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Computing Pathways: A quantitative inquiry into the dynamic pathways of students in computing with gender comparisons

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Abstract

The number of female students in computing fields remains low despite the millions of dollars spent on research for attracting more female students. In order to entice more female students to these male dominated fields, we first have to understand their pathways to CS and educational years we are losing female students. For the purposes of this study, we utilized the data from the Florida IT Paths (FLIT-PATH) project, an NSF funded study. Participants included approximately, 1650 students from three large public universities. The survey contained 39 questions on identity, field of study, and occupational interest during middle school, high school, and college. The responses gathered through the Qualtrics survey system and were analyzed in R by the research team. The research questions that guided this study were:

1- To what extent are female students interested in computing related fields at middle school, the beginning of high school, and the beginning of college?
2- How have these occupational pursuits changed over time? Do they differ for gender?

The results of the study indicated a majority of female students that were attracted to computing fields during middle school remained in those fields during high school and college years. However, there was no significant flow from other majors to computing fields observed during the different educational years.

Introduction

STEM fields have national importance for the United States (US) in order to remain technologically competitive in the world [1]. Therefore, the demand for graduates in STEM fields continues to grow at a rapid rate in comparison to other fields [2]. STEM fields are different from each other, and although participation in some fields like biology and chemistry are reaching parity, in other fields like computing and engineering, women's participation falls short [3]. There is a need to attract more students to these highly respected fields for the US to secure its rank as a technology driven country internationally. Several studies have demonstrated the stark gender gap in STEM fields, particularly computing and engineering in the United States [4][5][6]. Despite the effort and investment in STEM education and research, the occupying percentage of female students in these fields remains low. In the US, women occupy less than 20 percent of the computing and engineering fields [7].

According to a recent research study (2012), in order to increase participation we must expand our research into K-12 to better understand boosters and barriers to students entrance into STEM fields of study [8]. As such, in order to find out how to attract more female students to this male dominated field, it is important to further investigate and understand the barriers and factors that influence female students' educational pursuits and career choices along the key transition points middle school, high school and entire college. In this study we focused on female students' occupational aspirations and paths from middle school, beginning of high school, and beginning of college. Furthermore, we investigated when female students enter and how long they remain in the STEM pipeline.

Although the goal of this study is to shed light on female students' educational paths, we also included the male students' pathways to better understand how the pathways of students differ. The rest of this paper consist of a review of literature; the theoretical framework which shaped this study; a review of the methods applied in this study; the results; the discussion and conclusion.

Literature Review

Although the age range for adolescent decisions on career paths is not clear, it is determined that by adolescent years, a majority of students establish their career aspirations towards a real occupation [9][10][11]. According to the literature, predictors for studying a STEM field contains factors such as students' prior academic performance, self-confidence in math and science, encouragement from parents and friends, and exposure to the field [12][13] [14]. Therefore, in this study we examined students' occupational interests middle school (adolescent ages) to college level in order to better understand individuals' educational paths.

Additionally, it has been argued that students, regardless of gender, lose interest in science during the transitions to middle school and high school; however, the percentage of female students is higher [15]. According to the literature, girls perform in math as well as boys in middle school but lose confidence in their math abilities. Additionally, their negative self-reflection about themselves leads them to fall behind males in STEM fields like computing and engineering in high school [14][16]. According to a study by Riegel-Crumb (2011), children are " […] aware of how their skills do or do not match up to external expectations of their academic proficiency in math and science" [15]. However, external factors can play an important role on students career aspirations [15]. Various reasons have been identified as having impact on female student major and career choices both positively and negatively. Students get positive inspiration from role models [17], interaction with teachers [18], and early exposure to STEM [19]. On the other hand, they get negative influences from gender stereotypes [20], early gender socialization [21], and loss of confidence and interest in math related topics through cultural experiences and expectations in the US [22].

The cumulation of the above factors results in low participation of female students in STEM fields; particularly computing and engineering. For the purpose of this study we would like to understand during which time points computing and engineering fields are attracting female students and during which timeframes female students are lost. In order to engage more female students with computing and engineering fields, we need to focus on how to broaden the positive factors and dampen the negative ones.

Theoretical Framework

The theoretical framework guiding this study is Super's life-span, life-space theory. This theory has been used in different research areas by scholars including women's career trajectories[11][23]. In this study, we used this framework to better understand women's computing educational paths. In this theory, Super emphasized the importance of changes of one's self-concept during different periods of time [24]. He deliberated that people experience diverse roles during their lifespan, and based on the role salience, they choose different occupations [24]. According to Super, "[…] decision points occur before and at the time of taking on a new role, of giving up an old role, and of making significant changes in the nature of an existing role" [24].

Utilizing this theoretical framework as an analytical lens, in this study we focused on students' occupational pursuits during three important time points - middle school, high school, and college in which students take on new roles as they become older while giving up an old role from when they were younger.

Methods

Florida-IT-Pathways to Success (Flit-Path) is a Collaborative Research Grant awarded by the National Science Foundation (NSF). Flit-Path provides approximately 23 one-year fellowships to each institution to support senior students enrolled in one of three disciplines: computer science, information technology, or computer engineering. During the last two weeks of the semester, a validated survey containing questions about a student's background, interests, GPA, gender identities, demographics, desired fields from middle school to the university level, etc. [25]. was distributed to students utilizing a Qualtrics survey. Approximately 1650 students from three large public universities, voluntarily participated in the survey in Fall 2018. Five percent of all participants were students with Flit-Path scholarship. Chart 1 demonstrates the distribution of all students in the 3 universities. Chart 2 illustrates the distribution of student's current occupation among different fields including computer science, computer engineering and information technology.

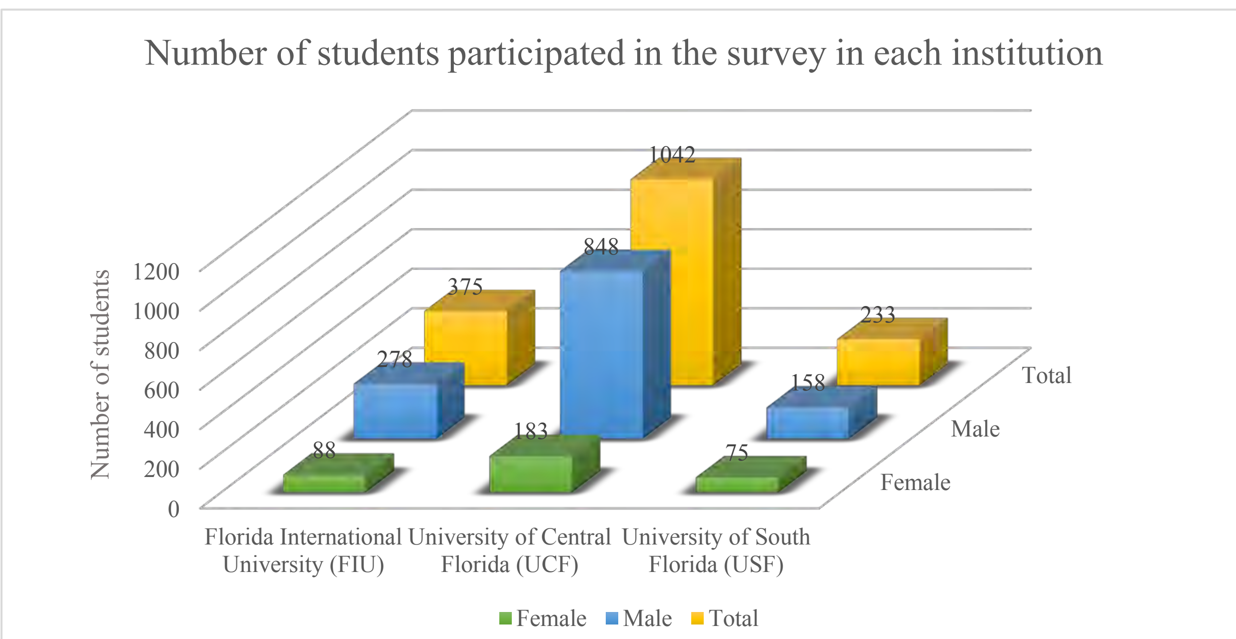

Chart 1: Number of students in each institution

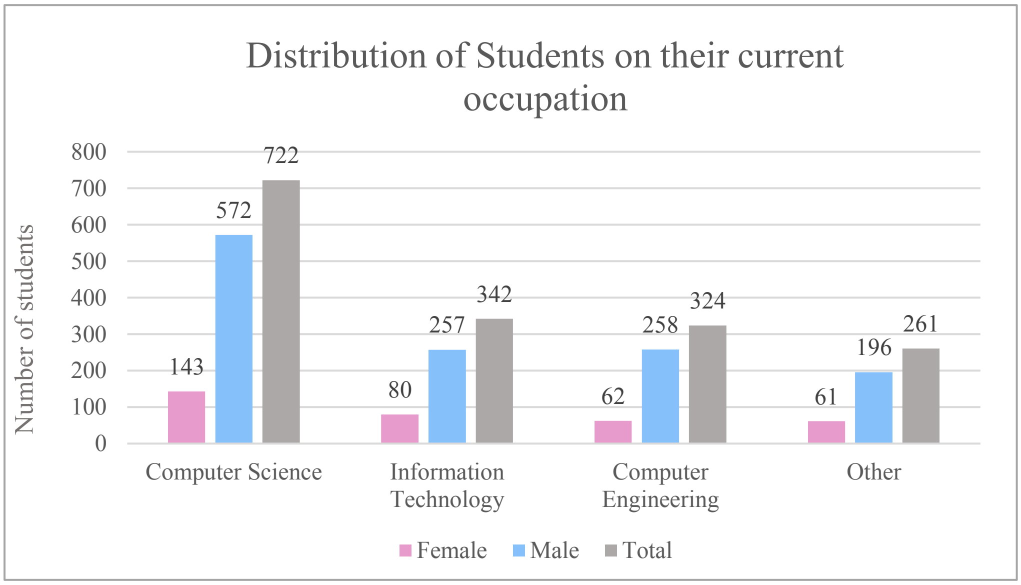

Chart 2: Distribution of students on their current occupation

In this study, we worked with two questions from the survey. First, students' self-reported gender identities; we studied students with either female or male gender identity, as the numbers for students that identified on the spectrum of gender identity was low. Second, students' identified occupation interests from middle school to the college level (see Figure 1). Students were asked to "mark all that apply" in this question meaning each student was able to select multiple fields at each time point from the 13 different fields offered in the survey (survey questions are in the appendix). We then categorized them into four major themes including: *computing* (computer science, information technology, computer engineering), *engineering* (electrical engineering, mechanical engineering, other engineering), *other STEM* (other technology-related field, natural science, mathematics, other STEM related field), and *non-STEM* (business, other non-STEM related field) (Figure 1). From this question we selected three time points to study including middle school, beginning of high school, and beginning of college.

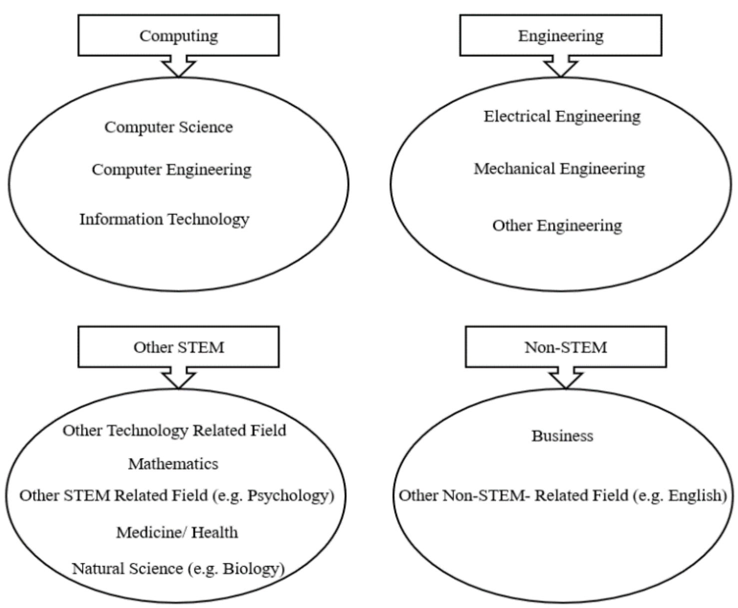

Figure 1

Our goal was to examine the definitive career interests and pathways of students who have committed to computing programs or related fields (n~1400). In order to avoid double counting students with multiple career interests at any timepoint, we recoded the responses to the survey accordingly. Students interested in computing, engineering, and non-STEM fields were identified as *computing*, *engineering*, and *non-STEM* respectively if and only if the students selected only one field and no other fields (shown in below figures by solid arrow). Thus, our grouping indicates a strong level of commitment to computing or engineering because the participants included in this group had no other interests (solid arrows in Figure 2).

The students who chose a mixture of two or more of the computing, engineering, and other-STEM fields were categorized as the *other-STEM* group. Figure 3 illustrates the majors in the recoded *other STEM* category (shown in Figure 3 by dash arrow). Figure 3 shows the other STEM by solid arrow meaning that those are only dedicated to *other-STEM.*

The students who selected one or more from the STEM related topics (shown by dash arrow in Figure 4) as well as the non-STEM field (shown by solid arrow in Figure 4) were categorized to the *interdisciplinary* group only. Figure 4 demonstrates the new *interdisciplinary* grouping.

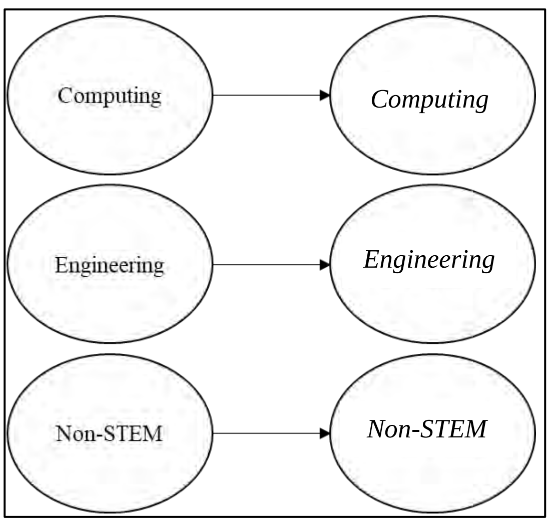

Figure 2: *Computing*, *engineering*, and *non-STEM* groups

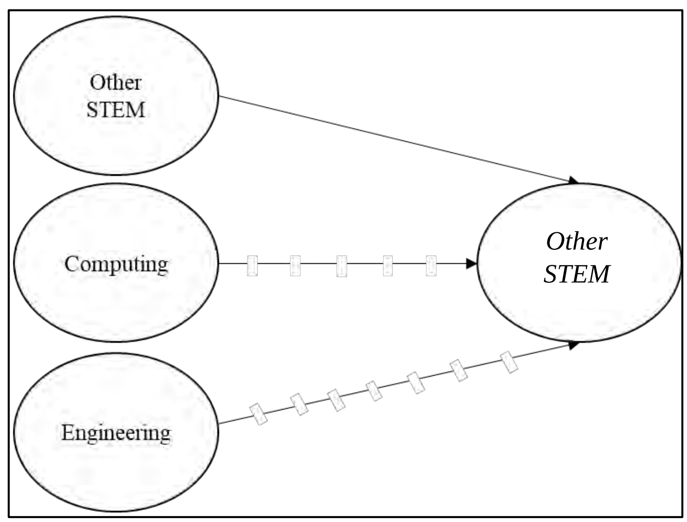

Figure 3: *Other-STEM* group.

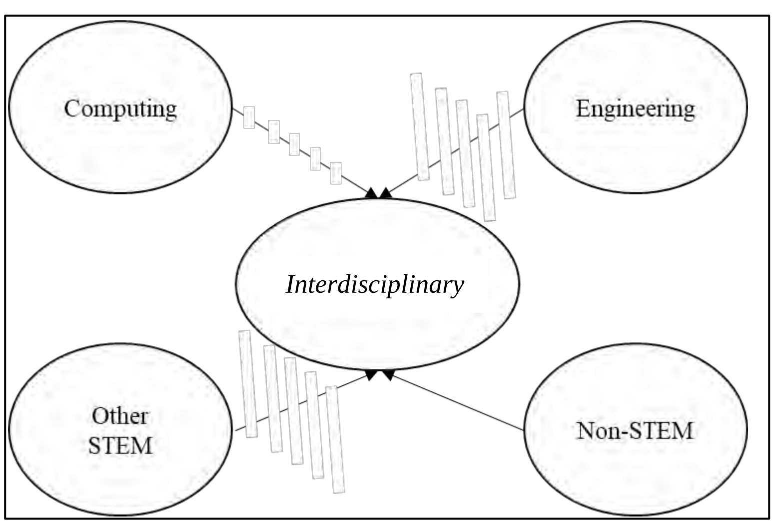

Figure 4: *Interdisciplinary* group.

Table 1 illustrates the percentage of females and males in each field and each timepoint. The three different timepoints include middle school, beginning of high school and beginning of college. It is important to point out that the overall numbers of participants in each field might seem stable; however, they are not the same students since some students lose and others gain interest towards a particular field.

Field	Middle School		High School		College	
	Male%	Female%	Male%	Female%	Male%	Female%
Computing	83.25	15.23	85.63	13.75	80.62	18.29
Engineering	89.36	10.64	86.36	12.12	83.08	16.92
Other STEM	74.13	24.63	74.48	25.22	69.94	28.53
Non-STEM	68.13	30.63	73.55	25.62	72.97	24.32
Interdisciplinary	72.55	25.98	69.5	29.08	79.84	17.83

Table 1

The data from Qualtrics was loaded into the R environment for analysis. In order to better understand the intention of majoring in a computing field between female and male students over the three time points, we created a Sankey diagram in R representing the flow of interest.

Research Questions

The research questions guiding this study were:

1- To what extent are female students interested in computing related fields at middle school, the beginning of high school, and the beginning of college?
2- How have these occupational pursuits changed over time? Did they differ for gender?

Results

While the purpose of this study is to understand female students' computing educational paths, we also examined male students' paths through computing fields. Furthermore, we analyzed students (both male and female) educational paths in engineering. In order to better understand students' educational paths, we used Sankey diagrams. Sankey diagrams are a specific type of flow diagram to visually illustrate quantity transfers, and the width of the arrows is proportional to the flow rate [26]. Each field in the diagram is represented with a color. Pink demonstrates *computing* fields, yellow is for *engineering* fields, blue shows all *other STEM* fields, green is for *non-STEM* fields, and gray illustrates the *interdisciplinary* group of students. Below is the table for representation of colors for each major.

Color	Discipline
Pink	*Computing*
Yellow	*Engineering*
Blue	*STEM*
Green	*Non-STEM*
Grey	*Interdisciplinary (Mix)*

Table 2: Representation of colors in each major

Figure 5 demonstrates the intention of studying *computing*, *engineering*, *other STEM*, *non-STEM*, and *interdisciplinary (mix)*, during different time points including middle school, beginning of high school, beginning of college for all students (female and male).

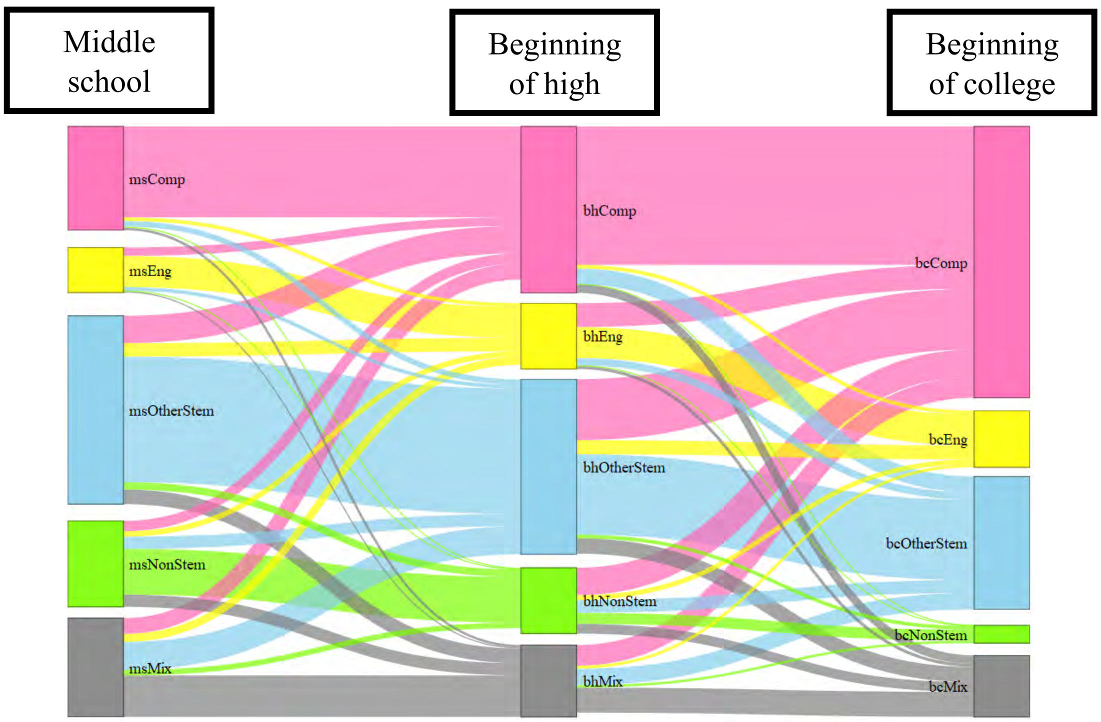

Figure 5: Sankey diagram for all participants

Figure 6 illustrates the female students *computing* and *engineering* path through middle school, high school, and college. According to the analysis, 15.23% of female students wanted to major in a *computing* field, and 10.64% desired majoring in an *engineering* field during middle school. The percentage of female students who desired majoring in a *computing* field dropped by almost 1.5% during the transition from middle school to high school; however, the percentage of students who aspired to major in an *engineering* field raised by almost 1.5%. Moreover, the percentage of female students that wanted to study a *computing*, or *engineering* field raised by almost 5% during the shift from the high school to the college level.

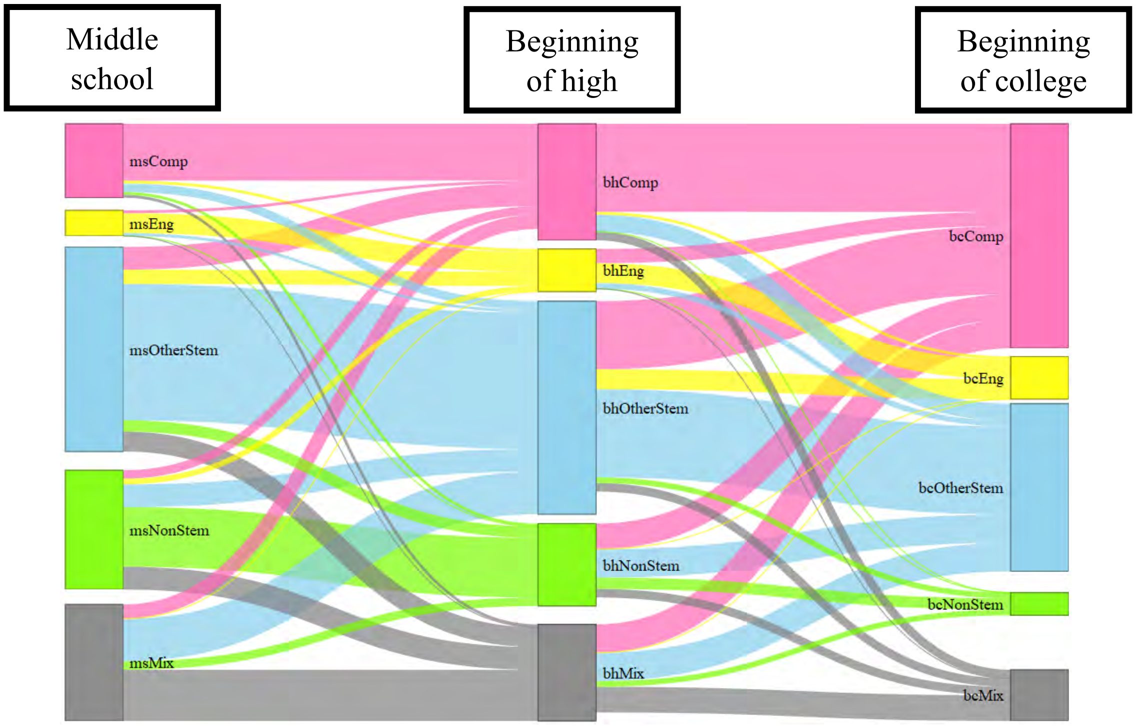

Figure 6: Sankey diagram for female participants

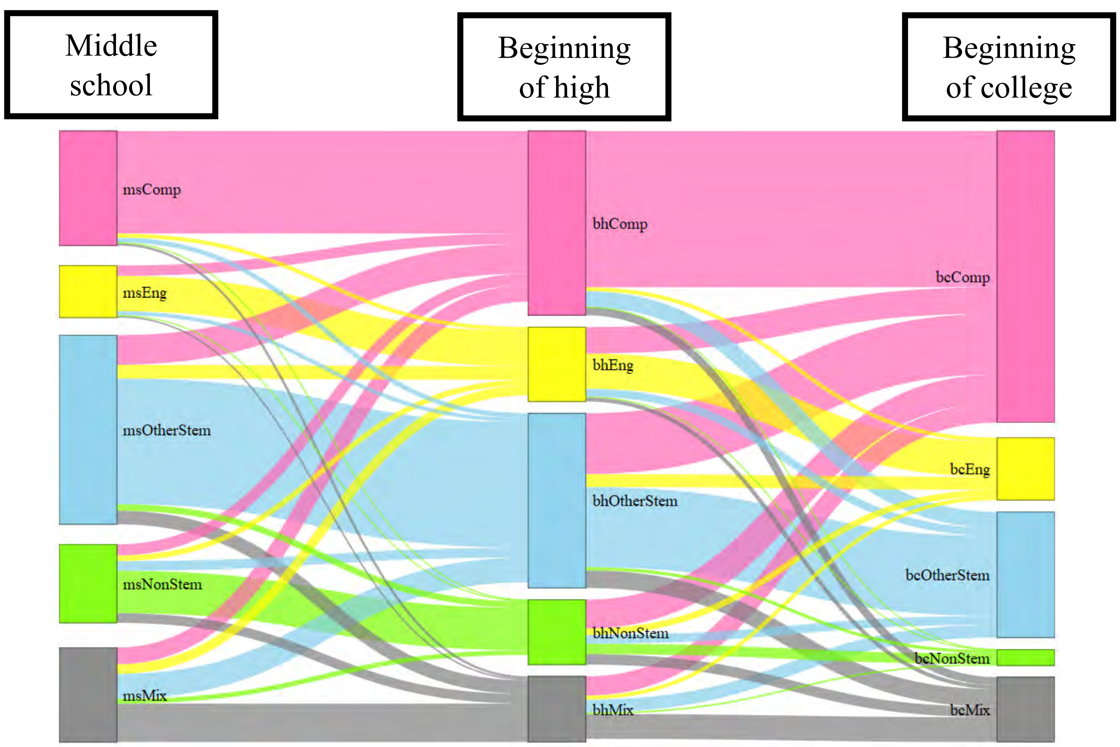

Figure 7: Sankey diagram for male participants

Figure 7 shows male students *computing* and *engineering* aspirations through the three different time points. During the transition from middle school to high school, male students saw more than a 2.3% escalation in the *computing* field; however, they experienced a 3% reduction in *engineering*. Moreover, from the shift from high school to college, male students' aspirations for the *computing* field dropped by 5% and they also experienced a drop by 3.3% in engineering.

Generalize linear models (GLM) are extension of linear regression models which allow the dependent variable to have non-normal distribution [27]. To better understand students' paths through *computing* fields, we used a predictive model and ran generalized linear regression. We studied the occupational interest of female and male students at different time points; the results illustrated that despite the students' gender identities, the most significant element in students' desired occupation for *computing* at the college level is their desired occupation for *computing* in high school. In other words, the flow diagram as well as the predictive model illustrated that the most noticeable number of students going to the *computing* field in college level are from students that identified in a *computing* field during high school. The same story was true for the students' transitions from middle school to high school. In other words, the only significant predictor of studying *computing* field in high school was to already having interest in *computing* as an occupation during middle school. Table 3 illustrates that studying a *computing* field in middle school has a significant positive effect on being a pursuer of a *computing* field in high school, regardless of gender. Table 4 demonstrates that studying a *computing* field during high school had a significant effect on studying a *computing* field during college.

Predictors	**Estimates**	**SE**	**z-Value**	**Sig.**
Intercept	-2.0349	0.128	-15.897	***
Middle School Computing	3.1678	0.2096	15.113	***
Middle School Engineering	0.2921	0.3167	0.922	ns
Middle School STEM	-0.0361	0.2035	-0.177	ns
Middle School non-STEM	-0.0946	0.2867	-0.33	ns
Middle School Interdisciplinary	0.1113	0.2459	-0.453	ns

ns: not significant, * p<0.01, ** p<0.001

Table 3: Middle school to beginning of high school for all students

Predictors	**Estimates**	**SE**	**z-Value**	**Sig.**
Intercept	-0.7006	0.0865	-8.100	***
High School Computing	1.593	0.1505	10.587	***
High School Engineering	-0.1684	0.2095	-.0804	ns
High School STEM	-0.1623	0.1473	-1.102	ns
High School non-STEM	0.1766	0.2070	0.853	ns
High School Interdisciplinary	-0.4459	0.2150	-2.073	*

ns: not significant, * p<0.01, ** p<0.001

Table 4: Beginning of high school to beginning of college for all students

According to the literature and our analysis, self-concept played an important role on their educational paths. According to the literature, female students lose intentions towards math related and computing fields during the transition to high school, and before entering college [28] [29]. From our data, we recognized that a noticeable number of female students during the transition from middle school to high school students lose intentions towards the *computing* fields.

A significant number of students who became familiar with *computing* fields during their early adolescent ages remained in those fields, as they believed they belonged to that specific *computing* pipeline. However, students who were interested in majoring in other fields during middle school were not significantly attracted to *computing* fields by their high school years. Additionally, students who considered majoring in other fields during their high school years were not significantly attracted to the *computing* fields by their college years. A non-significant number of students changed their minds on their majors via evolution of their self-concepts and life experiences.

Limitations

The data used in this study is coming from an online survey, thus the data is based on students self-reporting. The students who participated in this survey are in their bachelors' program from freshman to senior. Therefore, the student's occupation may reflect back on selecting their interested majors during middle school, high school, and college. Which means student's current field may affect the survey by the long-term memory.

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Appendix

Below please find question in the survey which studied for the purpose of this study.

Q. (field plans). “Mark all that apply.”
Which of the following options best describe what field(s) you wanted to pursue?

q6ms… = desired field in middle school
q6bhs… = desired field at the beginning of high school
q6ehs… = desired field at the end of high school
q6col… = desired field at beginning of college
q6now… = desired field currently

	Middle school	*Beginning of HS*	*Beginning of college*	*Currently (now)*
Computer Science	q6mscs	q6bhscs	q6colcs	q6nowcs
Information Technology	q6msit	q6bhsit	q6colit	q6nowit
Computer Engineering	q6msce	q6bhsce	q6colce	q6nowce
Electrical Engineering	q6msee	q6bhsee	q6colee	q6nowee
Mechanical Engineering	q6msme	q6bhsme	q6colme	q6nowme
Other Engineering	q6msoe	q6bhsoe	q6coloe	q6nowoe
Other Technology-Related Field	q6msot	q6bhsot	q6colot	q6nowot
Natural Science (e.g. Biology, Chemistry, Physics, Earth Science)	q6msns	q6bhsns	q6colns	q6nowns

Mathematics	q6msmath	q6bhsmath	q6colmath	q6nowmath
Medicine/Health	q6msmed	q6bhsmed	q6colmed	q6nowmed
Other STEM†-related Field (e.g. Social Science, Psychology)	q6msos	q6bhsos	q6colos	q6nowos
Business	q6msbus	q6bhsbus	q6colbus	q6nowbus
Other Non-STEM†-related Field (e.g. English, Music, Law)	q6msons	q6bhsons	q6colons	q6nowons

†STEM stands for Science, Technology, Engineering, and Mathematics

VALUES for all variables: 1 = checked this field, 0 = did not check this field