Broadening Participation in Computer Science by Helping Students Connect Computer Science to their Lives

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Abstract

The Exploring Computer Science (ECS) course is a primary strategy for broadening participation in the Chicago Public Schools. Flexibility is a core component of ECS that allows teachers to use their knowledge of students' identities to adapt lessons. Exploring Connections to Computer Science (EC2CS) is designed to support teachers in developing an understanding of their students and using that knowledge to adapt ECS lessons. The results of an analysis of students' perceptions of the connections between their lives and the lessons provide evidence that when teachers are successful at scaffolding students to make connections, students increase the value that they perceive in CS and in turn increase their interest in pursuing additional CS in the future.

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1 Purpose

A key strategy for broadening computer science (CS) participation in the Chicago Public Schools (CPS) has been the enactment of a high school CS graduation requirement in 2016 (Dettori et al., 2018; McGee et al., 2022). Exploring Computer Science (ECS) is the primary course that students have been taking to fulfill the requirement in CPS. ECS is composed of activities that engage students in CS inquiry around meaningful projects (Margolis et al., 2012). The ECS pedagogy is structured around three interwoven strands: equity, inquiry, and CS concepts. The accompanying ECS professional development program and instructional coaching prepares teachers to implement these inquiry-based activities. It emphasizes building a classroom culture that is culturally responsive (Goode et al., 2014).

The ECS curriculum activities are specifically designed to empower students as creators of technology to impact their community and solve problems they care about. Flexibility is a core component that allows teachers to use their knowledge of students' identities to adapt lessons. However, ECS instructional coaches have observed significant variations in teachers' ability to make such adaptations. There is a need to support teachers in developing an understanding of their students and using that knowledge to adapt ECS lessons so that students can make connections between their lives and CS. The purpose of this study is to investigate how supporting students in making those connections can contribute to broadening participation in CS.

2 Theoretical Framework

The pedagogy of ECS empowers teachers to take an asset-building approach by reflecting on the connections between the lives of their students and the CS course content. A key factor in adapting lessons in a culturally responsive manner is helping students find relevance in their learning experiences. In a study of the benefits of culturally responsive pedagogy on academic outcomes, Howard and Terry (2011) describe the characteristics of relevance: "Relevance can be observed when students gain personal meaning from the content by making connections with prior knowledge or by working out how it 'fits' into their world" (p. 359). However, in Ladson-Billings' critique (2014) of the scholarship around her original culturally relevant pedagogy (1995), she warns against defining relevance solely as "the next trendy thing that can be used to hook students, only to draw them back into the same old hegemonic, hierarchical structures" (p. 82). Rather, culturally responsive pedagogy encourages teachers to reflect on students' identities and use that knowledge to adapt lessons in a way that empowers students to transform the world around them (Scott et al., 2015).

The Exploring Connection to CS (EC2CS) program provides a set or resources and professional development to support teachers in developing an understanding of their students and using that knowledge to adapt ECS lessons. EC2CS is composed of four main elements designed to increase culturally responsive teaching in ECS (see Figure 1). (1) Students complete a student identity survey at three time points during the year. The identity survey provides teachers with a tool to learn information about their students' identities. This survey asks students to reflect on themselves and answer questions their gender, racial/ethnic, and linguistic backgrounds; their hobbies, skills, interests, and traditions; their future and graduation plans; what/who they value in their environments (family, school, community, friends); and their sense of belonging in computer science. Teachers are provided with the raw data and a summary of student responses. In addition, a physical bookmark is generated for each student that summarizes their responses to the identity survey. (2) EC2CS offers a model lesson for each unit in the ECS curriculum adapted to encourage the use of bookmarks to help students make connections between their identities and their learning of CS topics. (3) At the end of each EC2CS model lesson, students complete an End of Activity (EOA) survey that asks students to rate their current attitudes towards CS and their experiences with the day's lesson. Teachers received a summary report for each EOA survey. (4) EC2CS professional learning workshops and individual instructional coaching offers teachers additional guidance in how to use the information they learn about their students to adapt ECS lessons in culturally responsive ways.

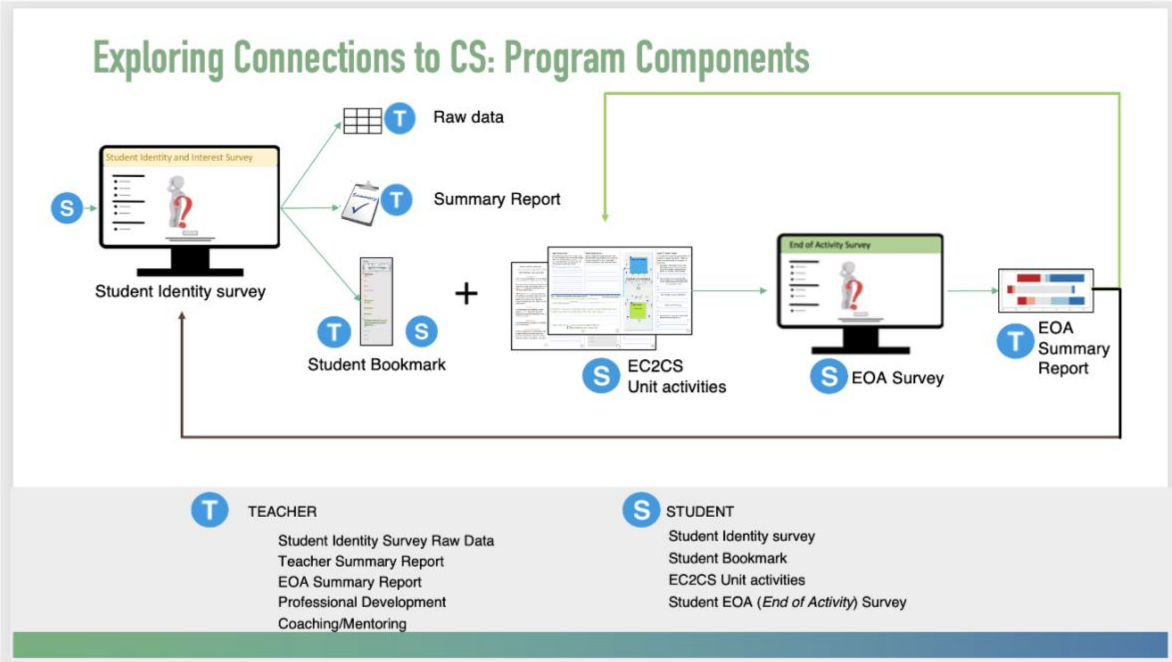

Figure 1: Exploring Connections to CS: Program Components

To investigate the association of participation in EC2CS with broadening participation, we use the Expectancy-Value model, which is based on decades of research on college students' choices about majors (Eccles, 2009). The basic premise is that students' choice of major is dependent on how much value they put in the field as well as their expectation that they will be successful. Eccles' research has shown that people's expectation 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 several social factors, such as enjoyment, perceptions of whether the major will meet personal goals, as well as family, friends, and educators' opinions. By making connections between students' lives and the content of ECS, we hypothesize that EC2CS will be associated with increased perception of the value of CS.

2.1 Research Question

Our previous research has focused on the extent to which teachers have successfully used the EC2CS scaffolds to help students make connections between their lives and CS content (Blazquez et al., 2023). In this research, we explore the association between students' connection making and changes in their attitudes towards CS. To what extent does students' perceptions of their connections between their lives and CS correlate with changes in attitudes towards CS? We predict that after controlling for students' initial perceptions of the value of CS and their initial interest in CS, students' perceptions of their connections will correlate with their end of course perceptions of the value of CS and changes in their level of interest in CS. We modeled these relationships using a structural equation model (SEM). (See Figure 2.)

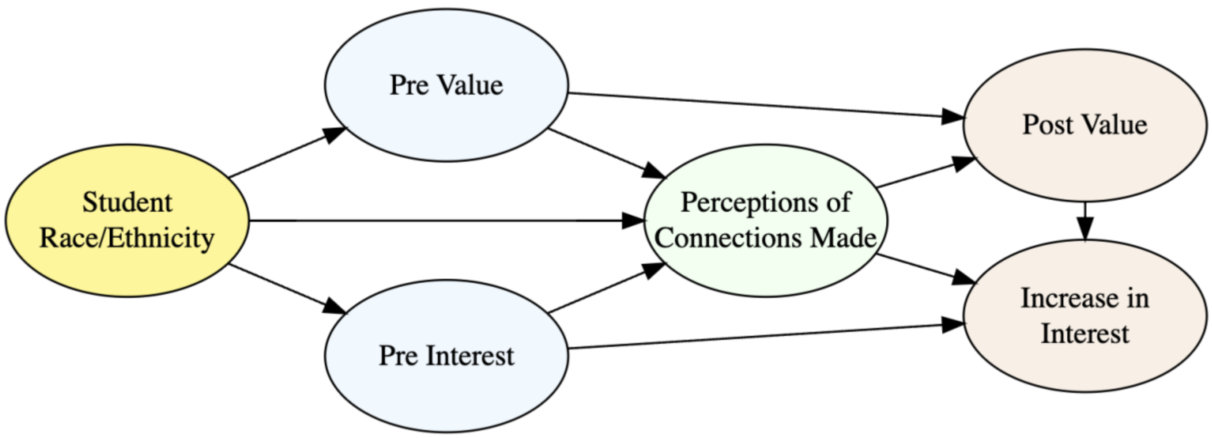

Figure 2: Conceptual Model of Relationships

3 Methods

3.1 Sampling Method and Size

The data were collected over the 2021-22 and 2022-23 school years from student surveys from a total of 13 CPS teachers who implemented the identity survey and EC2CS models with their students in their CS classes. For the data relevant to this analysis, students were given a pre survey at the beginning of the year, identity surveys to facilitate the creation of the bookmark, end of activity surveys at the end of each EC2CS lesson, and a post survey at the end of the year. From the 13 teachers, 1192 students participated in at least one EC2CS lesson over the two years and filled out at least one survey. Of these students, 315 answered both the question regarding increased interest and at least one of the post-value construct questions (average of 2.97 out of 3). This is above the recommended minimum number sample size to conduct SEM.

3.2 Race and Ethnicity Demographics

The racial and ethnic categories of the students were collected firstly from Chicago Public Schools data, and when unknown, supplemented by student self-report on the administered surveys. Below is a table that compares the sample to the wider CPS district.

Race/ Ethnicity	Sample Count	Sample Percent	CPS 21-22	CPS 22-23
Other	9	2.9%	2.2%	2.3%
Asian	42	13.3%	4.4%	4.4%
Black, Non-Hispanic	48	15.2%	36.0%	35.8%
Hispanic	154	48.9%	46.6%	46.5%
White, Non-Hispanic	61	19.4%	10.8%	11.0%

Table 1: Comparison of Race/Ethnicity Statistics for the Sample and the Population

Note that the “Other” category includes students who were identified as American Indian, Hawaiian or Pacific Islander, and students who identified under multiple categories. There are some differences between the sample and CPS demographics overall, notably that Asian and White Non-Hispanic students were oversampled and Black Non-Hispanic students were under sampled, however the proportion of Hispanic and students categorized as Other are close to accurate.

3.3 Definition of Latent Variables and Measured Variables

The variance of all latent variables was unspecified and handled automatically by the software. Additionally, no other variables were included in the model other than race and ethnicity demographic variables and those mentioned below, and no other variables were controlled for during data selection.

3.3.1 Pre-survey Questions

The two latent variables from the pre-survey used in this analysis were:

- **Pre-interest**: Indicated by the measured variable of responses to the question *What is the likelihood that you will take another computer science class in high school?* on a 4-point Likert scale and used numerically.
- **Pre-value**: Indicated by 3 measured variables from the value portion of the EV (Expectancy Value) statements measured on a 6-point Likert scale, then combined to use as a construct (Barron & Hulleman, 2015). The statements are:
  - *I think my computer science class is important.*
  - *I value my computer science class.*
  - *I think my computer science class is useful.*

3.3.2 Exploring Connections End of Activity Survey Questions

The latent variable used from the identity surveys in this analysis was called **Perceptions of Connections Made**, which was students' perceptions of their experience with the EC2CS model lessons. It was indicated by 3 measured variables used as a construct. Each measured variable was how much students agreed with these three statements on a 6-point Likert scale.

- *It is important to me to make personal connections to what I learn in class*
- *The bookmark activities (EC2CS) improve my learning experience in this class*
- *Making connections between what's important to me and the CS topics I am learning made CS more interesting to me*

To verify use of these statements as a construct, Cronbach's alpha was computed for the three questions, which was found to be 0.76 with n=150, an acceptable level of internal reliability for a construct.

3.3.3 Post-survey Questions

The two latent variables from the post-survey used in this analysis were:

- **Increased Interest**: Indicated by the measured variable of responses to the question *How has your interest in taking another computer science course changed as a result of this computer science course?* on a 5-point Likert scale, which was then collapsed into either increased or did not increase.
- **Post-value**: Indicated by 3 measured variables from the value portion of the EV (Expectancy Value) statements measured on a 6-point Likert scale, then combined to use as a construct (see Barron & Hulleman, 2015). The statements are the same as for the pre-value.

3.4 Missingness and Multiple Imputation

There was a large amount of missing data due to the nature of administering several surveys over a long period of time. To include as many students as possible and avoid bias, multiple imputation (MI) was used on the data (Baraldi & Enders, 2010). MI is a method which uses the data that is available for an individual to impute data that is not available for an individual. This is then done multiple times and the results are pooled to avoid results being impacted too heavily by the imputed data. In this analysis 20 versions of the data were used, up significantly from the suggested 5 which has lowered the variability of the results. Additionally, this randomness is reproducible since the seed number was specified during coding (seed=1).

4 Results

4.1 Summary Statistics of Measured Variables

Table 2 provides summary statistics for all measured variables.

Question	Mean	SD	Range
Pre-interest	1.96	0.86	1=Not at all likely to 4=Very likely
Pre-value Q1	4.50	1.24	1=Strongly disagree to 6=Strongly agree
Pre-value Q2	4.59	1.11	1=Strongly disagree to 6=Strongly agree
Pre-value Q3	4.62	1.16	1=Strongly disagree to 6=Strongly agree
Personal Connection	4.18	1.27	1=Strongly disagree to 6=Strongly agree
Improve Learning	4.31	0.87	1=Strongly disagree to 6=Strongly agree
More Interesting	4.38	1.02	1=Strongly disagree to 6=Strongly agree
Post-value Q1	4.73	1.21	1=Strongly disagree to 6=Strongly agree
Post-value Q2	4.70	1.19	1=Strongly disagree to 6=Strongly agree
Post-value Q3	4.79	1.18	1=Strongly disagree to 6=Strongly agree
Post-interest	3.55	1.10	1=My interest has decreased a lot to 5=My interest has increased a lot

Table 2: Summary Statistics for all Measured Variables

4.2 Model Assessment

The software used in this analysis was R version 4.3.0. To complete the analysis, the package semTools (version 0.5) was used, which required the use of the lavaan (version 0.6-15) and mice (version 3.16.0) packages for SEM and MI respectively. To assess the model as a whole, the difference between the data and the model is considered using three categories of fit indices, as recommended (Hancock & Mueller, 2010):

- **Absolute:** The SRMR absolute index is 0.071, with a good model fit indicated if below 0.08.
- **Parsimonious:** The RMSEA parsimonious index is 0.098, with a good model fit indicated if below 0.05.
- **Incremental:** The CFI incremental index is 0.879, with a good model fit indicated if above 0.95.

However, assessing the entire model as a whole excludes the importance of understanding which specific relationships in the model were found to be significant or not significant, and both findings and non-findings can give equally important and interesting information. To further illustrate this point, all fit indices indicated good model fit when this model excluding the race/ethnicity variable and its dependencies was run on the same data (SRMR=0.04, RMSEA=0, CFI=1).

4.3 Visualization of Results

Figure 3 provides a visualization of the SEM results. The statistically significant relationships ($p<0.05$) are indicated with black arrows and black standardized beta values. The grayed out standardized beta values and dashed-lined arrows were found to be not statistically significant ($p>0.05$). After controlling for pre-value, students' perceptions of making connections during the EC2CS model lessons was associated with students' perceptions of post-value. Students' perceptions of making connections during the EC2CS model lessons was not indirectly associated with students' increase interest in CS, but rather indirectly associated through changes in post-value. These findings were not impacted by the students' race or ethnicity, or their pre-interest in CS.

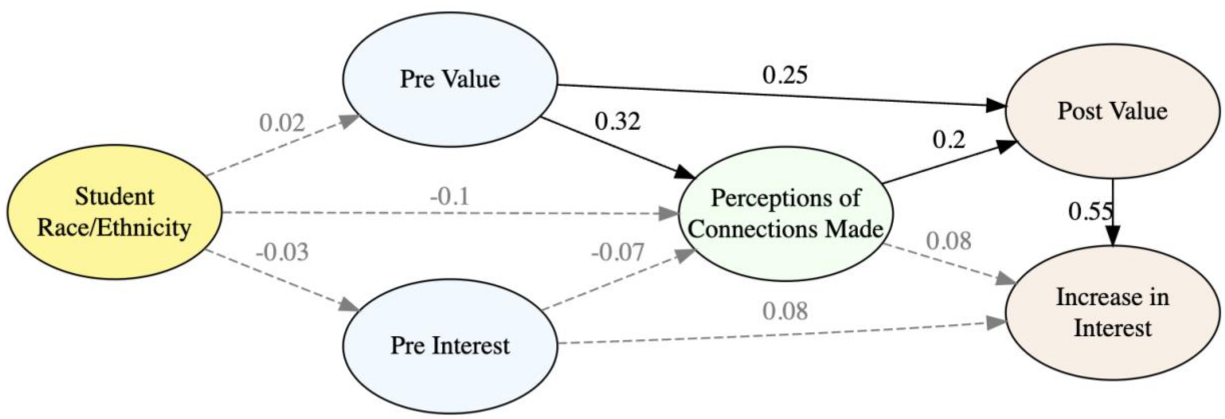

Figure 3: Modeled Relationships with Standardized Beta-Values

5 Discussion

The underlying program model for ECS is that teachers will adapt lessons to connect CS content to students' backgrounds and identities. It is through seeing the meaningfulness of CS that students increase their perceived value of CS, which contributes to broadening participation. The results of this analysis provide evidence that when teachers are successful at scaffolding students regardless of race or ethnicity or previous interest in CS to make connections between their lives and the content of the ECS course, students increase the value that they perceive in CS and in turn increase their interest in pursuing additional CS in the future.

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