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Understanding How Social Agents and Communicative Messages Influence Female Students' Engineering Career Interest From High School to First Semester of College (Fundamental)

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Understanding How Social Agents and Communicative Messages Influence Female Students' Engineering Career Interest from High School to First Semester of College

Abstract

Many researchers have investigated how to increase female and minority students' engineering career interest, but they are still severely underrepresented in the field of engineering. Prior literature demonstrated that various factors contribute to students' engineering career interests, such as self-efficacy and social support. Previous research also explained that students' early engineering interest was the most influential predictor of their engineering major and career choice. Therefore, it is necessary to examine students' engineering career interest trajectories prior to college to better understand how students develop or hinder their interest in an engineering career. This study answers the following research question: "Which social agents and what communicative messages influence female students' intentions to choose engineering as a career at the beginning of high school, end of high school, and the first semester of college?"

We used a cross-sectional dataset collected from students enrolled in first-semester English courses at 23 four-year institutions and 4 two-year institutions across the United States. The survey was a retrospective examination of students' (both engineering majors and non-engineering majors) career interests, attitudes, and beliefs about engineering and broadly STEM. Students indicated career interests at different stages in their lives (e.g., during middle school, beginning of high school, end of high school, and beginning of college). Logistic regression was used to understand the social support factors promoting engineering career interests during the four retrospective time points. Our findings demonstrated that at the beginning of high school, Latinas were more likely to choose engineering as a career. However, by the end of high school, Asian girls had higher odds of choosing engineering as a career, whereas multiracial girls had a decreased likelihood. These changes revealed the impact of race/ethnicity on girls' engineering career interest at different time points during high school. Our findings also indicated that different social agents, such as fathers, high school teachers, and siblings, had various impacts on girls' engineering career interest at different stages of high school. At the beginning of high school, female students who chose engineering as a career were more likely to be encouraged by their fathers and teachers, however, at the end of high school, female students were more likely to be encouraged by their fathers and siblings.

This study helps disentangle the influence social agents have on female high schoolers' interest in engineering careers. Furthermore, a deeper understanding of how factors influence the chances of female students' engineering career interest during high school and first semester of college will help the engineering education research community develop more effective strategies in improving female and minority student participation.

Introduction

Broadening participation in engineering has been a critical topic for more than a decade [1]. Moreover, engineering continues to be a male-dominated field; in 2017, the percentage of male first-year college students with an engineering career interest increased to 27.9% whereas only 9.5% of female first-year college students indicated intention to choose engineering as a career [2]. Therefore, to equitably attract more women into engineering, it is crucial to understand what supports and hinders female students' engineering career interest.

High school is a critical period for adolescents to develop their career interests [3]. Sadler [4] found that during the high school years, the percentage of males interested in engineering remained the same with only a slight increase, whereas the percentage of females decreased. Bystydzienski [5] found that female students' decisions against pursuing an engineering degree was not due to a lack of academic preparation or interest in engineering, but rather from a lack of financial resources, fears of failure, and minimal social support. Stake and Mares [6] found that, for high school students, support from family members, friends, and academic role models, was critical in developing career interest in science. Stake [7] highlighted that when controlling for gender, parental level of education, and measured scientific ability, the support from influential individuals, such as family members, peers, professors, and teachers, were strong predictors of positive science attitudes. Social support was found to be important for female students to develop their interest in an academic field, including engineering [5] [6] [8].

In this study we examined the importance of social support mechanisms (e.g., encouragement, external recognition, and family attitudes toward STEM, etc.) that promotes or hinders female students' interest in pursuing an engineering career. Previous studies indicated that influential others, such as teachers, parents, siblings, relatives, and peers, could significantly influence students' engineering career choices [9] [10]. Godwin [11] found that when female students received the recognition message as a "math person" or "physics person" by influential others, such as parents, teachers and friends, they were more likely to choose engineering as a career.

Previous studies mainly focused on how social support influence female students' STEM self-efficacy and attitudes toward STEM [12] [13] [11]. However, there is a lack of clarity in the existing body of research that specifically focuses on how social agents and their communicative messages influence high school female students' career interest in engineering at the pivotal transition from high school to college. This study will contribute to the engineering education research community by providing a deeper understanding of the different sources of messages that promote interest development during female students' different life stages, i.e., beginning of high school, end of high school, and first semester of college. Understanding how social agents help promote interest, through their messages, for female students at different time points can open opportunities to create interventions for secondary educators and families.

Research Question

Guided by the Vocational Anticipatory Socialization (VAS) of STEM model, this study examines how social agents (i.e., teachers, peers, parents, siblings, and other relatives) and communicative messages (i.e., recognition, encouragement, and career information) influence

high school female students' engineering career interests. Specifically, this study addresses the following research question:

> Which social agents and what communicative messages influence female students' intentions to choose engineering as a career at the beginning of high school, end of high school, and the first semester of college?

Theoretical Framework

Vocational Anticipatory Socialization (VAS), originally a theory in the field of communication, is the communicative and socializing process that could affect how individuals make their career decisions [10, 13]. According to VAS, the messages that students received socialize them toward a career path [15]. VAS stresses the importance of information, accessibility to career descriptions, and social agents, such as teachers, parents, or other STEM professionals students might know. These social agents might help students shape their understanding of what STEM is and what a STEM career involves, thus further developing their interest in choosing a career in the STEM field [16]. Kitchen et al. [17] also noted that VAS explains how individuals develop their interest in a discipline as well as the development of their educational and career pathways. More recent work by Myers and her colleagues extended VAS to a STEM specific career development model, which explains the development of career interests in science, technology, engineering, and mathematics-related fields [15] [16].

This study uses the VAS of STEM as a theoretical guide to better understand how social agents, (e.g., family members, teachers, and peers) and the messages they convey can influence high school female students to develop a career interest in engineering. The VAS Model of STEM, depicted in Figure 1, highlights the significance of socializing messages from influential others on students' academic and career pursuits. The model also considers the importance of students' backgrounds including race/ethnicity, socioeconomic status, gender and the circumstances that students may experience as a result of being a member from a minoritized group [16].The VAS Model of STEM (as seen in Figure 1) depicts the reciprocal relationships among the messages adolescents received from different VAS sources, experience and personal factors, which are influenced by demographic factors (e.g., culture, socio-economic status and gender) [16]. Overall, the model demonstrates the interaction between various factors and VAS messages, all influencing adolescents' future academic majors and career pathways. Unlike many other career models, the VAS Model of STEM highlights the central role communication plays in affecting adolescents' STEM-related academic and career interests [16].

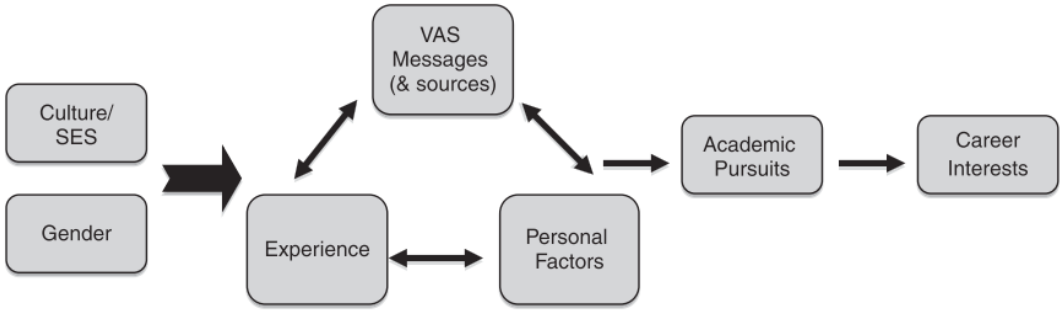

Figure 1. Vocational Anticipatory Socialization Model of STEM borrowed from [16]

Scholars have identified five primary VAS sources that transmit messages (i.e., parents/family, teachers/schools, peers/friends, part-time job, and the media) that support high school female students' engineering career development [18] [14]. Godwin et al. [9] found students were more likely to choose engineering as a career when there was a perceived family support of science and an awareness of the importance of science as a pathway to a better career. Observing parents' worked-related activities, discussing the importance of work with parents, and general conversations about career aspirations were found to aid adolescents' career decision-making process [19]. In addition, schools were cited as influential sites where adolescents could find teachers and career counselors who could enlighten and guide their career choices [16] as well as learn necessary information about careers [18]. Peers could help adolescents learn more about workplace skills by discussing their family members' jobs, thus expanding their career options through a second-hand exposure [18]. Peers could transmit both positive and negative messages about careers related to their family or relatives' occupations. When peers discussed their family or friends' jobs, they usually provide more details about this career [14]. Part-time jobs provided adolescents opportunities to learn the skills needed in certain jobs [16]. Media might not directly provide adolescents with certain career information, but a study found that it served as an introduction to certain careers, for example, the internet can provide various types of VAS information to users [19].

Jahn and Myers [16] identified that five major themes exist in VAS messages: value, expectation, prescription, opportunity, and description, which were informed by students' gender, culture, and/or social-economic status. Value messages were the most common messages and they informed receivers to pursue a career coinciding with family or social values [16]. Value messages could direct students (the message receivers) to pursue a career that their family or society regarded as a good job. Therefore, the value messages could lead students to prioritize their values and choose the careers aligned with those values [16]. Expectation messages were also a common way that students were advised on career direction, prompting them to consider the consequences of pursuing a career path, such as "Find a stable career," "Provide for your family," or "Be financially independent" [14, p.100]. Prescription messages, such as "Don't waste your math skills—be an engineer," identified specific careers for the receivers based on their talents, interests, and/or the career's prestige or income potential [16]. Opportunity messages, such as "We need more women in the medical field" and "There is a shortage of engineers in this country," encouraged the receivers to move toward less pursued careers that needed greater diversity [16]. Description messages conveyed details about the job environments, such as tasks and requirements [16].

Within the VAS framework, consideration of prior STEM-related experiences and students' demographic characteristics, such as gender and socioeconomic status (SES), were also significant factors in providing accessibility to career opportunities or career descriptions [15]. According to Jahn and Myers [16], VAS messages usually provide more direct career information and guidance to students than their demographic characteristics. However, we understand that there may be overt and covert racist and sexist messages that students might receive, prompting them to become discouraged to pursue a certain career path. Jahn and Myers [16] also asserted that personal factors could largely influence adolescents' career choices. Personal factors included self-efficacy, prior experiences, enjoyment, and resilience. Jahn and Myers [16] revealed that adolescents might pay more or less attention to aspects closely related

to their personal experiences based on the VAS messages they received. Personal experiences and exposure can overlap sometimes, but they are different in nature [16]. Experiences are activities that students participate and create according to their own interests, whereas exposures are non-voluntary circumstances based on the availability of resources, such as individuals living in rural or urban areas as well as teachers' different skillsets [16].

Scholars have found that a lack of information about STEM and/or STEM professionals could hinder students' interest in pursuing STEM as a career [15]. Therefore, it is crucial to understand the relationship between different social agents and the communicative messages that influence female students' STEM career interest through the lens of the VAS model of STEM.

Method

Data Collection

For this study, we used the dataset from the Outreach Programs and Science Career Intentions (OPSCI) survey. The OPSCI survey was administered to students enrolled in their first-semester English courses at twenty-three four-year institutions and four two-year institutions across the United States in Fall 2013 and it is a cross-sectional study. The OPSCI dataset includes 15,847 participants, of which 8,033 (50.69%) identified as female, 6,315 (39.85%) identified as male, and 1,499 (9.46%) participants did not specify their gender or did not complete the survey. To address our research question, we only examined the female student sample (n = 8,033). The survey was a retrospective examination of students' career interest (both engineering majors and non-engineering majors). The survey questions were in the following five areas: career interest at different stages in their lives (i.e., during middle school, beginning of high school, end of high school, and beginning of college), middle school math and science exposure, high school STEM courses, STEM-related interests, family STEM support, and students' demographic information.

Participants' Demographic Information

In our sample of female participants, 823 (10.7%) identified as Asian American, 1,123 (14.6%) identified as Black/African American, 1,660 (21.0%) identified as Latina, 446 (5.8%) identified as multiracial, 193 (2.5%) identified as Native American, and 5,018 (65.0%) identified as White. The first-generation college student variable was created using students' self-reported parents' level of education. Students who indicated their parents did not earn a bachelor's degree were coded as 1 and those who indicated their parents had a bachelor's degree or higher were coded as 0. A coded value of 1 suggested this participant was a first-generation college student, whereas a coded value of 0 indicated this participant was a continuing-generation college student. Among all the female participants, 3,487 (43.4%) were first-generation college students, 4,104 (51.1%) were continuing-generation college students, and 442 (5.5%) students did not specify their parents' education level.

A summary of our participants' demographic information can be found in Table 1. Additionally, in Table 1, we provide information about students' engineering career interest in four retrospective time points (i.e., middle school, beginning of high school, end of high school, and beginning of college) by race/ethnicity. Descriptive statistics show that in middle school, there

were 372 (4.6%) female students that indicated an engineering career interest. At the beginning of high school, more female students became interested in an engineering career increasing the value to 581 (7.2%). At the end of high school, the number and percentage of female students who were interested in engineering increased to 637 (7.95%), whereas at the first semester of college, both the number and percentage of female students who were interested in pursuing engineering dropped to 569 (7.1%).

Table 1. Demographic information of female students who had an engineering career interest

Race/Ethnicity	Middle School	Beginning of High School	End of High School	Beginning of college
Asian / Pacific Islander	65 (0.8%)	97 (1.2%)	110 (1.4%)	100 (1.2 %)
Black/African American	69 (0.9%)	89 (1.1%)	82 (1.0%)	78 (1%)
Latina	93 (1.2%)	125 (1.2%)	128 (1.6%)	119 (1.5 %)
Multiracial	24 (0.3%)	31 (0.4%)	28 (0.3%)	29 (0.4 %)
Native American / Alaska Native	15 (0.2%)	20 (0.2%)	16 (0.2%)	10 (0.1%)
White	175 (2.2%)	318 (4%)	359 (4.5%)	318 (4 %)
Overall Sample	372 (4.6%)	581 (7.2%)	637 (7.95%)	569 (7.1 %)

Analysis

To answer our research question, "Which social agents and what communicative messages influence high school female students' intentions to choose engineering as a career at the beginning of high school, end of high school, and beginning of college?" Three logistic regression models [20] [21] were analyzed to understand the social support factors that promoted engineering career interests during three retrospective time points (i.e., the beginning of high school, the end of high school, and the first semester of college). Students were asked to mark their interest in the following engineering disciplines: engineer (in general), mechanical, electrical, civil, chemical, biomedical, environmental, industrial, engineering technologist, and computer scientist/programmer during three time points. We grouped all engineering careers from the survey into one variable to capture students' overall interest in an engineering career rather than specific disciplinary interest. Engineering career interest at each time point was coded as a binary variable: 1 means the respondent indicated engineering career interest and 0 means the respondent did not have an engineering career interest.

Students' race/ethnicity and parents' level of education were included in the model as control variables and were not removed from the model. The independent variables analyzed in each logistic regression pertained to students' perceived social support factors and communicative messages. We asked students to report their family and school environment support as it relates to STEM. Table 2 provides the survey questions used in our analysis. These variables will help us better understand how social support factors, such as agents (e.g., teachers, peers, parents,

siblings, and other relatives) and communicative messages (e.g., recognition, encouragement, and career information accessibility), influence high school female students' engineering career interests.

In the logistic regression analyses, a backward elimination method was used to select the best model. Backward elimination is an algorithm that begins by introducing all variables into the model; through multiple iterations, variables that are not significant are deleted one at a time until a final parsimonious model is achieved. Independent variables whose odds ratio is greater than one suggests that under the influence of this independent variable, the participant had a higher likelihood to choose engineering as a career at the beginning of high school, end of high school, and first semester in college. In comparison, under the influence of independent variables whose odds ratios is less than one, the participant had a lower likelihood of choosing engineering as a career at the beginning of high school, end of high school, and first semester in college.

Table 2. Measures for the independent variables (not including demographic variables)

Area	Question	Option
Supportive Home environment of science	Was your home environment supportive of science, for example, did you often visit science museums or zoos?	Not supportive Occasionally supportive Moderately supportive Generally supportive Very Supportive
Encouragement toward STEM career path	Who encouraged you to select a STEM career path? (Mark all that apply)	No One Mother/Female Guardian Father/Male Guardian Siblings Other relative School Counselor Middle School Teacher High School Teacher Someone in that career field
Family's interest in, and attitudes toward, STEM	Which of the following statements describe your family's interest in, and attitudes toward, STEM? Mark all that apply	STEM is involved in my father's career STEM is involved in my mother's career STEM is involved in a sibling's career STEM is involved in another relative's career STEM is considered a diversion or hobby STEM is a way for people to have a better career STEM is not a family interest STEM was a series of courses that I had to pass Someone could help me with STEM homework

		My family arranged for tutoring in math or science
External Recognition as a STEM person	To what extent do you disagree or agree with the following statement:	My STEM teacher see me as a STEM person My family see me as a STEM person My friend/classmate see me as a STEM person
External Recognition as a physics person	To what extent do you disagree or agree with the following statement:	My physics teacher see me as a physics person My family see me as a physics person My friend/classmate see me as a physics person

Results

The goal of this study was to understand which social agents and what communicative messages influence high school female students' engineering career interest. All models were screened for multicollinearity and influential cases. The correlation matrix of all predictor variables did not exceed 0.80 [22]. The variance inflation factor is another tool that can help identify the degree to which there is multicollinearity in a model. The variance inflation factors values for each variable in our three models were less than 5; a recommended cut-off value [23][24][25] and tolerance was above the recommended 0.1 cutoff value [23][24][25]. Once the final models were determined we proceeded to conduct case wise diagnostics to evaluate if there were influential observations that were biasing the model. Casewise diagnostics were evaluated by examining the standardized residuals and Cook's distance for each model, the test of normality showed no evidence of any significant deviation of normality for each model [26]. Below are the results of the three final parsimonious models, which investigated female students' engineering career interest at the beginning of high school, end of high school, and first semester in college.

The first logistic model we present provides the odds of high school female students being interested in engineering at the beginning of high school (see Table 3, Nagelkerke R Square = 0.222). Following, we modeled female students' career interest in engineering at the end of high school (results are summarized in Table 4, Nagelkerke R Square = 0.306). Lastly, we examined participants' engineering career interest during their first semester in college (see Table 5, Nagelkerke R Square = 0.510). Since the survey was administered to students in introductory English courses, we had an opportunity to identify female students interested in both engineering and non-engineering majors. Thus, we could retrospectively triangulate those who might have lost or gained interest in engineering after transitioning from high school to college. Specifically, comparing the results from Table 3, Table 4, and Table 5, we found that being recognized as a STEM person by family members could increase participants' likelihood to choose an engineering career at all three retrospective time points: the beginning of high school, the end of high school, and the first semester of college. Both at the beginning and end of high school, fathers' encouragement could promote participants' engineering career interest.

More specifically, at the beginning of high school (see Table 3), we found that female students who were interested in engineering in middle school had higher odds of being interested in an engineering career at the beginning of high school (*OR* = 13.735). Female students who identified as Asian, Black/African American, and Latina were more likely to choose engineering as a career in the beginning of high school (*OR* = 2.096; *OR* = 2.032; *OR* = 1.441). When female students were encouraged by their fathers (*OR* = 1.949) and their high school teachers (*OR* = 1.708), they were more likely to demonstrate engineering career interests at the beginning of high school. Conversely, when female students were encouraged by their siblings (*OR* = 0.633), they were less likely to indicate an engineering career interest at the beginning of high school. If STEM was involved in their fathers' careers, high school female students were less likely to choose engineering as a career (*OR* = 0.750). High school female students who received messages of being a "physics person" by their friends and a "STEM person" by their family members were more likely to choose engineering as a career (*OR* = 1.22 and *OR* = 1.260, respectively). However, female students who received messages of being a "STEM person" by friends had lower odds of being interested in engineering careers at the beginning of high school (*OR* = 0.863). Female students who were viewed as a "physics person" by their friends were more likely to choose engineering as a career than female students who were regarded as a "STEM person" by their friends, possibly because physics concepts are closely related to engineering compared to the general STEM disciplines (e.g., life sciences).

Table 3. Female students' engineering career interest at the **beginning of high school**

	Sig.	**Odds Ratio**
Constant	.000	.023
Control Variables		
Parents level of education	.709	.953
Asian	.004	2.096
Black	.005	2.032
Latina	.049	1.441
Multiracial	.048	.498
Native American	.119	1.829
White	.595	1.128
Main Effect		
Engineering career interest at middle school	.000	13.735
Family see me as a STEM person	.000	1.260
Friend see me as a STEM person	.026	.863
Friend see me as a physics person	.000	1.229
Father/male guardian encouraged me toward STEM career	.000	1.949
High school teacher encouraged me toward STEM career	.000	1.708
Sibling(s) encouraged me toward STEM career	.023	.633
STEM is involved in father's career	.034	.750

Female students who reported being interested in an engineering career at the beginning of high school had higher odds of choosing engineering as a career at the end of high school (*OR* = 9.500; Table 4). It was noticeable that interest in engineering in middle school no longer increased female students' odds of choosing engineering as a career at the end of high school. It could be inferred that female students' engineering career interest in middle school only affected their interest at the beginning, not the end of high school, as students might have the option to take more advanced physics courses. Female students who identified as Asian were more likely to choose engineering as a career at the end of high school (*OR* = 2.020), whereas female students who identified as multiracial were less likely to choose engineering as a career at the end of high school (*OR* = 0.389). Compared to the results in Table 3, at the beginning of high school, the odds of Asian female students being interested in engineering careers remained almost the same with a slight decrease. Female students who were encouraged by their fathers (*OR* = 1.471) and siblings (*OR* = 1.506) were more likely to show an engineering career interest at the end of high school. We found that encouragement from siblings could decrease the odds of female students choosing engineering as a career at the beginning of high school but increase the odds at the end of high school. This result may be because the end of high school is a critical transition from high school to college. Female students may be clearer and more serious about their career pathways, whereas at the beginning of high school, they still needed more exploration. It can also be possible that during high school, with more exposure to STEM and receiving more social support, these female students gradually changed their attitudes toward STEM careers and developed stronger interests and confidence in pursuing a STEM career.

However, when female students received encouragement from their mothers or were not encouraged at all, they were less likely to choose engineering as a career at the end of high school (*OR* =0.597 and *OR* = 0.638, respectively). Receiving communicative messages as a physics person or STEM person by family members also increased the odds of female students being interested in engineering careers at the end of high school (*OR* =1.383 and *OR* =1.323, respectively). On the other hand, the results revealed that families who view STEM as a series of courses to be passed decreased female students' likelihood to choose engineering as a career at the end of high school (*OR* = 0.724). Female students with a sibling working in a STEM field had a lower likelihood of choosing engineering as a career at the end of high school (*OR* = 0.707). However, it is possible that some of the participants' siblings did not reach the age to have a career or the participants did not have siblings; thus, our findings may not represent the true participant-sibling social support mechanisms. Establishing an interest in engineering during middle school was included in the model, yet it was not significant in increasing or decreasing female students' odds of being interested in an engineering career at the end of high school.

Table 4. Engineering career interest at the **end of high school** for female students

	Sig.	**Odds Ratio**
Constant	.000	.026
Control Variables		
Parents level of education	.246	.861
Asian	.012	2.020
Black	.676	1.128

Latina	.498	1.143
Multiracial	.019	.389
Native American	.306	1.557
White	.882	1.037
Main Effect		
Engineering career interest at the beginning of high school	.000	9.500
Family see me as a STEM person	.000	1.323
Family see me as a physics person	.000	1.383
Father/male guardian encouraged me toward STEM career	.019	1.471
Mother/female guardian encouraged me toward STEM career	.001	.597
No one encouraged me toward STEM career	.008	.638
Sibling(s) encouraged me toward STEM career	.034	1.506
Family viewed STEM as a series of courses to pass	.028	.724
STEM is involved in sibling's career	.041	.707

During the first semester of college (see Table 5), participants who had the highest odds of choosing an engineering career in their first semester of college (*OR* = 40.041) were those who reported an engineering career interest at the end of high school. Receiving communicative messages from their family as a physics person and/or STEM person increased female students' odds of choosing an engineering career (*OR* = 1.292 and *OR* = 1.169, respectively). Female students who received communicative messages from their friends that they saw them as a STEM person were also more likely to choose engineering as a career (*OR* = 1.195). However, receiving the communicative messages from their family that STEM is a series of courses to be passed, resulted in female students being less likely to choose engineering as a career in the first semester of college (*OR* = 0.544). Female students' odds of choosing an engineering career at two consecutive retrospective time points — the end of high school and the first semester of college — decreased after being influenced by their family's perception that STEM is a series of courses to be passed. Family's view of STEM as courses to be passed may discourage female students from choosing engineering as a career and it does not convey to their students that STEM can lead to more career possibilities at the critical transitional time point between high school and college. Family's view of STEM as courses to be passed can also indicate that there is probably no one in this family who works in the STEM field, thus they were unable to provide detailed STEM-related career information to their student.

Nevertheless, when female students received the message that STEM is a way for people to have a better career from their family, they were more likely to choose engineering as a career during their first semester of college (*OR* = 1.453). Lastly, engineering career interest in middle school and beginning of high school were included in the model, however they did not influence female students' odds of being interested in an engineering career in their first semester of college.

Table 5. Female students' engineering career interest at the **first-semester of college**

	Sig.	**Odds Ratio**

Constant	.000	.009
Control Variables		
Parents level of education	.452	1.125
Asian	.235	1.483
Black	.799	1.091
Latina	.551	1.158
Multiracial	.246	1.616
Native American	.059	.332
White	.518	.828
Main Effect		
Engineering career interest at the end of high school	.000	40.041
Family see me as a STEM person	.039	1.169
STEM Teacher see me as a STEM person	.020	1.195
Family see me as a physics person	.000	1.292
Family viewed STEM as a way for a better career	.021	1.453
Family viewed STEM as a series of courses to pass	.002	.544

Discussion

We investigated how social agents (e.g., teachers, peers, parents, siblings, and other relatives) and their communicative messages (e.g., recognition, encouragement, and career information accessibility) influence high school female students' interest in engineering in three retrospective time points (e.g., beginning of high school, end of high school, and beginning of college). In this discussion section, we will first discuss the impact of demographic backgrounds (e.g., race /ethnicity and parents' educational level) on female students' engineering career interest. Then, we will talk about social agents' impact on female's engineering career interest.

We found that being from a certain race/ethnic group did not consistently increase or decrease participants' odds of being interested in pursuing an engineering career. For example, in the beginning of high school, Latinas were more likely to be interested in engineering careers (*OR* = 1.521), whereas at the end of high school, these female students did not have an increased or decreased interest. At the beginning of high school, Black female students were also more likely to choose engineering careers (*OR* = 2.032), whereas they were no more or less likely to do so by the end of high school. Both Latina and Black students' decreased odds of choosing engineering careers from the beginning to the end of high school suggests that they might not get enough support and exposure to develop their engineering career interests during high school. A prior study has affirmed that the marginalization of STEM education limits the opportunities of Black and Latina students [27]. At the beginning and end of high school, Asian female students were more likely to be interested in an engineering career, the likelihood of their interests did not change once enrolled in college. Female students who identified as multiracial had lower odds of being interested in an engineering career only at the end of high school.

Moreover, participants' parental level of education did not support or hinder their interest in an engineering career in any of the three retrospective time points. Although our study did not find a

consistent time-related relationship between race/ethnicity and engineering career choice, scholars have found there is an association between STEM career interest and social support [13][12]. In prior literature, Asian American students mentioned their families regarded STEM careers as opportunities to obtain financial resources, stability, and success. Asian American students' families usually provided STEM-related support to them, whereas other students indicated their family had less control of their career path and did not provide specific support [28]. Moreover, female students who received more support from family and school were more likely to choose engineering as a career at the end of high school. Social support from within and out of school could serve as an influential socializing agent for female students in making decisions on which fields of study to pursue [8].

Participants' engineering career interests were not consistent throughout the retrospective time points examined in this study (see Figure 2). Female students who showed aspirations for an engineering career during middle school had the highest likelihood of demonstrating an engineering career interest at the beginning of high school. Female students' interest in engineering at the beginning of high school had the highest odds of supporting their engineering aspirations at the end of high school, yet female students' middle school aspirations did not increase their odds. Furthermore, female students' interest at the end of high school had the highest likelihood of supporting their engineering career interest in the first semester of college. However, engineering career aspirations in middle school and beginning of high school did not increase their odds of being interested in engineering at the first semester of college. Our participants' engineering career interests at the end of high school were not affected by their middle school interest, which demonstrates that there are opportunities to develop interest in engineering during the later years of secondary education.

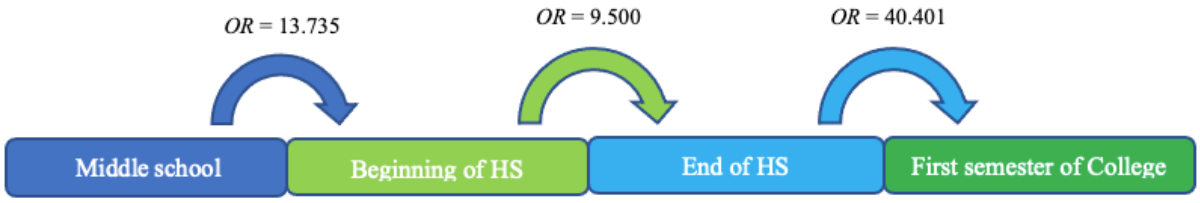

Figure 2. Participants' engineering career interests were not consistent throughout the retrospective time points examined in this study.

At the beginning of high school, female students who were interested in engineering were more likely to be encouraged by their fathers and high school teachers, whereas at the end of high school, those who were interested in engineering were more likely to be encouraged by their fathers and siblings. Our results demonstrate that fathers have a consistent impact on female students' engineering career interests at both the beginning and end of high school. Prior studies examining fathers' involvement on female students' career aspirations in engineering have been conflicting. Some mentioned that fathers served as important role models [29], whereas others reported that fatherly involvement was not significant [30] or even decreased student interest in pursuing engineering careers [9] [30]. Likewise, Fredricks et al. [31] assumed that parents' (particularly fathers') concerns about STEM study and job-related requirements would interfere with students' interest in choosing STEM as a career. Although a prior study [31] emphasized

fathers' negative impact on female students' engineering career interest, our results showed that fathers had a significant positive impact on female students' decision to pursue an engineering career.

In this study, female students who received messages of encouragement from their mothers had decreased odds of being interested in an engineering career at the end of high school. This result is possibly because mothers usually were the ones who encouraged their children to pursue their passion [13, p. 95][14]. However, such vague encouragement was often regarded barely helpful, since many students were confused about what their passions were [14]. Furthermore, our study suggests that it is not merely about which social agents encourage or discourage students to pursue an engineering career, but also the content of the VAS messages the social agents convey to the students that matters. In many cases, fathers and teachers were the ones who conveyed to their student the details about a certain career. In this way, the students could envision the work scenario, such as who they would work with and what the job entailed [14]. However, influential social agents (e.g., parents, teachers, and career counselors) might also be barriers for students to choose a STEM career as they might provide misleading information to students [15]. For example, students learned little or limited information from their parents about STEM careers unless their parents worked in a STEM field [15]. Fathers and teachers usually provided more detailed information, thus students were more confident about their choices and ability based on fathers' and teachers' suggestions and evaluations [14].

We found that female students who received recognition messages of being a physics person from their families had a higher chance of choosing an engineering career at the beginning and end of high school and the first semester of college. The consistency of perceived external recognition messages were important for our participants to pursue engineering. In addition, receiving the recognition message of being a STEM person also increased the likelihood for female students to choose engineering during high school, both at the beginning and later years, as well as in their first semester of college. Thus, being recognized as a STEM person or a physics person by family members is a critical message during high school that promotes engineering career interest. Godwin et al. [11] also confirmed that external recognition (e.g., from parents, teachers and peers) influenced undergraduate students' choice to pursue an engineering degree. Female students that are recognized as a STEM person or physics person by their family may also have greater family support and feel motivated to meet their family's expectations.

Our initial findings suggested that participants' family members viewing STEM as a series of courses to be passed can hinder their interest in engineering careers at the end of high school and in the first semester of college as they might not see greater social values in STEM careers. In contrast, if the participants' family consider STEM as opportunities for better careers, participants had a higher chancer to indicate an engineering career interest at the first semester of college. Knowing the social values of STEM and connecting them with lived experiences could help female students engage more in STEM [31]. Fredricks at el. [31] found that female students were more prone to give up when the STEM content was challenging and they needed more teachers' support to engage in math and science courses. Bystydzienski [5] proposed that some female students may not choose engineering careers because of their fear of failure and the lack of social support, not because of the lack of competency or interest. Another possible reason is

that this narrow perspective, of merely viewing STEM as a series of courses to be passed, did not inspire female students' interest in STEM.

In summary, social support is critical to the entry and persistence of female students' interest in engineering. Belonging to a certain race/ethnic background supported female high schoolers' engineering career interest, but its impact was inconsistent. Parental educational level, which is often used as a proxy for socioeconomic status, was not a significant influencer toward students' decision to pursue engineering. Influential others and their communicative message played a more significant role than female students' demographic backgrounds (e.g., race/ethnicity and SES). To answer our research questions, social agents and their communicative messages can influence female students' engineering career interest in different ways. Although there were inconsistencies in other social agents' impact on female students' engineering career interest, father's encouragement was positively influential toward female students pursuing engineering at both the beginning and end of high school. Moreover, by understanding the value of STEM (viewing STEM as a way to better careers versus viewing STEM as a series of courses to be passed) can increase female students' odds of choosing engineering careers. Receiving external recognition by family could increase female students' odds of choosing engineering careers from high school to first semester of college.

Limitations and Future Work

This study does not come without limitations. Since the data were cross-sectional, the responses may not capture students' interest in engineering at different time points as accurately as a longitudinal study. Another limitation is that we did not investigate interaction effects. For example, race/ethnicity itself may not be significant in the model, but when it interacts with some independent variables (e.g., family attitudes toward STEM courses), race/ethnicity may become significant. Future work will investigate the interaction effect between gender, race/ethnicity identification, parental level of education, family attitudes toward STEM, encouragement from family members, and whether STEM is involved in family members' career on engineering career interest. Additionally, qualitative data can help deepen the understanding of how and why social agents and communicative messages influence students' engineering career interest.

A previous study found that media was one of the five primary VAS sources influencing students' career choices [14]. However, we did not collect data that helps us understand how media influenced female high schoolers' engineering career interest. Future work can examine the role media plays in informing female students' interest in pursuing STEM careers, specifically, engineering.

Conclusion

This study used the Vocational Anticipation Socialization of the STEM model to understand female students' engineering career interests at the beginning and end of high school into the first semester of college. This study revealed that social agents (e.g., teachers, friends, and parents, especially encouragement from fathers) and the types of communicative messages, especially external recognition and positive family attitude toward STEM, received from these

social agents were more influential than demographic factors on female students' engineering career choices.

Although female students are the agents making the final career decision, they are only one facet of the whole VAS process. Depending on the social agents and types of communicative messages received, we found that female students' interest in engineering careers may change, which opens opportunities for the engineering education community to create more effective interventions to attract female students at different academic stages.

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