS as her first class and received an average grade in the class (18%).

VI. CONCLUSION

The design of the ECS course weaves together three strands of equity, inquiry, and CS concepts. With equity at the core, the professional development program is designed to prepare teachers to develop strategies for reaching all students. Prior research has shown that students value the course experience and the extent to which they value the course predicts the probability that students will take additional computer science coursework. In this study, we sought to investigate whether students taking an ECS course as their introduction to computer science had a higher probability of pursuing additional computer science coursework in comparison to students who other CS courses that were not specifically designed with equity at its core. Overall, students who took ECS as their introduction to computer science were twice as a likely to pursue additional coursework as those students who took a traditional class as their introduction to computer science. There were some differences by demographic factors. Males were more likely than females to take additional coursework, by about 10% and Hispanic students were about 2% less likely to pursue additional computer science coursework. However, despite these differences, ECS has a net positive effect at increasing the number of students from groups underrepresented in computer science who are pursuing additional coursework in computer science. These results provide evidence that designing a curriculum and professional development program with equity at its core can play a significant role in broadening participation in the field of computer science.

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