

Analysis of Initial Entry-Level Technology Course Impacts on STEM Major Selection

Ethan Shafer, Timothy Graziano, Jay Fisher

Abstract—This research seeks to answer whether first-year courses at institutions of higher learning can impact STEM major selection. Unlike many universities, an entry-level technology course (often referred to as CS0) is required for all United States Military Academy (USMA) students—regardless of major—in their first year of attendance. Students at the Academy choose their major at the end of their first year of studies. Through student responses to a multi-semester survey, this paper identifies a number of factors that potentially influence STEM major selection. Student demographic data, pre-existing exposure and access to technology, perceptions of STEM subjects, and initial desire for a STEM major are captured before and after taking a CS0 course. An analysis of factors that contribute to student perception of STEM and major selection are presented. This work provides recommendations and suggestions for institutions currently providing or looking to provide CS0-like courses to their students.

Keywords—STEM major, STEM, pedagogy, digital literacy.

I. INTRODUCTION

UNDERGRADUATE academic major selection and transition is an often-studied field because it impacts multiple aspects of a person's life. Choosing the "right" major is a difficult task and people frequently regret their choice of major. According to the 2021 Survey of Household Economics and Decisionmaking by the Federal Reserve, 37% of American adults would change their field if they could make the decision again [2]. To help limit these regrets, educators should seek to understand how they influence students' academic major choices, including the effects of course offerings.

Numerous studies have shown that a student's major selection often begins in high school. Counselors, peers, significant others, the job market, and other informational materials provide guidance and input into such an important choice [4], [16], [19], [21]. Beggs et al. suggest that there are four broad categories of factors that influence students' major choice: Sources of Information and Influence, Job Characteristics, Fit and Interest in Subject, and Characteristics of the Major/Degree [6]. These four categories continue to impact a student's selection as they enter college and continue their education.

However, major selection does not stop once a choice has been declared. Students often change their majors after they reach college. This demonstrates that a student's mind

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has not been made up by the time they choose a major, and that increased exposure to the four factors cited above might help the student identify a more ideal major. The time between high school and full adulthood, often discussed as "emerging adulthood", is a time of growth and discovery, where students discover more about themselves and their life goals [13]. As time goes on, it often becomes either fiscally or administratively more challenging for a student to change their major, so major changes are often done early in a student's college career.

Therefore, it is important that any introductory course to a topic be mindful of the impact that it can have on a student's perception of the discipline. An introductory computer science course (often labeled as CS0) is offered at many colleges. These CS0 courses can be a student's first exposure to disciplines related to Electrical Engineering or Computer Science. Studies on CS0 have highlighted various methods that CS0 courses can utilize to change the impact of the course [15], [12], [3], [10], [18].

There is some discussion of how introductory-level university courses may shape the student's perceptions or if a student's experience in an introductory course changes their major selection. While CS0 courses have been shown to improve retention among students that have already selected a major, a separate question remains as to whether a CS0 course influences the choices of students that have not selected a major.

The United States Military Academy (USMA) is in an interesting position to analyze these questions as a major must be declared near the end of the first year. Additionally, each student is required to take the same introductory CS0 course in their freshman year. The course, titled CY105: Computing Fundamentals, is discussed in detail in [5]. This study seeks to quantify what impact an introductory CS0 course may have on a student's major selection in STEM. Furthermore, it seeks to evaluate whether this impact is represented differently across demographics.

II. BACKGROUND

A. STEM Major Selection

Selecting a major is a complicated and varied process. Students across all majors often consider multiple criteria when choosing a major and those criteria can change throughout the course of their college career [9]. Hill et al. suggest that a student's perception of their peers' goals impact their own goals and thus major selection [13]. Malgwi et al. identify eleven separate categories of factors

influencing major choices upon entry and ten factors that have positive or negative effects determining when students change majors [16]. Pinxten et al. demonstrate that prior student achievements, occupational interests, and career goals are significant factors impacting major selection [19]. They further identify issues present in the complexity and numerous conflict factors that are present within the study area.

With regards to STEM-specific majors, similar trends emerge. Students interested in STEM majors took more AP STEM courses in high school [23] and often more computer science courses as well [14]. The manner of instruction can impact a student's likelihood of selecting a STEM major [11], with effective project-based learning in classes having a positive association with choosing a STEM majors. Whitehead utilized a qualitative survey to show that categories such as siblings, parents, friends, educators, difficulty of subject, and career opportunities can impact a student's STEM major choice very early in life [21]. Much of this work focuses on experiences prior to postsecondary attendance and thus does not capture those who may decide to choose a STEM major after beginning postsecondary education.

B. CS0 Specific Impacts

Students in a Computer Science or related discipline have commonly begun in what is termed a CS1 course, centered in fundamentals of computer programming. Many universities also have begun offering a CS0 course, which can provide a non-required starting point for major students with less programming experience and who would not be served as well by entering directly into a CS1 course [20]. CS0 is also used for students of other academic majors who need programming experience, or as an elective, and it can be a general graduation requirement for some universities [15]. Schools often employ placement exams to determine if a student should take CS0 or CS1 [20], [17]. CS0 course content varies, including programming and possibly computer-related topics such as hardware, networking, security, and ethics [7], [15]; variety can also exist for different CS0 courses within the same school [12], [22] Often, a CS0 course is shorter in academic hours than a CS1 course, sometimes being as brief as three days [10]. Some courses are labeled by academic institutions as "CS0.5"; for the purposes of this paper, these courses will be grouped with courses labeled CS0.

There are a variety of purposes served by CS0 courses. Many institutions of higher education design or redesign a CS0 course to improve pass rates, retention (either within an academic program or the school), and graduation [12], [18], [17], [22], [15], [3]. CS0 often bridges a programming experience gap, with the hope of reducing dropout rates [10]. Some schools intend to improve students' attitude toward their major and instill a sense of major ownership [17], [22]. Other schools use a CS0 course specifically for non-majors [8] or to give computer science more exposure among their student body, and to make the subject matter more accessible to non-major students who otherwise would only rarely take a CS course as an elective. By offering a CS0 course, they find a greater number of students taking CS1 but also a

greater incidence of students taking CS1 who understood what programming entailed and who wanted to learn it [7]. When CS0 is offered as an elective, a school can expect some recruitment into a CS or similar major as a result [3].

Another goal of a CS0 course can be to bridge the gender and ethnicity gaps; women and non-Caucasian persons in Computer Science and related majors are often underrepresented and feel a lower sense of belonging [10], [3]. Improved retention from redesign of CS0 courses can be especially pronounced for female students [15]. It should be noted, however, that undergraduate retention is not enough of a factor to increase the overall number of women in computer science; for that purpose, recruiting is vital [20].

USMA's purpose in offering a CS0 course is uncommon. USMA has had a tradition of teaching this course for decades [5]. The course serves to support the Academy's Academic Program Goals of What Graduates Can Do (WGCD), particularly Goal 5: STEM. Goals that are specifically supported by the course include WGCD 5.1 ("Apply mathematics, science, and computing to model devices, systems, processes, or behaviors.") and WGCD 5.5 ("Explain and apply computing and information technology concepts and practices in the context of the Cyber Domain.") [1] While many institutions use a CS0 course to improve retention, USMA requires the course for all cadets, and most begin (or complete) the course before selecting an academic major. Major retention is not a concern for undeclared students; however, faculty members in the Electrical Engineering and Computer Science Department have some hope that the course might encourage enrollment in the department's majors (Electrical Engineering, Computer Science, and Cyber Science), thus raising the question of whether the course actually has such an impact.

III. DESIGN & METHODOLOGY

A. Research Questions

The goal of this study is to determine the overall impact of CS0 courses on student major selection, and evaluate potential avenues for increases of underrepresented populations in STEM majors through CS0 experiences. To accomplish this, the following research questions were asked:

R.1 - Does an introductory CS0 course have an impact on student major selection? If so, by how much and in which direction? Are these impacts unique per demographic analyzed?

R.2 - Are student experiences, both prior to and after an introductory CS0 course, varied across race and gender? If so, how does that impact major selection? How do students self-assess CS0 impacts on major selection?

R.3 - Are either of the above impacts affected by prior exposure to and familiarity with technology?

B. Procedure

This study utilized two surveys to measure the relevant variables from the population. The surveys were optional and students were not offered any payment or benefits for completion of the survey. The survey questions are described

TABLE I
 INITIAL SURVEY QUESTIONS TO RESEARCH QUESTIONS

Question Group	R.1	R.2	R.3
Technology-clubs			X
Computing Accessibility			X
Interest Factors			X
CS0 Course			X
Comfort w/technology	X	X	
Major Interest	X	X	

in Section III-C and the target and participating populations are identified in Section III-D. The surveys were anonymous with the exception of an identifier that was provided to the institution's research office so that the demographic data could be correlated to the survey responses. The researchers did not have access to the participants' identifiers in accordance with the approved institutional review board (IRB) protocol.

The first survey (the initial survey) utilized nine questions designed to assess a student's prior experience with technology, their current major interest (by department), what influenced their current major interest, and their opinion about the CS0 course. This survey was administered within the first two weeks of the course.

The second survey (the final survey) utilized four questions designed to assess any changes in the participants' major interest and how the CS0 course influenced their selection. This survey was administered within the last two weeks of the course.

C. Survey Questions

The initial survey questions were written to assess the baseline for R.1, R.2, and R.3. The questions are grouped together by area in Table I.

The second survey questions were written to assess the effects of the CS0 course with regards to R.1, R.2, and R.3. These questions include both quantitative (rate your experience, rate your preferences) and qualitative aspects (what influenced your selection).

A full listing of the survey questions and the available responses are listed in the Appendices.

D. Participants

The study was offered to all students enrolled in the CS0 course during the Spring 2022 ($n \approx 480$) and Fall 2022 ($n \approx 530$) semesters. As mentioned earlier, this CS0 course is a core curriculum requirement at the institution and thus is not limited to cadets who will choose STEM majors. The course participants are largely first-year college students, with less than 5% of students taking the course after their first year.

Participants were asked to self-report their school ID number so that responses could be associated with demographic data. Demographics are based off of the school's enrollment data, which is self-reported at the time of enrollment. If the participant chose not to provide their ID number, or if a matching record could not be found (most likely due to a typing error), their numbers are included in the "Other" category.

TABLE II
 STUDY PARTICIPANTS BY RACE AND GENDER

Sex	Race	Initial	Final	Both	Total	
Male	American Indian	1	0	1	2	
	Asian	2	13	1	16	
	African American	11	10	3	24	
	Hispanic/Latino	5	16	2	23	
	Pacific Islander	1	2	1	4	
	White	42	66	30	138	
	Two or more races	2	2	0	4	
	Other	2	4	2	8	
	Female	American Indian	1	0	1	2
		Asian	7	4	0	11
African American		4	2	2	8	
Hispanic/Latino		2	2	3	7	
Pacific Islander		0	1	0	1	
White		22	18	19	59	
Two or more races		1	0	1	2	
Other		0	0	0	0	
Other		6	13	0	19	
Total			108	154	65	327

TABLE III
 INITIAL SURVEY - SCIENCE/TECH CLUB (HS) PARTICIPATION

Demographic	Participation in Science/Tech Clubs (HS)
White	15.7%
African American	47%
Hispanic	55%
Asian	41%
Total	23.8%

Participants either completed one or both of the surveys. Overall, there were 327 unique participants across the survey, with 65 participants electing to complete both surveys across the two semesters. A breakdown of the participants' race, gender, and survey completion information is included in Table II. These numbers largely align with the demographic proportions across the institution and are thus representative of the institution as a whole.

IV. RESULTS

Results of the survey were analyzed in temporal clusters based on which survey (initial or final) respondents completed. Relatively few completed both the initial and final survey, indicating potential survey fatigue.

A. Initial Survey Respondents

Student responses to the initial survey were specifically analyzed to identify factors that indicated self-reported interest vs factors that indicate final major selection. High-school information, self-reported proficiency, demographics, and final grades are considered. Initial survey demographics are shown in Table II. 63% of survey takers were male.

91% of survey takers indicated access to science or technology clubs in high school. Minority groups indicated higher club participation than white, shown in Table III.

Almost every respondent (97.6%) reported access to at least 2-3 computing devices in a previous home while 53% self-assessed comfort with video games and 86% indicated comfort using social media. No discernible demographic trends were identified concerning self-reported comfort with technology. Only 6 respondents (all white) professed a

TABLE IV
 FINAL SURVEY - POSITIVE RATING OF CS0 EXPERIENCE

Demographic	Positive Post Rating
White	75.15%
African American	76.4%
Hispanic	82%
Asian	77%
American Indian / Pacific Islander	60%
Total	72.2%

discomfort with social media, console gaming, computer gaming, and using technology for home/school uses.

45% of students indicated an initial excitement for CS0 coursework and 42% indicated that CS0 course could impact their major selection. No discernible demographic trends were identified. 13 students (11 white, 2 African American) reported no initial interest in any STEM Major. No interest is considered as not rating Biology, Chemistry, Mechanical Engineering, Electrical Engineering/Computer Science, Environmental Engineering, Physics, Systems Engineering, or Math in one of the top 3 considered majors. 65% (112) showed no initial interest in EE or CS as a potential major.

51.7% (89) of initial survey respondents eventually selected a STEM major. Performance in CS0 was a major indicator as only 6/89 did not receive a final grade of B or higher. High initial excitement (5+ out of 7) is a strong indicator of final CS0 performance as 88.3% (68/77) received a B or higher.

B. Final Survey Respondents

Student responses to the final survey were specifically analyzed to identify factors that indicated self-reported interest vs factors that indicate final major selection. Self-reported proficiency, demographics, and final grades are considered. Final survey demographics are shown in Table II. 74% of survey takers were male.

72% of survey takers indicated a positive (5+ out of 7) experience with CS0 course as shown in Table IV.

Only 25.9% (57/220) reported that their CS0 experience had any impact on their major selection. CS0 performance remains a strong indicator of STEM major selection. Only 38% of students who received a C or lower final grade selected a STEM major. 53% of students receiving a C or lower were non-white, which remains a disproportionate amount. 47% of African American student respondents received a C or lower. 12% of Asian students, 8% of Hispanic students, and 9% of white students received a C or lower.

C. Intersection Survey Respondents

Students who took both the initial and exit surveys provide an opportunity to observe indicators of perception changes over the course of the semester. Specific analysis focused on respondents whose perception of STEM or CS0 changed negatively or positively, and their respective major selection and final grade performance.

Only 65 students responded to both the initial and final survey with the demographic distribution shown in Table II. 61.5% of students who took both surveys were male.

In the initial survey students were asked to gauge their excitement for the CS0 course. In the final survey they were asked to rate their overall experience. Results shown in Table V indicate a positive experience across demographics, regardless of initial perception of CS0 courses. Survey respondents indicated that despite the CS0 experience being positive, it did not impact their major selection.

Survey respondents, when asked to re-evaluate their major selection ratings showed an average improvement of Electrical Engineer, Computer Science, and Cyber Science Majors rankings of 0.37 places with African American students showing an increase in favorable ranking by 1.2 places.

V. DISCUSSION

The survey results indicate that students are hesitant to change their majors based on a single CS0-like experience. Most students remained consistent in their desired field of study, despite a majority holding a positive outlook on the course upon completion. Regardless of initial perception, most students enjoyed the CS0 course while simultaneously stating it had little to no bearing on their major selection.

Students who performed well in CS0 were more likely to choose a STEM major. This may be due to an initial predisposition toward STEM majors more than the CS0 experience itself. This aligns with prior work that shows that major selection is often decided prior to a student's attendance at post-secondary institutions [19], [4], [21]. The vast majority of students reported comfort with technology and access to technology based clubs in high school.

Despite the majority of students self-reporting no influence of CS0 on major selection, students rated EE and CS 0.37 places higher after taking the course. African American students rated EE and CS a full 1.2 places higher after the course. This indicates a positive change on potential STEM major selection as a result of this mandatory CS0 enrollment, even if the students themselves do not perceive so, and especially within minority groups. Additional research can support methods to improve underrepresented population grades and may increase STEM major selection even further.

VI. CONCLUSION

This study supports previous work that indicates that students often choose their majors prior to attending college. Additionally, it shows that students continue to adapt their preferences for majors based on more exposure to the subject material. Interestingly enough, the students did not perceive the course to impact their preferences, although the changes were statistically significant. We suggest that institutions continue to offer CS0 courses as our work indicates that exposure to the material generally increases a student's preference toward the field.

DISCLAIMER

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TABLE V
ENTRY AND EXIT SURVEY RESPONDENT PRIOR AND POST COURSE PERCEPTIONS

Demographic	Initial Positive	Exit Positive	Self Reported CS0 Influence	B or better
White (49)	46.7%	89.8%	22.4%	95.9%
Black or African American (5)	80%	80%	20%	40%
Hispanic (5)	20%	100%	40%	100%
Asian (1)	100%	100%	0%	100%
Native American (1)	0%	100%	100%	0%
Pacific Islander (1)	0%	100%	100%	100%
Total (62)	46.7%	75.4%	25.8%	86.2%

This study was managed under an approved IRB protocol at the United States Military Academy as study #CA-2022-49.

APPENDIX A

IT PERCEPTIONS ENTRY SURVEY QUESTIONS

A. General Background

- 1) Prior to attending USMA: Have you even been involved in science or technology-based clubs (robotics, rocketry, online gaming)?
 - Yes
 - No
- 2) If yes, how many months approximately?
- 3) Did your high school or past college provide technology courses or clubs for students?
 - Yes
 - No
- 4) How many computing devices (smart phone, smart TV, personal computer, gaming console, tablets, etc.) did you have access to in your previous home?
 - Little to none (0-1 device)
 - Moderate (2-3 devices)
 - Heavy (more than 3)
- 5) On a scale of 1-7 with 1 being not comfortable at all and 7 being extremely comfortable, how do you feel about the following?
 - Using console-based video games
 - Writing software programs to solve problems
 - Using computers for work/school
 - Using technology for social media access (Twitter, Facebook, etc.)
 - Installing a home router
 - Using computers for gaming
 - Assisting other with technology problems

B. Major Selection

- 6) Based off of your current interests, rate the academic departments for potential major selection with 1 being the most desirable and 7 being the least desirable. (Provided list of USMA departments; respondents answered for each department.)
- 7) Which top 3 factors would you say contributed to your ratings in the previous question the most?
 - Potential Salary
 - Job Opportunities
 - Peer Influence

- Family Influence
- Major Advertising (flyers, course catalog, etc from the major)
- Comfortability with Subject
- Subject Difficulty
- Other

C. CY105 Questions

- 8) How excited are you for CY105? (Rating from 1-7, where 1 = not excited: I'm only here because it is a required course, 7 = very excited: I may learn a lot and I'm very interested in cyber based topics)
- 9) Do you believe CY105 has the potential to change your opinion about which major you plan to select?
 - Yes
 - No

APPENDIX B

IT PERCEPTIONS EXIT SURVEY QUESTIONS

- 1) Based off of your current interests, rate the academic departments for potential major selection with 1 being the most desirable and 7 being the least desirable. (list of USMA departments)
- 2) In retrospect, how would you rate your CY105 experience? (Rating from 1-7, where 1 = very poorly, 7 = exceptional)
- 3) Did your experience in CY105 influence your major selection?
 - Yes
 - No
- 4) What CY105 experiences influenced your selection and how?

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