2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
Paper ID #37400

Degree Attainment in Computing: Intersectional Switching Trends

Jia Zhu, Florida International University

Jia Zhu is a Ph.D. student in the Knight Foundation School of Computing and Information Science at Florida International University (FIU). Her research interests include computer science education, educational data mining, and data science, focusing on broadening participation in engineering and computing.

Stephanie Jill Lunn, Florida International University

Stephanie Lunn is an Assistant Professor in the School of Universal Computing, Construction, and Engineering Education (SUCCEED) and the STEM Transformation Institute at Florida International University (FIU). She also has a secondary appointment in the Knight Foundation School of Computing and Information Sciences (KFSCIS). Previously, Dr. Lunn served as a postdoctoral fellow in the Wallace H. Coulter Department of Biomedical Engineering at the Georgia Institute of Technology, with a focus on engineering education. She earned her doctoral degree in computer science from the KFSCIS at FIU, in addition to B.S. and M.S. degrees. She also holds B.S. and M.S. degrees in neuroscience from the University of Miami. Her research interests span the fields of computing and engineering education, human-computer interaction, data science, and machine learning.

Dr. George D. Ricco, University of Indianapolis

George D. Ricco is an engineering education educator who focuses on advanced analytical models applied to student progression, and teaching first-year engineering, engineering design principles, and project management.

Degree Attainment in Computing: Intersectional Switching Trends

Abstract

Although efforts have been made to broaden participation in computing, ongoing reports and counts in the field continue to illustrate the need to improve engagement and retention. There remains a minoritization of Black or African American men and women, Hispanic or Latinx men and women, Indigenous men and women, White women, and Asian women. As such, it is vital to explore trends over time and find new potential avenues to attract students to computing. Developing a better understanding of students' trajectories, and potentially the variable ways they may enter the major before obtaining their degrees, can offer avenues for recruitment. We conducted a quantitative analysis of switching behaviors using the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). The theoretical framework of intersectionality guided the inquiry as we examined patterns and disaggregated them by gender, race, and ethnicity. We sought to explore trends in switching behaviors for those entering computing, including potential variations in: 1) the major in which students earn their first undergraduate degree; and 2) different intersectional groups. We focused specifically on students from CIP6 11, Computer and Information Sciences and Support Services. Our analysis of MIDFIELD illustrated that many intersectional populations of students who transferred into computing came from another engineering field. However, several racial and ethnic groups of women primarily entered through non-STEM fields. Among these women, those who identified as Black and those who identified as Hispanic or Latinx most often switched from a Business major, at 31.5% and 29.4%, respectively. Meanwhile, women classified as International and those who identified as White most often transferred from the Liberal Arts/Humanities, at 41.7% and 32.7%, respectively. The findings of this work suggest that women who enter computing may do so through distinctive pathways. Going forward, this provides new opportunities for educators and administrators to consider what may appeal to different intersectional populations of students, particularly for women that identify as Black, Hispanic or Latinx, International, and/or White. This study offers information that could shape what topics may attract students to a computing field and how they could be incorporated into computing lessons or examples.

1 Introduction

Despite ongoing efforts to broaden participation, there continues to be a minoritization of women, Black, Hispanic or Latinx, and Indigenous students in computing fields [1]. While women may represent 50.5% of the population in the United States (U.S.) [2], only 22.3% of bachelor's degrees in computer science (CS) are awarded to women, as of the 2022 Taulbee report [3]. Likewise, 13.6% of the population in the U.S. identifies as Black or African American [2], but only 3.2% of bachelor's degrees in CS are awarded to Black or African American students [3]. Meanwhile, 18.9% of the population in the U.S. identifies as Hispanic or Latino [2], but only 9.1% of CS bachelor's degree recipients are [3]. Diversifying students and professional populations working in computing can have important implications for equity in society. As such, it is necessary to find new opportunities to recruit and engage additional populations, while also bearing in mind that students cannot be treated as a monolith.

In this study, we explore students' pathways to degree attainment and consider the avenues that different intersectional populations of students may take prior to majoring in computing. Specifically, we focus on aspects of their social identity pertaining to their race, ethnicity, and gender. To assess patterns in students' academic trajectories over time, we employed the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). The database contains student unit-record data, which allows examination of trends beyond just demographics and also offers detailed semester-by-semester tracking of students' major and degree attainment. Other scholars have described its merits and how it can be employed to study students' persistence, pathways, and the broader ecosystem in engineering [4, 5]. In our research, we focused on students who obtained degrees in computing fields and sought to answer the following research questions (RQs):

- **RQ1)** *How does switching behavior into computing vary by major in which students earn their first undergraduate degree?*
- **RQ2)** *How do trends in the switching behavior of different intersectional groups vary?*

To answer these questions and explore students' major switching, we utilized descriptive statistics. Although we seek to use inclusive terminology when possible, we will also describe the variables applied as categorized when referring to the results. For example, MIDFIELD utilizes terms such as "male" and "female" to describe "sex" and we use these labels based on what the institutions reported. However, we want to recognize that such a binary here is presented using a cisnormative classification using the sex assigned at birth rather than gender identification [6]. Also, although the database included "male," "female," and "unknown," in which the "unknown" category may encompass additional gender identities, no students who were reported in computing identified in this way.

We also want to acknowledge that terminology has changed over time, and the categorizations that we use in this investigation are applied in alignment with the labels in the longitudinal database. Along these lines, an "International" designation is included as a race classification. Additionally, while the term "Indigenous people" is the more inclusive nomenclature, we employ the term "Native American" to refer to this group using the database's given label.

The rest of the paper is organized as follows: We describe the framework guiding this study in Section 2 and pertinent information related to this work and switching behaviors in Section 3. In Section 4, we elaborate further on the database employed and the analysis conducted. We present the results in Section 5 and discuss the implications in Section 6. Then, we address some of the limitations of this investigation in Section 7 and present the future work in Section 8. Finally, we present our conclusions in Section 9.

2 Theoretical Framework: Intersectionality

The framework of intersectionality guided this inquiry. Intersectionality considers the multiple axes of a person's social and political identities and the role that power, privilege, and societal and cultural structures may play in discrimination [7]. This paradigm emphasizes that individuals cannot be treated as a homogeneous group since they do not all experience life the same way [8, 9]. It highlights the complexity of those who face overlapping forms of oppression based on their identities, such as their sex, race, religion, ability status, immigration status, sexual orientation, socio-economic status, and age [10, 11]. In STEM fields, scholars have described that the advantages afforded to White, able-bodied heterosexual men can further reinforce inequality [12].

The marginalization and minoritization of men and women from different racial and ethnic groups have encouraged researchers to further disaggregate data to gain insight into the unique pathways taken and participation and explicitly explore the plurality of intersectional experiences [13, 14, 15, 12]. Using context and relationality to compare students' experiences can offer insight into the distinctive trajectories among different populations [7]. In our investigation, we limit our focus on intersectionality to exploring the intersection of students' gender, race, and ethnicity. We applied this framework in the creation of our research questions, data analysis, and interpretation of the findings.

3 Background

The need for CS education has been justified from multiple perspectives, including: 1) the need to maintain a sustainable labor market; 2) the rationale for computational thinking for solving everyday problems; 3) the computational literacy value of generating new ways of expression, thinking, and learning; and 4) the need for equity in participation [16]. These differing viewpoints are the impetus behind how lessons and curricula are established and implemented and have the potential to shape the training of the future workforce. Developments in coursework, non-profits, organizations, informal programs, and research work to ensure that all students receive high-quality CS education but also that learners are supported and empowered [17]. However, the first step in such efforts to get students to interact with computational thinking as part of their education and to broaden participation is student engagement [18].

Individuals may engage with computing in many different ways. They may start early on, with computational thinking integrated into elementary or middle schools in the U.S. [17], and other people may elect to enroll in a computing major as soon as they start in tertiary education. Meanwhile, others enter a computing career later in life, entering through alternative pathways such as coding bootcamps and self-learning through online resources [19]. Yet, given that it has been argued that "the majority of youth have been systematically denied access to quality CS learning opportunities" [17, p. 36:2], finding additional opportunities to engage students who may not utilize any of these computing touchpoints (i.e., moments of exposure) can be valuable. One potential way to do so, which we explore in this work, is for students who engage through another mechanism and who deliberately decide to switch majors as part of their university studies.

Switching majors tends to occur fairly regularly and is cited as a "process" that occurs among 37% of graduates [20]. Despite its frequency, the perception of students who switch majors — especially those who switch multiple times — is typically negative, or at the very least considered a negative act. There is the notion of a penalty for switching one or multiple times that may differ depending on the initial major or college for a student within a university [21].

Alongside such perceptions and concerns about graduation time metrics, many educators and researchers take a deficit perspective on switching behavior, associating non-direct paths with additional costs and implications for major switching. Likewise, students' motivations may be called into question. Wessel [22] suggests that one consideration of a major change should be the commitment (or lack thereof) to the previous major. While items such as *normative*, or commitment based on obligation or duty, may be perceived as important, *affective* commitment is a stronger indicator of major switching. Wessel also defines another useful definition for the theory of major change — *continuance* commitment — the commitment based on need and lack of alternatives. Continuance commitment is akin to the theory of sunk cost.

While the reasons for students to switch may vary and do impact retention in a chosen discipline, we aim to change the perspective on switching to an asset-based approach. Given the large influence of contextual and institutional factors that can affect such decisions (e.g., quality of instruction, student supports) [23, 24], we suggest that rather than viewing changes as a "lack of commitment," they are instead a way for students to take agency over their future plans. Many students in STEM fields do not follow a "traditional 4-year path" [24], yet this does not mean these students will not excel. Researchers have described how, in engineering, students who "migrate" to other majors can not only be successful but may also have enhanced graduation rates relative to those who initially began in the field [25]. In recognition of the fact that students often do not follow a linear trajectory to a career [19], it is important to consider what factors can attract students to a field and encourage their persistence.

One approach is to describe switching behaviors in STEM more broadly [26], in terms of gender, race, family background, college preparedness, college experience, financial support, and institutional characteristics [27]. Researchers have noted there might be gender differences among those who elect to enter a STEM major and that certain experiences can influence retention as well (e.g., study group participation led to an increased likelihood of retention for women). Interestingly, it has been shown that women who may not have initially planned to major in a STEM field in college choose a STEM major later on in their studies at a higher rate [28]. Trying to understand what support structures can aid in such decisions and what patterns exist in transitions can be important towards trying to further expand on such findings.

In computing, an ACM report on undergraduate CS programs has described issues such as the lack of diversity and called for increased efforts to gather data about students' progressions, to inform retention [29]. Qualitative studies around attitudes towards computing [30] illustrated how non-computing majors might be frustrated by programming. When considering a quantitative approach to switching behaviors, several scholars have focused on transitions in terms of leaving a CS major [31]. Yet, less work has considered what variables may encourage post-secondary students to enter the field. Additional quantitative studies are needed to capture the pathways and overall trends around behaviors to identify avenues to prioritize in the research and educational agenda. In the work that follows, we performed a quantitative analysis considering the majors students may come from when they engage with the discipline.

4 Methods

We analyzed trends in students' trajectories quantitatively using MIDFIELD. In the sections that follow, we describe this dataset, our processing approach, and the analysis.

4.1 MIDFIELD

Other scholars have already provided more detailed information on MIDFIELD, including its history, organization, and contents [32]. The version of MIDFIELD we employed contained longitudinal undergraduate records collected across 19 academic institutions in the U.S. [4]. The data is a multi-institution database, which allows us to study trends across various institutions from 1987 to 2019. From the total of 1,048,576 students included in the database, 807,505 attained a degree. These students come from 19 institutions across the nation, which is representative of a large fraction of U.S. engineering students attending large public institutions. We further divided the database to meet our computing-centric focus, as described further below.

4.2 Data Processing and Analysis

Data were cleaned and analyzed using Python version 3.9.7 in Jupyter Lab, version 3.4.8. We utilized the Python libraries Numpy (version 1.23.3), Pandas (version 1.5.0), Matplotlib (version 3.6.1), and Plotly (version 5.10.0) to complete the data analysis. We conducted exploratory descriptive analyses to generate insights in computing more broadly as well as for each intersectional population.

In our study, we limited the analysis to students who obtained a degree in a computing field, as determined by the degree's Classification of Instructional Programs (CIP) 6 code being listed as "11," which refers to Computer and Information Sciences and Support Services. This filtering led to a total of 19,468 records across 18 institutions (one included in the dataset did not report degrees in computing), which were then further disaggregated by students' reported gender, race, and ethnicity. We want to note that student retention within the database is limited to degree completion within six years, consistent with the timeframe recommended by the National Center for Educational Statistics [33].

The goal is to investigate the computing degree-switching behaviors of the students in the database. We filtered by the entered degree through the CIP code, starting with 11, to exclude those entered with a computing degree. We further filtered the database with the blank values in entering years and CIP for entering. We also converted the fields of CIP values with five digits as they are CIP codes starting with "0" as the first digit. By doing so, we obtained the non-computing to computing majors' records in 6,498 total.

To better capture the themes of majors for the non-computing degrees, we employed a classification scheme described in a prior study [19] to label the degree programs as computing, engineering, other STEM (referring to programs in science, technology, engineering, and mathematics), non-STEM, and interdisciplinary. We grouped the degrees based on the CIP code categorization, and the details are shown in Table 1.

5 Results

5.1 RQ1: How does switching behavior into computing vary by major in which students earn their first undergraduate degree?

For all the records identified in this database, we observed an overall majority of students (Figure 1) who transferred to computing (51.2%) did so from an engineering major. Compared to "Other STEM" majors (15.6%), "Non-STEM" majors had a higher percentage of students (31.4%) who transferred to computing majors. Although there are limited records, 1.8% of students enrolled in interdisciplinary majors switched to computing. To further investigate the switching behaviors to answer RQ1, we explored the top five majors by each of the themes of the entering majors as described in Table 2.

For engineering majors, Pre-engineering (26.8%), Computer Engineering (19.9%), and Electrical,

Table 1: Themes for Entering Degrees and Categorization

Theme	**Description and Examples**	**Degree Categorization based on CIP codes**
Computing	Computing-related fields in the STEM major list computer science, computer engineering, information technology, data science, information sciences, etc.	11-Computer and Information Sciences and Support Services
Engineering	Engineering related fields in the STEM major list electrical engineering, material engineering, mechanical engineering other engineering, etc.	14-Engineering, 15-Engineering Technologies
Other STEM	Other technology/science-related fields in the STEM major list Mathematics, Statistics, Psychology, Medicine/Health, Biology, etc.	26-Biological Sciences, 51-Health/Clinical Sciences, 40-Physical Sciences, 27-Mathematics/Statistics, 42-Psychology, 41-Science Technologies, 49-Transportation
Non-STEM	Business related fields Other Non-STEM fields English, Media studies, etc.	13-Education, 16-Languages/Linguistics, 19-Consumer/Human Sciences, 23-English Language/Literature, 24-Liberal Arts/Humanities, 25-Library Sciences, 31-Recreation/Leisure Studies, 38-Philosophy/Religious Studies, 43-Criminal Justice, 44-Social Work, 45-Social Sciences, 47-Mechanic/Repair Technologies, 50-Visual/Performing Arts, 52-Business, 54-History
Interdisciplinary	Majors with two or more fields from two themes. Economics & Mathematics, Physics & Arts, Economics & Psychology, etc.	30-Interdisciplinary

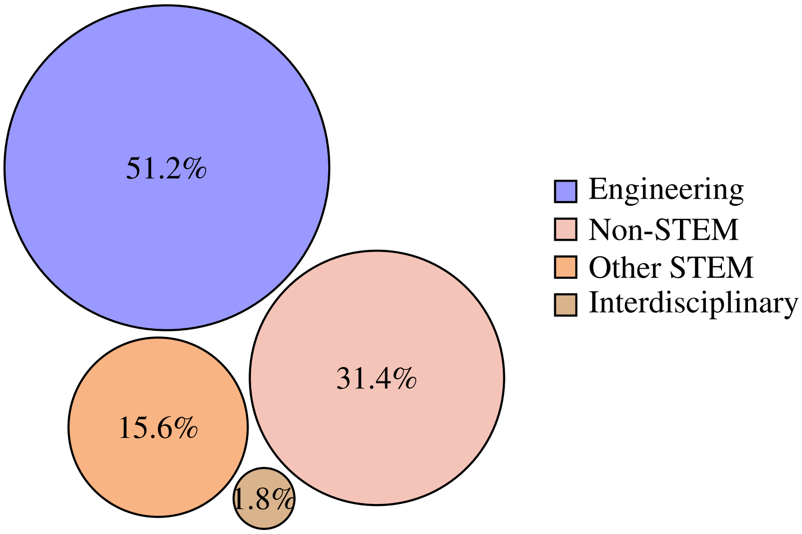

Figure 1: Overall Percentage of Prior Majors

Table 2: Ranking of Prior Majors by Themes for Entering Degrees

Ranking of Prior Majors by Themes	**Engineering**	**Interdisciplinary**
1	Pre-Engineering (26.8%)	Multi-/Interdisciplinary Studies, General (50.8%)
2	Computer Engineering (19.9%)	Multi-/Interdisciplinary Studies, Other (21.7%)
3	Electrical, Electronics & Communications Engineering (12.1%)	Biological and Physical Sciences (16.7%)
4	Engineering General (11.8%)	Mathematics and Computer Science (8.3%)
5	Mechanical Engineering (6.7%)	Natural Sciences (0.8%) & Nutrition Sciences (0.8%) & International/Global Studies (0.8%)
Ranking of Prior Majors by Themes	**Non-STEM**	**Other STEM**
1	Liberal Arts/ Humanities (51.7%)	Physical Sciences (30.3%)
2	Business (17.8%)	Biological/Biomedical Sciences (26.6%)
3	Library Sciences (5.5%)	Mathematics/Statistics (19.8%)
4	Social Sciences (5.4%)	Health/Clinical Sciences (8.6%)
5	Visual/Performing Arts (4.0%)	Psychology (7.7%)

Electronics and Communications Engineering (12.1%) are the top-ranking engineering majors that transferred to computing. Liberal Arts/Humanities (51.7%), Business (17.8%), and Library Sciences (5.5%) remain the top-ranked prior majors for those who entered undergraduate studies with a non-STEM major. Other STEM majors include Physical Sciences (30.3%), Biological/Biomedical Sciences (26.6%), and Mathematics/Statistics (19/8%) as the top-ranking prior majors before switching to computing. More than half of the students who switched from interdisciplinary majors were those coded as general (50.8%) or other (21.7%) multi-/interdisciplinary studies, followed by biological and physical sciences (16.7%).

5.2 RQ2: How do trends in the switching behavior of different intersectional groups vary?

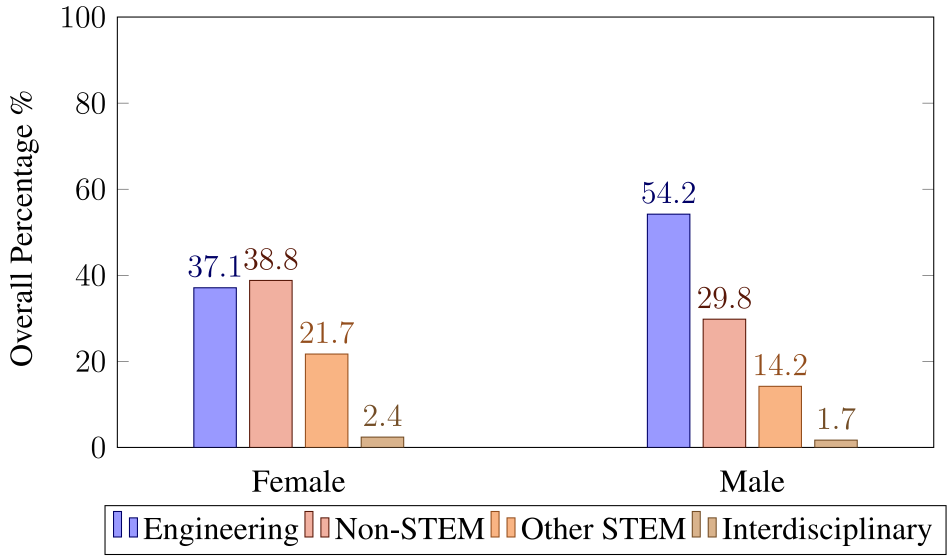

Figure 2: Overall Percentage of Each Prior Major Theme Compared by Gender

Overall, the majority of men (82.1%) switched to computing majors relative to women (17.9%) from 1987 to 2019 as reported in MIDFIELD. To further disaggregate with the major themes (Figure 2), men who transferred into computing most often came from another engineering field (54.2%). However, this was not always the case for women. Women who transferred into computing did do so through engineering (37.1%), but they also did so through Non-STEM majors (38.8%).

By applying the lens of intersectionality to examine trends by gender, race, and ethnicity, we observed trends of different switching behaviors among intersectional groups (Table 3). Across all racial and ethnic categorizations of men, all were more likely to enter through engineering than other areas. However, this was not the case for women. Black women primarily entered through non-STEM fields (44.7%). As mentioned previously, the "International" race destination is included since we kept the categorizations consistent with the terms defined in the database. For International women, non-STEM majors (44.0%) were also higher than those who transferred from engineering (38.5%). Hispanic/Latinx women were relatively close, with (42.5%) coming from a non-STEM field, and 37.5% coming from an engineering field. In addition, for White women, those who came from non-STEM majors were slightly higher than (38.0%) those who transferred from an engineering major (36.5%).

Table 3: Intersectional Race, Gender, Degree Themes

Race	Sex	Engineering	Interdisciplinary	Non-STEM	Other STEM	Grand Total
Asian	Female	48.1%	1.9%	27.4%	22.6%	1.6%
	Male	58.9%	2.2%	24.9%	13.9%	6.3%
Black	Female	30.7%	1.0%	44.7%	23.6%	3.1%
	Male	56.5%	0.8%	30.6%	12.2%	3.9%
Hispanic/Latinx	Female	37.5%	5.0%	42.5%	15.0%	0.6%
	Male	50.0%	0.5%	35.4%	14.1%	3.2%
International	Female	38.5%	4.6%	44.0%	12.8%	1.7%
	Male	55.3%	3.5%	29.9%	11.4%	6.2%
Native American	Female	33.3%	0.0%	33.3%	33.3%	0.1%
	Male	66.7%	0.0%	20.0%	13.3%	0.2%
Other/Unknown	Female	47.2%	2.8%	36.1%	13.9%	0.6%
	Male	48.6%	2.8%	35.9%	12.7%	2.8%
White	Female	36.5%	2.4%	38.0%	23.2%	10.3%
	Male	53.9%	1.6%	29.8%	14.8%	59.4%

Given that men were more likely to enter from an engineering field, we focused on the intersection of women who identified with different racial or ethnic groups. As non-STEM majors are the primary prior majors for women to enter computing, we further explored the trends of switching behaviors through the intersectional groups as displayed in Table 4. As mentioned above, Liberal Arts/Humanities, Business and Library Sciences are the top non-STEM majors overall, however, rankings vary significantly between women from different intersectional groups. For Black women, the top-ranked non-STEM major is Business (31.5%) followed by Education (18.0%), and Social Sciences (10.1%) & Communication/Journalism (10.1%). Business remained the top prior major for Hispanic/Latinx women with 29.4% transferring from it. Liberal Arts/Humanities (23.5%), Library Sciences (11.8%) and Visual Arts/Performing (11.8%) then followed Business as the top-ranking prior majors for Hispanic/Latinx women. Liberal

Arts/Humanities (41.7%) and Business (27.1%) are the top two prior majors for International women. The same major ranking trends have been shown for White women in Liberal Arts/Humanities (32.7%) and Business (20.1%). However, we observed a difference in prior majors ranked third between International women and White women with 14.3% Visual Arts/Performing for International women and 16.5% Library Sciences for White women.

Table 4: Ranking of Prior Non-STEM Majors for Intersectional Populations of Female Students

Ranking of Prior Non-STEM Major	**Black**	**Hispanic/Latinx**
1	Business (31.5%)	Business (29.4%)
2	Education (18.0%)	Liberal Arts/Humanities (23.5%)
3	Social Sciences (10.1%) & Communication/Journalism (10.1%)	Library Sciences (11.8%) & Visual Arts/Performing (11.8%)
Ranking of Prior Non-STEM Major	**International**	**White**
1	Liberal Arts/Humanities (41.7%)	Liberal Arts/Humanities (32.7%)
2	Business (27.1%)	Business (20.1%)
3	Visual Arts/Performing (14.3%)	Library Sciences (16.5%)

6 Discussion

The findings of this work suggest potential areas to attract different populations of students going forward, particularly for Black, Hispanic/Latinx, International, and White women. This study offers educators and administrators information that could help them think about how students may become engaged with the computing field and demonstrates that a “one-size-fits-all” approach to thinking about how to broaden participation is problematic. The results further our collective understanding and provide opportunities to think about how and why different intersectional populations may be attracted to a computing major from other fields (as demonstrated for varying racial and ethnic groups in Table 3). To address the ongoing barriers and challenges students may have connecting with computing, it may be important to think outside the box. For computing to become more equitable, in terms of access and participation, it is necessary to consider applying culturally relevant pedagogy and disaggregating by more than just gender. The switching behaviors described by the descriptive analysis illustrate unique patterns.

Figure 1 illustrates that the majority of students did transition to computing from engineering (51.2%), a finding that may stem, in part, from the overlap between courses required. However, given the fundamental goal of engineering is problem-solving, and the design, creation, and assessment of products, there may be some conceptual overlap as well [34]. Similar skills and goals are applied to software in CS, as the design, development, and testing of products are an important focus.

However, while it may make sense from a programmatic standpoint for students to switch from an engineering field, given the overlap in requirements, 31.4% of students came from other non-STEM areas as well (Figure 1). As shown in Table 2, the majority of the overall population of students from a non-STEM field came from Liberal Arts/Humanities (51.7%). This was also the most highly ranked prior major for International women (41.7%) and White women (32.7%), as articulated in Table 4. This presents an opportunity to think about how computing can be combined with such fields or cover topics related to these areas.

Increasingly, institutions are beginning to consider “CS+X” options, where X refers to an emphasis in another discipline, allowing for students to complete a core curriculum in computer science while considering intersecting fields as well. At the University of Illinois, options range from areas like “CS + Advertising,” “CS + Economics,” and “CS + Music” [35]. Apart from the emergence of degree options, stand-alone courses can also create opportunities for students to combine their expertise and interests. As an example, a CS + Theater methods course offered at Northwestern University combines computing and art to allow students to create “virtual costumes that overlay graphic masks and hands-on video and track body and face movements” [36]. While such efforts present an opportunity to engage students in interdisciplinary applications of computing, at present, they remain a more limited offering.

Moreover, as shown in Tables 2 and 4, 17.8% of the overall student population from a non-STEM field came from Business, and this was the highest prior major for students that identified as Black (31.5%) and Hispanic/Latinx (29.4%). This presents an opportunity to engage these populations minoritized in computing with concepts and courses that may appeal to a broader range of interests. For example, offering data science for business and decision-making could be advertised to provide an entry point to increase engagement and help students recognize the “hierarchy between data, information, and knowledge” [37, p. 3]. Although data science is heavily linked with statistics, and being able to write code in software related to analysis, it also involves many tasks and skills related to the business domain and understanding processes and problems companies may have to drive value [38].

Beyond thinking about how students are engaged with the major, an important factor going forward for students will also be their retention. As a practical approach to retaining women in computing, a prior study identified using research assistantships (RA) to combine computing skills with projects in other STEM fields [19]. As social values of “helping others” have previously been linked to career aspirations [39], this approach can assist in women’s perception of computing as a domain with social values of “helping others” and staying in this field [19]. Infusion of topics and meaningful examples may help students make connections with the content to attract those from other areas. However, creating inclusive environments and offering opportunities to develop a sense of belonging to the community is also critical to ensuring students make their switch more permanent. Literature has described how counter-structures can aid in overcoming the harms imposed by negative culture and curricula, and that is necessary to situate sustainable programs within “the communities they intend to serve and that intentionally attempt to counter historical and current harms caused by unjust policies and practices in society and in computing” [40, p. 27:19]. Along these lines, finding ways to promote agency while using CS towards thinking about social justice and societal needs, can encourage students to work towards concrete goals and project development.

Technical projects and computing research have been described as allies for political and social change [41]. Such connections, particularly when coupled with positive group environments, have been shown to be especially important for women of color to resist marginalization and apply computing to challenge deficit notions [42]. Towards this goal, we want to encourage educators to consider the opportunities to introduce learning activities and content which may help to apply core concepts while working towards broader societal goals. As an example, spurring students to work on application development to address a problem in the community could allow them to practically apply knowledge gained in a class while selecting a topic meaningful for them. Given each student comes to computing with their own background, values, and trajectory, such a focus could allow them to find connections that resonate with them in the work.

While it is true that computing needs more graduates in general, we also need to understand what makes it appealing to support additional populations who may want to join. The work conducted illustrates that students do not all follow the same path to degree attainment in CS. It can be important to consider the unique intersectional trajectories of students to explore more about the range of fields that could influence their motivations and goals, and in the future, to better support others looking to make a switch to the major.

7 Limitations

There are several limitations we want to acknowledge. The scope of the study is exploratory and descriptive in nature. This limits the findings of the study and only identifies the general trends from the existing data collected in the specific timeframe. Furthermore, rather than measuring a small sample, MIDFIELD includes information about a population. Since there are no similar datasets that have this level of detail, it is not possible to compare the findings to others. Thus, we only report on the observed trends extrapolated from the data available, and we cannot claim it can be generalized to all students in all areas. Moreover, we only focused on a limited subset of social identities in this work, including race, gender, and ethnicity. Exploration of additional identities and backgrounds (e.g., ability status, age, and/or socioeconomic status), could expand our understanding. Lastly, we focused on the pathways and overall trends for the focused intersectional groups to enter computing, which neglects to provide insight about the retention of these populations in computing.

8 Future Work

In the future, there are multiple ways to expand upon this work. First, it would be worth exploring additional methods, such as qualitative inquiry or inferential statistics, to delve further into the details of the switching behaviors. While this analysis revealed trends for students, the motivations to select computing require additional insight. Second, it would be valuable to build upon the findings from this inquiry and take an asset-based approach to further examine “how” and “why” each intersectional group may change majors and to delve into the support mechanisms that may help them as they successfully switch to computing. To facilitate such in-depth inquiries, we suggest exploring additional theoretical frameworks that can be used to guide asset-based approaches (e.g., community cultural wealth). Lastly, it would be valuable to understand the factors that support the retention of each of the intersectional groups in computing, as it is necessary to understand what makes them stay in computing and/or how and why they may leave computing.

9 Conclusion

Students who transfer into a computing field during their undergraduate studies may enter through a multitude of majors. While many undergraduates do switch from another engineering area, Black, Hispanic/Latinx, International, and White women are more likely to switch from a non-STEM field. This study demonstrates the need to disaggregate data when exploring trends in students' participation and trajectories. Furthermore, it illustrates potential opportunities to find synergy between existing programs in other majors and computing, which may make lessons more appealing to a range of interests and mindsets.

There are many strategies that could be employed to attract and engage different populations of students with computing concepts. We encourage educators and researchers to consider these findings and further explore the various factors that could influence decisions to pursue a computing major. We hope that the information presented will inform efforts to create inclusive learning environments and lessons that can appeal to students with a broad range of interests.

References

[1] Stephanie Lunn, Leila Zahedi, Monique Ross, and Matthew Ohland. Exploration of intersectionality and computer science demographics: Understanding the historical context of shifts in participation. *ACM Transactions on Computing Education (TOCE)*, 21(2):1–30, 2021.

[2] U.S. Census Bureau. U.S. Census Bureau quickfacts: United States, 2022. URL `https://www.census.gov/quickfacts/fact/table/US`.

[3] Stuart Zweben and Betsy Bizot. 2021 Taulbee survey. Computing Research Association, 2022. `https://cra.org/wp-content/uploads/2022/05/2021-Taulbee-Survey.pdf`.

[4] Susan M Lord, Marisa K Orr, Matthew W Ohland, Russell A Long, and Richard A Layton. Is MIDFIELD for me? Exploring the Multiple Institution Database for Investigating Engineering Longitudinal Development. In *2021 IEEE Frontiers in Education Conference (FIE)*, pages 1–4. IEEE, 2021.

[5] Susan M Lord, Matthew W Ohland, Richard A Layton, and Michelle M Camacho. Beyond pipeline and pathways: Ecosystem metrics. *Journal of Engineering Education*, 108(1):32–56, 2019.

[6] Abbie E Goldberg, Genny Beemyn, and JuliAnna Z Smith. What is needed, what is valued: Trans students' perspectives on trans-inclusive policies and practices in higher education. *Journal of Educational and Psychological Consultation*, 29(1):27–67, 2019.

[7] Joya Misra, Celeste Vaughan Curington, and Venus Mary Green. Methods of intersectional research. *Sociological Spectrum*, 41(1):9–28, 2021.

[8] Kacey Beddoes and Maura Borrego. Feminist theory in three engineering education journals: 1995–2008. *Journal of Engineering Education*, 100(2):281–303, 2011.

[9] PH Collins and S Bilge. *Intersectionality*. Polity Press, Cambridge (UK), 2016.

[10] Kimberlé Crenshaw. Demarginalizing the intersection of race and sex: A black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *U. Chi. Legal F.*, page 139, 1989.

[11] Richard Delgado and Jean Stefancic. Critical race theory: An introduction, 2001.

[12] Erin A Cech. The intersectional privilege of white able-bodied heterosexual men in STEM. *Science Advances*, 8(24):eabo1558, 2022.

[13] Sarah L Rodriguez, Charles Lu, and Daisy Ramirez. Creating a conceptual framework for computing identity development for latina undergraduate students. In *An Asset-Based Approach to Advancing Latina Students in STEM*, pages 25–39. Routledge, 2020.

[14] Yolanda A Rankin and Jakita O Thomas. The intersectional experiences of black women in computing. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, pages 199–205, 2020.

[15] Jayce R Warner, Joshua Childs, Carol L Fletcher, Nicole D Martin, and Michelle Kennedy. Quantifying disparities in computing education: Access, participation, and intersectionality. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, pages 619–625, 2021.

[16] Paulo Blikstein and Sepi Hejazi Moghadam. Computing education. *The Cambridge handbook of computing education research*, pages 56–78, 2019.

[17] Jean J Ryoo. Pedagogy that supports computer science for all. *ACM Transactions on Computing Education (TOCE)*, 19(4):1–23, 2019.

[18] Beryl Hoffman, Ralph Morelli, and Jennifer Rosato. Student engagement is key to broadening participation in cs. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, pages 1123–1129, 2019.

[19] Jia Zhu, Stephanie Lunn, and Monique S Ross. Characterizing women's alternative pathways to a computing career using content analysis. In *Proceedings of the 2023 ACM SIGCSE Technical Symposium on Computer Science Education*, Toronto, Canada, March 2023.

[20] Carmen Astorne-Figari and Jamin D Speer. Are changes of major major changes? the roles of grades, gender, and preferences in college major switching. *Economics of Education Review*, 70:75–93, 2019.

[21] GD Ricco. *Degree Program Changes and Curricular Flexibility: Addressing Long Held Beliefs About Student Progression*. Thesis, 2013.

[22] Jennifer L Wessel, Ann Marie Ryan, and Frederick L Oswald. The relationship between objective and perceived fit with academic major, adaptability, and major-related outcomes. *Journal of Vocational Behavior*, 72(3):363–376, 2008.

[23] Casey George-Jackson. Stem switching: Examining departures of undergraduate women in stem fields. *Journal of Women and Minorities in Science and Engineering*, 17(2), 2011.

[24] National Academies of Sciences, Engineering, and Medicine and others. *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways*. The National Academies Press, Washington, DC, 2016.

[25] Susan M Lord, Matthew W Ohland, Richard A Layton, and Michelle M Camacho. "not all those who wander are lost." examining outcomes for migrating engineering students using ecosystem metrics. In *2018 IEEE Frontiers in Education Conference (FIE)*, pages 1–5. IEEE, 2018.

[26] Elaine Seymour and Anne-Barrie Hunter. Talking about leaving revisited. *Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*, 2019.

[27] Joseph J Ferrare and You-Geon Lee. Should we still be talking about leaving? A comparative examination of social inequality in undergraduate patterns of switching majors. 2014.

[28] Carlton J Fong, Kristen P Kremer, Christie Hill-Troglin Cox, and Christie A Lawson. Expectancy-value profiles in math and science: A person-centered approach to cross-domain motivation with academic and stem-related outcomes. *Contemporary Educational Psychology*, 65:101962, 2021.

[29] Chris Stephenson, Alison Derbenwick Miller, Christine Alvarado, Lecia Barker, Valerie Barr, Tracy Camp, Carol Frieze, Colleen Lewis, Erin Cannon Mindell, Lee Limbird, et al. *Retention in computer science undergraduate programs in the us: Data challenges and promising interventions*. ACM, 2018.

[30] Michael Hewner and Mark Guzdial. Attitudes about computing in postsecondary graduates. In *Proceedings of the fourth international workshop on computing education research*, pages 71–78, 2008.

[31] Amanpreet Kapoor and Christina Gardner-McCune. Considerations for switching: exploring factors behind cs students' desire to leave a cs major. In *Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education*, pages 290–295, 2018.

[32] Matthew W Ohland and Russell A Long. The multiple-institution database for investigating engineering longitudinal development: An experiential case study of data sharing and reuse. *Advances in Engineering Education*, 5(2):n2, 2016.

[33] U.S. Department of Education. The integrated postsecondary education data system (ipeds) glossary. "graduation rates (gr)" definition, 2007. URL `http://nces.ed.gov/ipeds/glossary/index.asp?id=812`.

[34] Christianne Corbett and Catherine Hill. *Solving the Equation: The Variables for Women's Success in Engineering and Computing.* ERIC, 2015.

[35] University of Illinois. Cs + x degree programs. URL `https://cs.illinois.edu/academics/undergraduate/degree-program-options/cs-x-degree-programs`.

[36] Erica Masini. Coding costumes, May 2021. URL `https://www.mccormick.northwestern.edu/news/articles/2021/05/coding-costumes/`.

[37] Luiz Favero and Patrícia Belfiore. *Data science for business and decision making*. Academic Press, 2019.

[38] Thomas Davenport. Beyond unicorns: Educating, classifying, and certifying business data scientists. *Harvard Data Science Review*, 2(2):5, 2020.

[39] Kathleen J. Lehman, Annie M. Wofford, Michelle Sendowski, Kaitlin N. S. Newhouse, and Linda J. Sax. Better late than never: Exploring students' pathways to computing in later stages of college. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, SIGCSE '20, page 1075–1081, New York, NY, USA, 2020. Association for Computing Machinery. ISBN 9781450367936. doi: 10.1145/3328778.3366814. URL `https://doi.org/10.1145/3328778.3366814`.

[40] Sheena Erete, Karla Thomas, Denise Nacu, Jessa Dickinson, Naomi Thompson, and Nichole Pinkard. Applying a transformative justice approach to encourage the participation of black and latina girls in computing. *ACM Transactions on Computing Education (TOCE)*, 21(4):1–24, 2021.

[41] Rediet Abebe, Solon Barocas, Jon Kleinberg, Karen Levy, Manish Raghavan, and David G Robinson. Roles for computing in social change. In *Proceedings of the 2020 conference on fairness, accountability, and transparency*, pages 252–260, 2020.

[42] Jean J Ryoo, Tiera Tanksley, Cynthia Estrada, and Jane Margolis. Take space, make space: How students use computer science to disrupt and resist marginalization in schools. *Computer Science Education*, 30(3):337–361, 2020.