TITLE: Students' Perceived Expectancy, Value, and Cost of Computer Science after Participation in a GIS-Infused Unit

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ABSTRACT: Students' engagement with geographic information systems (GIS) can improve spatial skills, which are predictors of STEM success (Jant et al., 2019). We used a survey motivated by Eccles's (2009) expectancy-value-cost framework to assess students' perceptions of their computer science (CS) courses before and after participation in a GIS unit. The unit provided opportunities to apply GIS to inquiry-based projects focused on solving problems in their own communities. Across four teachers, 158 students participated in the GIS unit and completed the survey. We found that students' reports of classroom equity predicted their expectancy for success in CS and their desire to take additional CS courses or major in CS. We also examined students' performance on a geospatial problem-solving assessment to investigate their understanding of GIS and their spatial reasoning.

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I. OBJECTIVE

Spatial cognition, which is the mental process of representing, analyzing, and drawing inferences from spatial information, contributes to science, technology, engineering, and mathematics (STEM) achievement (Stieff & Uttal, 2015; Uttal et al., 2013) and occupational and creative success (Kell et al., 2013; Wai et al., 2009). Importantly, spatial skills can improve substantially through training (Uttal et al., 2013). In this paper, we focus on how engagement with spatial technologies like geographic information systems (*GIS*) can improve high school students' spatial skills, as well as their expectancy of success in and value of computer science.

GIS comprises a variety of software that can create, manage, analyze, and map spatial data. GIS connects data to a map, integrating location data (where things are) with descriptive information (what things are like there), and these types of mapping and analysis skills are relevant in a wide range of careers. Faculty at James Madison University in Virginia developed the Geospatial Semester (GSS), in which high school students learn about geospatial technologies and apply them to local problems of interest. The hands-on class allows teachers and students flexibility to follow their interests while using and gathering data connected to their communities (Kolvoord et al., 2019). Students who have participated in GSS show improvements in their spatial skills and STEM problem-solving (Jant et al., 2019).

The GSS work in Virginia is the foundation for our current work, in which we adapt and implement GIS-infused curriculum into relevant courses in Chicago Public Schools (CPS). The focal unit for this research is an end-of-year unit on geospatial data analysis embedded within a yearlong computer science curriculum called *Exploring Computer Science* (ECS). The ECS curriculum and professional development program is designed to support teachers in making computer science culturally relevant for students as a means to broaden participation in computer science (Goode et al., 2014; Margolis et al., 2012). Our team collaborated with CPS teachers, GIS educators, and the ECS developers to co-design a GIS-based version of the data analysis unit. The overarching research question is: To what extent do students' experiences with a GIS-based data analysis unit relate to changes in attitudes towards computer science, as well as their development of spatial problem-solving skills and understanding of GIS principles?

II. THEORETICAL FRAMEWORK

To examine the impact of the GIS-infused coursework, students completed a validated survey (Hulleman & Harackiewicz, 2021; Kosovich et. al., 2015) built upon Eccles's (2009) expectancy-value-cost framework at the start and end of the GIS-infused ECS unit. We focused on outcomes related to expectancy, value, and cost because these factors are predictive of STEM-related achievement and career aspirations (Wang & Degol, 2013). Students' perceived expectancy, value, and cost in STEM fields like computer science are informed in part by sociocultural components of their educational experiences, such as their interactions with teachers and peers and the personal relevance of coursework (Vygostsky, 1978; Wang & Degol, 2013). For example, past research has demonstrated that students who participate in the ECS curriculum, which is centered on equity and inquiry, are more likely to pursue future computer science coursework than students who take traditional computer science classes (McGee et al., 2018b). With this in mind, we sought to explore the components of ECS classroom experiences that best promote students' expectancy for success and value of computer science.

Students' experiences were analyzed using an adapted version of the Tripod 7C survey (Ferguson & Danielson, 2014), which align with the ECS teaching strands of equity, inquiry, and computer science concepts (McGee et al., 2018a). Equitable educational experiences are tied to success in STEM subjects (Lee & Buxton, 2008), and inquiry-based learning, which allows for active engagement and authentic problem-solving, is connected to academic achievement and critical thinking (Friesen & Scott, 2013). Therefore, we predicted that students' reports of equity and inquiry in their GIS-infused ECS class would be positively related to their expectancy for success and value of computer science, and negatively related to perceived cost.

III. METHODS

Four teachers implemented the GIS-infused lessons in their ECS courses. These teachers were part of the Exploring Connections to Computer Science year-long professional development program to support teachers in implementing culturally-relevant pedagogy practices into ECS (Blazquez et al., 2023). To prepare for implementation, the teachers participated in two 2-hour afterschool virtual workshops. They were introduced to the ArcGIS online software and practiced the skills expected of the students.

The GIS-infused lessons were designed to provide (1) student-driven inquiry, (2) culturally responsive instruction, (3) opportunities for spatial reasoning, (4) connections to disciplinary computer science content, and (5) collaborative communities of learners. For example, one lesson explored food access, and students collected and mapped data of food resources (e.g., gardens, grocery stores, farmers' markets) in their communities. Class discussions centered on spatial patterns related to access to healthy food in the city of Chicago. Final projects involved proposing solutions (i.e., identifying locations for new food resources) which would create more equitable food access. The GIS data unit included 15 total days of instruction in which students were taught GIS analysis skills and completed their personally-relevant GIS final project.

There were 158 total students who completed both the pre- and post-assessments at the start and end of the GIS-infused unit. Among those students, 68 identified as male (43%), 79 identified as female (50%), and 11 (7%) identified as transgender, non-binary, or did not report. Forty-three students reported their race/ethnicity as white (27%), 52 as black or African American (33%), 36 as Hispanic or Latino (23%), ten as Asian (6%), eight as American Indian or Alaska Native (5%), and three as more than one (2%). For academic year 2021-2022 when data was collected, Chicago Public Schools reported that their student population included 11% white students, 36% black or African American students, 47% Hispanic or Latino students, 4% Asian students, <1% American Indian or Alaska Native students, and 1% multi-racial students.

IV. MATERIALS

Students completed pre- and post-assessments which asked ten questions about their expectations that they can be successful in computer science (expectancy), their value of computer science (value), and their perception that success in computer science requires burdensome effort (cost). For each question, students read a statement and were asked whether they strongly agreed, agreed, slightly agreed, slightly disagreed, disagreed, or strongly disagreed. Expectancy questions asked students whether they felt that they could learn and understand computer science and whether they would be successful in the course. Value questions asked students whether they thought their computer science class was important, useful, and valuable. Cost questions asked students whether they felt they were unable to put in the necessary time to be successful.

The post-assessments included an additional twenty questions built upon a modified version of the Tripod 7C survey (Ferguson & Danielson, 2014) along with additional constructs from Vekiri (2013). These constructs aligned with the ECS teaching strands of equity, inquiry, and computer science concepts (McGee et al., 2018a). Students again rated their agreement or disagreement with the statements. Equity questions focused on whether students believed that their teacher valued students' ideas and views (confer), whether their teacher showed concern for students' emotional and academic well-being (care), whether there were opportunities to work with other students (collaboration), and whether learning highlighted how computer science can solve everyday problems and be utilized across occupations (meaningful learning). Inquiry questions examined whether students felt that their teacher made learning enjoyable and interesting (captivate), whether teachers asked students to explain and persevere (challenge), whether teachers fostered an orderly and respectful classroom (control), and whether learning involved class discussions and explanations (active learning). Finally, the assessment of computer science concepts focused on whether students felt that their teachers knew when the class understood concepts and explained content well (clarify) and whether teachers provided useful comments (consolidate).

Students' pre- and post-assessments also included a geospatial problem-solving portion, which asked students to use data and maps to solve problems. Students were asked two questions on each assessment. One question focused on identifying which location to add resources to in an area, based on a current lack of resources; for example, "Based on the locations of existing free pre-kindergarten programs, where would the best location for a new free pre-kindergarten program be?" The second question focused on identifying areas to target to maximize impact of a service, based on prevalence of existing locations in the area; for example, "If you were an election monitor hoping to visit as many polling locations as possible, which area would you target?" In answering these questions, students were asked to choose a location on a map, describe their reasoning for their selection, and identify whether additional data might be needed to make a better decision. For each question, we scored students' responses to the GIS question on a scale of 1-3, with 3 representing the best choice. Students' explanations were coded for their use of spatial language (e.g., above, between, clustered, edge, nearby, region, spread) and equity language (e.g., accessible, affordable, benefit, crowded, disparity, impact, inclusive, resources).

V. RESULTS

Because we aim to create equitable educational opportunities, we first explored whether students' gender or racial/ethnic identity were related to our outcomes. An analysis of variance (ANOVA) demonstrated gender differences in students' change in perceived value of computer science from pretest to post-test, $F(2, 121) = 3.38$, $p = .037$. Specifically, female-identifying students' value of computer science increased after the GIS-infused unit ($M = .24$, $SD = 1.01$), whereas male-identifying students' value decreased ($M = -.14$, $SD = .82$) and transgender/non-binary students' value decreased ($M = -.23$, $SD = 1.12$). We also found gender differences in students' change in perceived expectancy for success in computer science from pretest to post-test, $F(2, 121) = 2.62$, $p = .040$. We found that female-identifying students' expectancy for success in computer science increased after the GIS-infused unit ($M = .08$, $SD = .77$), whereas male-identifying students' expectancy decreased (M = -.10, SD = .70) and transgender/non-binary students' expectancy decreased (M = -.47, SD = 2.00). Another ANOVA demonstrated differences in perceived cost of participation in computer science at pre-test by students' race/ethnicity, $F(5, 114) = 3.06$, $p = .012$, with white-identifying students rating cost (M = -1.54, SD = 1.06) significantly lower than Hispanic/Latino-identifying students (M = -.514, SD = 1.48). However, we found no differences in perceptions of cost by race/ethnicity at post-test, $F(5, 114) = 1.37$, $p = .240$. Therefore, students' gender and racial/ethnic identity, as well as their expectancy-value-cost ratings at pretest, were included as variables in the main regression analyses examining expectancy, value, and cost. There were no differences by students' gender or racial/ethnic identity for students' score on the geospatial assessment questions at post-test, nor for students' use of spatial or equity language in their explanations.

Multiple regression analyses were used to examine whether the equity, inquiry, and computer science content teaching strands predicted students' expectancy, value, and cost perceptions. We first found a significant regression model (Adj. $R^2 = .672$, $F(3, 115) = 16.93$, $p = .000$) demonstrating that students' post-test ratings of expectancy for success in computer science were predicted by their reports of equity in the computer science course, B = .526, SE = .144, $\beta = .475$, $p = .000$. We also found a significant regression model (Adj. $R^2 = .569$, $F(3, 113) = 13.08$, $p = .000$) demonstrating that students' post-test ratings of value of computer science were predicted by their reports of equity in the computer science course, B = .363, SE = .172, $\beta = .326$, $p = .037$. None of the regression models suggested that equity, inquiry, or computer science content strands predicted students' perceptions of cost. We also asked students about their interest in taking another computer science course and interest in majoring in computer science after the GIS-infused unit. A significant regression model (Adj. $R^2 = .318$, $F(3, 130) = 18.00$, $p = .000$) indicated that students' interest in taking another computer science course was predicted by reported course equity, B = .405, SE = .167, $\beta = .428$, $p = .017$. Specifically, 48% of students reported that their interest in taking another computer science course had increased (38% reported no change). Likewise, another significant regression model (Adj. $R^2 = .228$, $F(3, 129) = 11.25$, $p = .000$) showed that students' interest in majoring in computer science was predicted by reported course equity, B = .467, SE = .179, $\beta = .493$, $p = .010$. Among students in our sample, 35% reported that their interest in majoring in computer science had increased (49% reported no change).

For the geospatial assessment, a repeated measures ANOVA indicated that students' performance on the "Add Resource" question significantly increased from pretest (M = 1.31, SD = .82) to post-test (M = 1.50, SD = .70), $F(1, 146) = 7.41$, $p = .007$. Students' performance on the "Maximize Impact' question increased from pretest (M = 1.28, SD = .87) to post-test (M = 1.33, SD = .84), but this change was not significant, $F(1, 146) = 3.51$, $p = .063$. Students' use of spatial language and equity language in their explanations did not change from pretest to post-test.

VI. SIGNIFICANCE

In exploring ECS classroom experiences that promote students' expectancy, value, and cost, we found that students' perceptions of class equity were predictive of their expectancy for success in and value of computer science. Perceptions of equity also predicted students' interest in taking additional computer science courses and majoring in computer science. Although teachers had been participating in a yearlong professional development program on culturally relevant pedagogy, the effects of their participation from prior units was captured by the pre-survey values. These findings suggest that the infusion of GIS into a computer science class in which teachers show respect for students' ideas, care for students' well-being, provide opportunities for collaboration, and offer meaningful learning experiences can support students' confidence and interest in STEM-related fields. We also found that students' performance on a geospatial problem-solving question increased from pretest to post-test, demonstrating the effectiveness of the GIS unit for students' geospatial thinking.

The data for this study was collected in spring 2022, and a new cohort of CPS teachers plan to implement the GIS-infused unit in their ECS courses in spring 2023. With this cohort, we will be able to collect pre- and post-assessments from new students and observe lesson implementation in the classrooms. We will revise and expand the assessments to better understand students' geospatial problem-solving processes. We also plan to observe and qualitatively examine teachers' classroom practices during lesson implementation. Ultimately, we aim to investigate how observed teacher practices align with students' reports of equity, inquiry, and computer science concepts in their lessons, as well as whether observed teacher practices relate to students' perceived expectancy, value, and cost and their performance on geospatial assessments.

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