"I'm Not Good at Math," She Said: Gender and Engineering Majors

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Research indicates that women underestimate their math and science ability. This underestimation leads to a perennial under-representation of women in engineering. Self-perception of ability, not ability itself, is the main barrier to women when it comes to studying engineering and physical science. Even when women are given equal opportunities to men, they tend to self-select and not pursue engineering. This paper explores causes of this phenomenon, and ideas for reversing the trend. The original data presented here indicates that family of origin configuration can be a predictor of choice of college major, especially for women choosing engineering.

Keywords: women in engineering, selection of major, perception of ability, family of origin

INTRODUCTION

It remains a mystery: why do so few females choose engineering as a college major? Although evidence is emerging, aspects of the question remain unanswered. In the United States (US), approximately 18% of engineering students are females, compared to 64% of humanities students (Wang, 2017). It was previously assumed, erroneously, that males had better mathematics and spatial skills than females, but this self-evident "truth" has been debunked by research (Anelli & Peri, 2015). In fact, high school females tend to have higher average mathematics scores than high school males, yet they enter science, technology, engineering and mathematics (STEM) fields in much lower numbers (Shettle, et al., 2007). College enrollment of females has surpassed that of males in the health sciences, while other historically male-dominated fields have gained gender parity. Meanwhile, the percentage of females in engineering remains low and virtually unchanged (Anelli & Peri, 2015).

As a short personal vignette, it is a common occurrence when the first author meets someone, and they ask, "What do you do?" and she says, "I'm an engineer; I teach engineering science and math." If the person asking the question is female, she will often say, "I'm not good at math! I hate math! I really can't do math at all!" And this makes the first author wonder what happened to the female to make her believe that about herself? Consider if a person were to say, "I hate English! I can barely read! I'm practically illiterate!" Culturally we would assume this person is not educated. As a society, we have parameters for what we expect from educated people, which includes literacy; yet society as a whole does not hold this same value for mathematics, at least not for females (Hill, 2020).

On of the primary occupations in STEM fields is engineering. Currently, STEM job growth outpaces non-STEM job growth by nearly a factor of 3 (24.4% vs. 8.9%), and STEM workers have a disproportionately significant influence on a country's economic growth, competitiveness, and standard of living (Noonan, 2017). This means that the US needs more engineers of every kind (e.g., chemical, material, mechanical). The fact that the US is not educating more female engineers means that we are losing nearly half of the able engineers in the United States. If the US had more engineering students, then these successes might be possible (Sokanu, n.d.):

- Generate more electrical power
- Grow better crops
- Make water cleaner
- Update the infrastructure
- Invent new things
- Make life better for everyone

Are females choosing other science, technology, and mathematics fields over engineering, or are they rejecting engineering as a college major? In either case, if ability and achievement are not the primary issues, then what are? Clearly, something aside from mathematical ability influences females' college major choices, and not enough females choose engineering.

LITERATURE REVIEW

A review of the literature reveals that social, cultural, interpersonal and personal factors all influence females' college major choices and career aspirations. Many of these factors can be traced to family origin and early childhood, not just to experiences in school. To this end, the literature review in this paper explores gender-related factors relevant to females' college major choices, including family influences, self-image and self-efficacy, perception of gender roles, students' value systems, and outcome expectancies for attaining a college degree.

Although several of these factors have been widely studied, and family of origin configuration in relationship to college major has been studied in other countries (specifically Italy), there is a gap in the literature for this relationship as concerns US students.

Factors Correlated With College Major Choice by Gender

A consistent theme found in the literature indicates that factors affecting choice of college majors vary with gender. Females and males view the desirability of a major using different criteria. Notably, this is true for other demographic groups as well. In one study, researchers analyzed the extent to which occupational segregation by gender, race/ethnicity and family of origin affect patterning of individual college choices. The study showed a positive influence on students from particular demographic groups if they see members of their demographic group in a technical or science career (Ma, 2011).

Childers & Lisi (2001) examined careers traditionally dominated by one gender and the factors affecting the choice of the opposite-gender students majoring in that field. The data analyzed as *individual factors* were 1) perception of gender roles, 2) self-concept of ability, and 3) expectations of success while *social factors* were 1) locus of control, 2) utility, and 3) cost, with expectation of success in attaining particular college degrees differing between males and females (Childers & Lisi, 2001). The researchers concluded that students' value systems were strong predictors of choice of majors. Specifically, engineering was incorrectly perceived as less humanitarian, which tended to be a more important value for females, leading some of them away from engineering.

Riegle-Crumb et al. (2016) investigated the empirical argument that gender differences in STEM majors are due to prior achievement. Their research indicates that STEM is universalistic and that the underachievement arguments failed to provide answers to the gender inequality in STEM. Morgan et al. (2002) found little correlation between achievement, ability, work-family orientation and choice of STEM majors. Instead, they found that detailed occupational plans created at the end of high school had high correlation to initial college major selection.

Family and Psychosocial Factors in Choice of College Major

Social, interpersonal, and personal factors also affect choice of major, including configuration of family of origin. Gonzalez-Pinto et al. (2003) conducted research involving 6,013 college students. Females were represented in greater proportion in all career studies except for engineering. The youngest and intermediate children were over-represented in journalism and fine arts, while firstborn children more commonly study engineering. The authors concluded that choice of college major is associated with gender and birth order, as well as family size and personality, which is, in turn, a function of birth order and family size.

Ferry et al. (n.d) developed a model that integrates personal, contextual, and experiential factors in determining career choice. Their research classified parental involvement, parenting style, socioeconomic status (SES), parental math/science proficiency, and family relationships as "family variables," and they found that encouragement and outcome expectancies had a significant direct effect on grades in mathematics and science. Significant effects were also found between gender and learning experiences. Self-efficacy and outcome expectancies also directly affected interests and goals, in particular academic goals involving mathematics (e.g., people who think they are good at math, like math, and pursue math careers). They concluded that family variables influence social cognitive career choice.

Eccles (2009) examined identity formation based on self-perception of competencies and personal values as a basis for expectation of success and motivators of action. This research focused on how lifetime identity development influenced behavioral choices, and how collective identities associated with gender affected the life choices of females. Anelli & Perry (2015) found a relationship between the gender of siblings and their choice of college major; specifically, families with same-gender siblings encouraged academic choices that are less gender stereotyped. This included females in engineering, science, and business. Males who grew up in families with sisters seem to reinforce a "male role" in their choice of major, while males who grew up with all-male siblings chose less stereotypic male majors, such as nursing and teaching. Females growing up in families with brothers do not appear to significantly increase a "female role" in their choice of major. In other words, mixed-gender families of origin tend to reinforce gender stereotypes.

Ma (2011) found that family SES and parental involvement influenced patterned college major choice by gender, race/ethnicity, and nativity. Children of lower SES families favored more lucrative college majors, with differences between males and females. Ma also found that females valued intrinsic, altruistic, and social job rewards, while males valued extrinsic rewards such as money or prestige. Parental involvement in education exerted significant effects on choice of college major. Cryon (2016) found that in early childhood, males with sisters benefitted in cognitive skills, learning skills, and self-control. No similar benefit based on siblings was found for females, and the brothers' benefit began to fade by first grade.

Literature Discussion

The literature suggests that the reasons for selecting a major and persisting or leaving that major are complex and cannot be attributed to ability and interest alone. The reasons consist of social, interpersonal, and personal factors, including family of origin configuration. Personal values and family values are different for different demographic groups, and also have an influence on choice of major. Notably, many of these factors are interrelated and may be correlated to family of origin as well.

Females Are Awesome at Mathematics and Science

Mathematical ability is essential for successful engineers, and a common misunderstanding is that males are better at mathematics than females. The fact is, females do as well or better than males in mathematics by most measures (Hill, 2020). For example, in high school, female average performance and participation in mathematics and science have improved over time and, in some cases, surpassed that of males. High school females, on average, graduate with higher math and science grades than their male classmates, and since 1990, females have earned more high school credits in mathematics and science than males (Riegle-Crumb, et al., 2016).

Despite the overall positive trends in high school mathematics scores, females are less likely than males to declare engineering as their major in college (Riegle-Crumb, et al., 2016). In 2006,about 15% of first-year female college students planned to declare a major in all STEM fields combined; but if biological and agricultural sciences are removed, only about 5% of first-year female college students intend to major in a STEM area of physical sciences, including engineering (Shettle, et al., 2007). At the same time, more than a quarter (25%) of first-year male college students declared a physical science major (Shettle, et al., 2007).

So, if it's not ability, why do more males pursue physical science and engineering while females do not? The reasons are complex and intricately tied to culture, but research indicates one primary reason is that females believe that they are worse at mathematics than they really are. They also think that males are better at mathematics than females (Meyer & Marx, 2014).

Females Underestimate Their Ability in Mathematics

Years ago, the first author taught the algebra sequence to a wide array of community college students in a self-paced lab. If students did poorly on an exam, she met with them individually to review their tests. As she remembers, males and females tended to respond differently to this critique. Males tended to blame the material ("This is stupid!"), whereas females tended to blame their ability ("I'm stupid!"). Interestingly, international students tended to feel they would have done better if they had worked harder. Although this information is anecdotal, she was struck by how often she could predict students' responses based on gender or nationality.

Researchers have also found repeatedly that the "stereotype threat" has a negative effect on females' performance on mathematics tests (Meyer & Marx, 2014). It works like this: In an experiment, researchers give a math test to two groups of female and male college students who have similar math abilities. One group is told that males perform better than females do on the test (the "stereotype threat" group), and the other group is told that there were no gender differences (the "no stereotype threat" group). Female performance improves when there is no "threat" and diminishes when there is a threat. This result is shown repeatedly in other studies. Interestingly, the threat/no threat scenario has no measurable effect on male math performance.

The Impact of a Growth Mindset

In her book *Grit* (2016), Angela Duckworth says that humans love "a natural." Talent seems magical and glamorous, whereas practice and hard work are more pedestrian. But teachers can emphasize the possibility of growth, of developing ability, rather than viewing ability as inherent and permanent. Teachers can emphasize that ability is accomplished, rather than something that is an inherent ability. This mindset is essential for females in engineering because encountering obstacles and challenging problems is in the nature of STEM work. When females believe they have only a fixed amount of intelligence and ability, they are more likely to lose confidence and disengage from engineering when they inevitably encounter difficulties in their course work (Duckworth, 2016). This is true for all students, but it is particularly relevant for females in STEM subjects, where negative stereotypes persist about their abilities.

Researchers could consider drawing an analogy between athletic ability and mathematical ability: Athletes have natural ability, but they also train. No one performs at the top of their sport without exercise, a healthy diet, and practice. So it is with mathematics. Ability is important, and helpful, but it is overrated. This obstacle can be scaled.

A Historical Note

Females have always had the ability to become quality engineers, yet historically few have chosen this career path. As a trends example of females studying engineering, the history of The Montana School of Mines (now, Montana Technological University, or simply "Tech") provides an interesting case study. Tech opened its doors in 1900 and graduated its first class in 1904. That first graduation, there were two majors (mining engineering and electrical engineering) and eight graduates. Of the eight, two were females, and one was the valedictorian. The females' names were Clara Clark Reese and Elizabeth Little Stephenson (Hoffman, 2015).

The School of Mines was always co-ed, and females always studied with males. Yet, while many females attended Montana Tech, there were no other female graduates until the 1960s. The next female graduate was Delores "Dolly" LaBranche, who earned a degree in metallurgical engineering in 1966 (Montmarquette, et al., 2002). When the first author graduated from Tech in 1986, about 5% of the class was female -- still a low number, but a marked improvement over previous years. In 2018, about 15% of engineering graduates at Tech were females (McCoy, 2011). The Tech engineering female graduation pattern is indicative of a few things: Females have always been capable of studying engineering, yet they overwhelmingly choose not to; and there are more female engineering graduates than in previous years, but society is far from reaching gender equity.

METHODS

The first author was initially interested in gender engineering studies when she observed that most female engineers come from all-female families. This led her to ask, "Are sibling groups for female engineers different than for male engineers? Does family of origin configuration affect choice of college major?" Based on her observation, she decided to investigate one main research question: **Is family-of-origin configuration a factor in choosing a college engineering major?**

To study this question, she developed the 'Family of Origin' questionnaire (see Appendix). This questionnaire was designed as a quantitative instrument, specifically to facilitate the use of t-tests to determine if there were significant differences in the mean of various groups. The z- score, or standard score, is the measure of how many standard deviations below or above the population mean the data point lies and is reported in the findings.

In this paper, we explore the percentage of female engineers who have brothers compared to the sample as a whole and also compared to other groups (male nurses, female agriculture majors, humanities majors of both genders, etc.). The first author ran multiple t-tests rather than ANOVA (analysis of variance) because she was initially only concerned with female engineers compared to the sample as a whole; the additional t-tests were an outgrowth of this inquiry. Responses to the 'Family of Origin' questionnaire were collected between February 7, 2017, and March 27, 2017. Prior to February 2017, IRB approval from Northwest College (NWC) was obtained. All questionnaire responses were collected online. Initially, 44 responses were collected from students at NWC; an additional 138 responses were collected through social media (e.g., Facebook).

A total of 182 responses were collected (see Table 1). Of the respondents, 54 (29.7%) were males, and 128 (70.3%) were females. Respondents were divided by seven major areas of study, corresponding to the six colleges at the University of Wyoming (UW), the state's flagship research university. A seventh category was included for Other/Undeclared students. The categories were further subdivided by gender within each major area of study. Table 1 also shows the subgroups, the number of respondents in each subgroup, and the percentage of each subgroup with brothers, with sisters, and with neither (only children).

TABLE 1
SURVEY RESPONDENT (PARTICIPANT) INFORMATION (n=182)

GROUP DESCRIPTION	FAMILY OF ORIGIN CONFIGURATION			n in group
			% only	number
	% w/brothers	% w/sisters	children	responses
All	70	71	5	182
Males	65	74	6	54
Females	72	70	5	128

Major				
Ag	64	71	14	14
Arts&Sciences	60	74	7	42
Business	78	87	0	23
Education	79	60	2	42
Engineering	61	61	10	31
Health Science	73	93	7	15
Other/undeclared	80	73	0	15
Major by gender				
Female Ag	57	43	14	7
Male ag	71	86	14	7
Female Arts&Sci	63	67	10	30
Male Arts&Sci	50	92	0	12
Female Business	76	88	0	17
Male Business	83	83	0	6
Female Education	84	59	0	37
Male Education	40	60	20	5
Female Engineer	47	73	13	15
Male Engineer	75	50	6	16
Femal Health Sci	75	92	8	12
Male Health Sci	67	100	0	3
Female Other/Undecl	90	70	0	10
Male Other/Undecl	60	80	0	5

ANALYSIS

Statistical analysis was performed using SPSS and Excel software. One-tailed T-tests were used to determine if female engineers were less likely to have brothers as compared to other gender/major subgroups as well as the total sample. A one-tailed test was utilized because it was important not to confound the results if they were actually in the other direction (in other words, if female engineers were actually more likely to have brothers). The number of brothers and sisters of subgroups, the frequency of same-sex sibling groups, and the frequency of no brothers and sisters (only children) by college major and gender were examined. Percentages of each subgroup with no brothers, no sisters, and neither (only children) were compared to other subgroups and to the aggregate.

Results/Findings

When compared to the average of the entire group of respondents (n=182), the following *statistically significant* results (at the p=.05 level) for a one-tailed test were found in the following subgroups:

- Fewer male engineers have sisters (Z-score = -1.7882, p = 0.03673)
- Fewer female engineers have brothers (Z-score = -1.8448, p = 0.03288)
- More health science majors (genders combined) have sisters (Z-score = 1.8388, p=0.03288)
- More female education majors have brothers (Z-score = 1.7322, p=0.04182)

Thus, the answer to the original research question is yes, female engineers tend to come from all female families. The Z-score shows this to be statistically significant. Additionally, there are three other subgroups with statistically significant differences. These statistically significant results are summarized in Table 2.

TABLE 2
RESULTS WITH STATISTICALLY SIGNIFICANT DIFFERENCES FROM AGGREGATE (p<.05, ONE-TAILED TEST)

GROUP DESCRIPTION	z-score (one-tailed)	z-score (one-tailed)	p-value
	Comp.to aggregate	Comp. to aggregate	
	without brothers	without sisters	sig.@ p<.05
Health Science		1.8388	0.03288
Female Education	1.7322		0.04182
Female Engineers	-1.8448		0.03288
Male Engineers		-1.7882	0.03673

Limitations and Future Research

There are several categories of data that appear to be significant when viewed graphically, but only these four comparisons (highlighted in the findings) show statistical significance on examination of Z-scores (p=0.05, one-tail tests). This study used a relatively small sample size (n=182), and if larger samples were collected, significance may be present. It may be worthwhile to explore why the only child data is not significant, given the variance from subgroup to subgroup on this variable. Due to the small effect size, especially for only children, the authors would like to view this work as a pilot study. Future research calls for larger scale tests (n=2000) to determine whether more results are statistically significant.

CONCLUSION

The original hypothesis, female engineers are less likely to have brothers than other college students, was found to be statistically significant (Z-score = -1.7882, p=0.03673) for this study. This result is consistent with the literature review, which indicates that families with same-gender siblings encouraged academic choices that are less gender stereotyped. Other correlations were also found; three others were statistically significant. Even others, although not statistically significant in this study, appear graphically to show a difference. The authors plan to repeat this survey with a larger sample size, especially with respect to the number of only children in each of the subgroups.

Most of the work done on family of origin and career choice comes from longitudinal studies in Italy, but studies in various cultures and countries could benefit from understanding what leads females to choose engineering careers. Specifically, what could be some US cultural phenomena that lead females away from engineering that might not have been investigated to date? There is a gap in the literature about why this happens in some countries but does not happen in others. In this study, the authors verified their observations.

The results of this study have implications for females in engineering because the literature and this pilot study suggest that females make decisions about their choice of college major and future careers based on cultural, interpersonal, and personal factors at a very early stage in life, and that US culture is an integral part of these factors. This study supports evidence that the antecedents for these decisions may be rooted in early childhood and shaped by the family of origin configuration.

As researchers look to the future, awareness is the first step in helping teachers and parents recognize that the decision to choose engineering as a major could be formed early in life. College major choices are also influenced while growing up and attending school. Finding a means to support females' choices (and encouraging engineering) based on cultural interactions with them from an early age and throughout schooling is crucial, and may include place-based, authentic-science, integrated STEM activities (Burrows, 2018; French & Burrows, 2018; Sabo, et al., 2014; and Burrows, et al., 2013) that bridge the spaces between the STEM disciplines.

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APPENDIX

Family of Origin Survey

Informed consent: this is a research project being conducted by the author. The purpose of this survey is to investigate relationships between family of origin configuration and college major.

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. All data is stored in a password protected electronic format. To help protect your confidentiality, the surveys will not contain information that will personally identify you. The results of this study will be used for scholarly purposes only.

If you have any questions about the research study, please contact the author. This research has been reviewed according to the IRB procedures for research involving human subjects at the author's college.

1. By clicking agree, I certify that I have read the above information, I voluntarily agree to participate, and I am at least 18 years old.
   - Agree
   - Do not agree

2. What is your primary area of study in college?
   - Agriculture and Natural Resources
   - Arts and Sciences
   - Business and Commerce
   - Education
   - Engineering and Applied Science
   - Health Science
   - Other/Undeclared

3. What is your college major?

4. How many brothers do you have?
   - 0
   - 1
   - 2
   - 3 or more

5. How many of your brothers are older than you?
   - 0
   - 1
   - 2
   - 3 or more

6. How many sisters do you have?
   - 0
   - 1
   - 2
   - 3 or more

7. How many of your sisters are older than you?
   - 0
   - 1
   - 2
   - 3 or more

8. What is your class standing?
   - Freshman
   - Sophomore
   - Junior
   - Senior
   - Other

9. What is your GPA?
   - 4.0 or above
   - 3.5-less than 4.0
   - 3.0- less than 3.5
   - 2.5-less than 3.0
   - 2.0 - less than 2.5
   - Below 2.0

10. What is your gender?

- Male
- Female

11. What is your age?

12. Are you a first generation college student?

- Yes; none of my parents has a college degree
- No; at least one of my parents has a college degree

13. Do any of your siblings have college degrees?

- Yes
- No

14. Thank you for participating in this survey! Please rate the difficulty

Very easy	Easy	Moderately easy	Difficult	Very difficult
☆	☆	☆	☆	☆

FIGURE 1
NUMBER OF MALE STUDENTS WITH NO BROTHERS, BY AREA OF STUDY

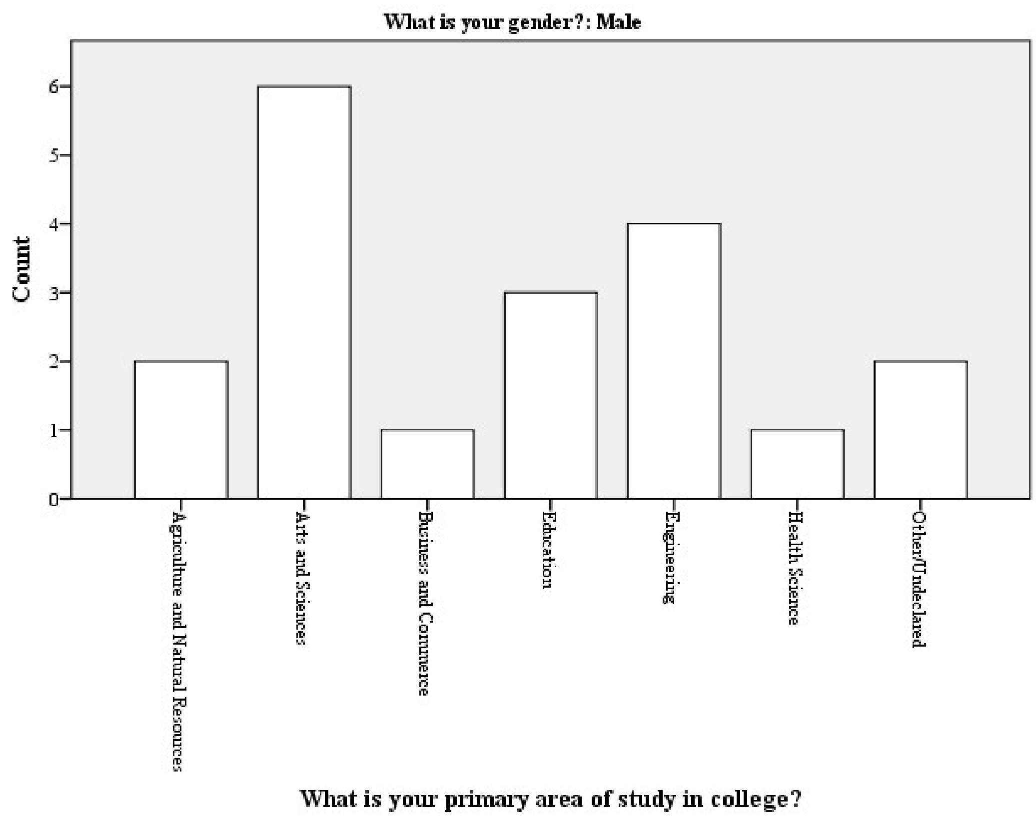

FIGURE 2
NUMBER OF FEMALE STUDENTS WITH NO BROTHERS, BY AREA OF STUDY

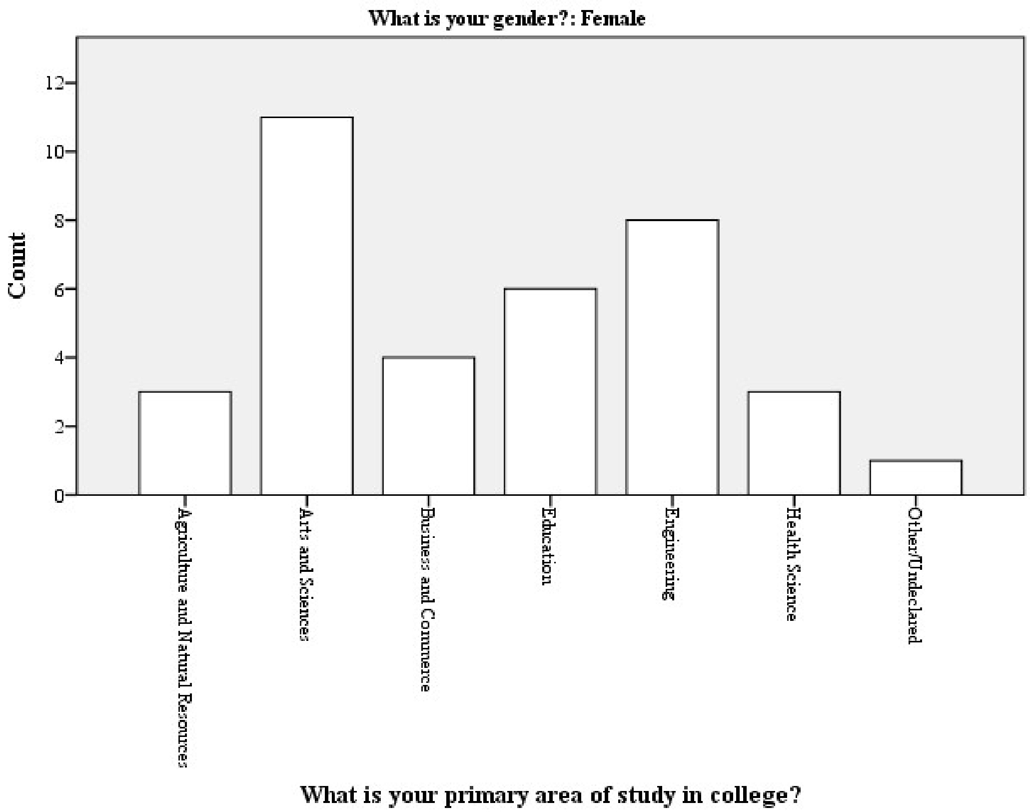

FIGURE 3
FOCUS ON ONLY CHILDREN AND PRIMARY AREA OF STUDY (NO GENDER)

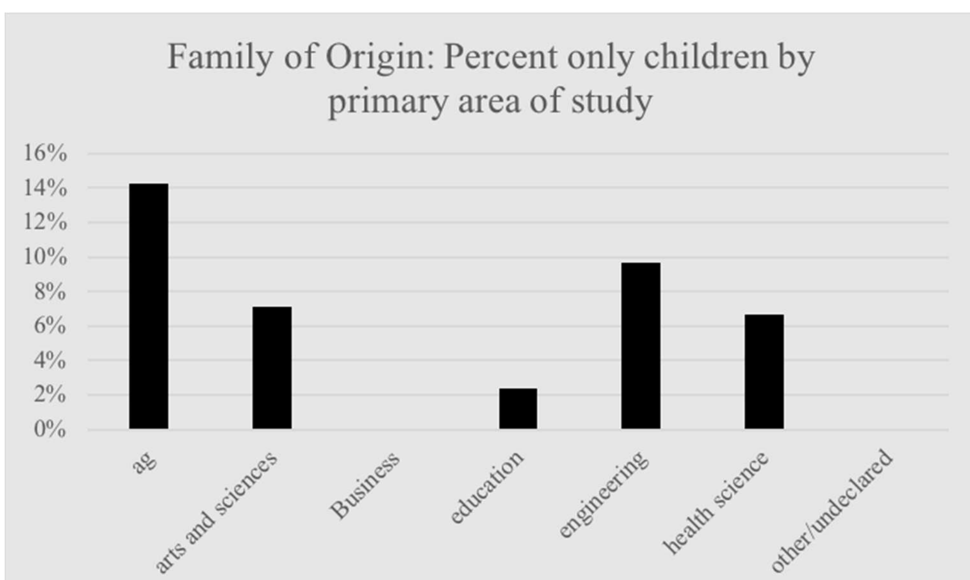

FIGURE 4
FOCUS ON STUDENTS WITH BROTHERS AND PRIMARY AREA OF STUDY (NO GENDER)

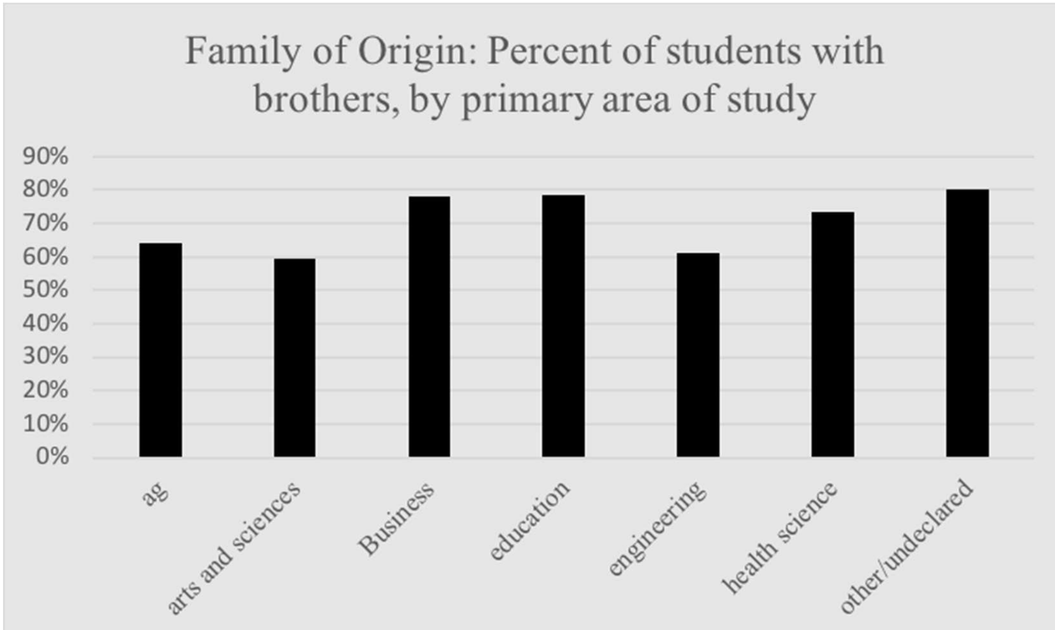

FIGURE 5
FOCUS ON STUDENTS WITH SISTERS AND PRIMARY AREA OF STUDY (NO GENDER)

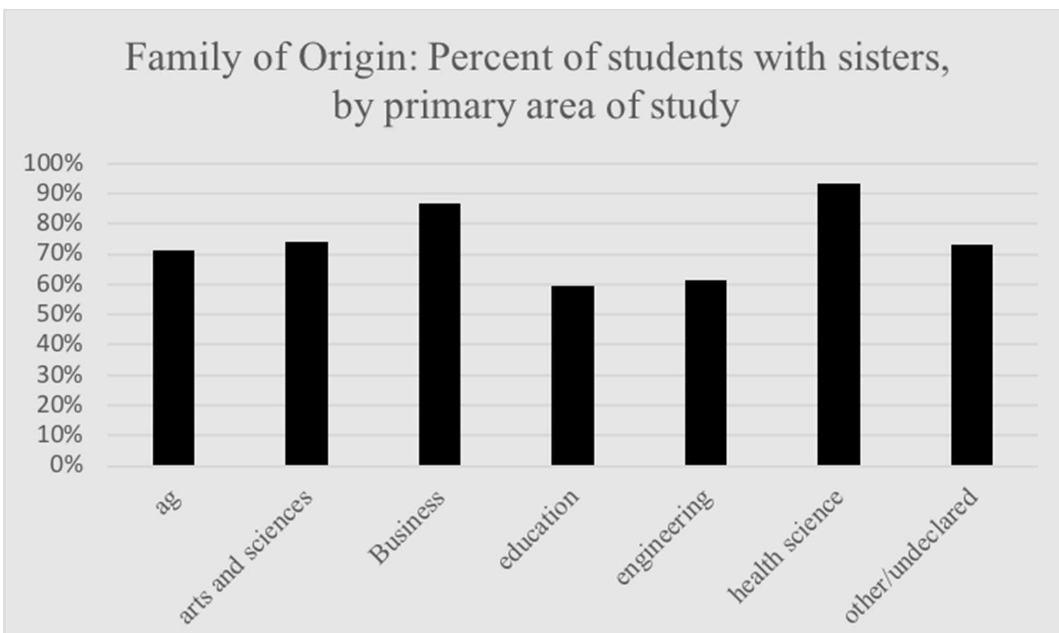

FIGURE 6
FOCUS ON ONLY CHILDREN, PRIMARY AREA OF STUDY, AND GENDER

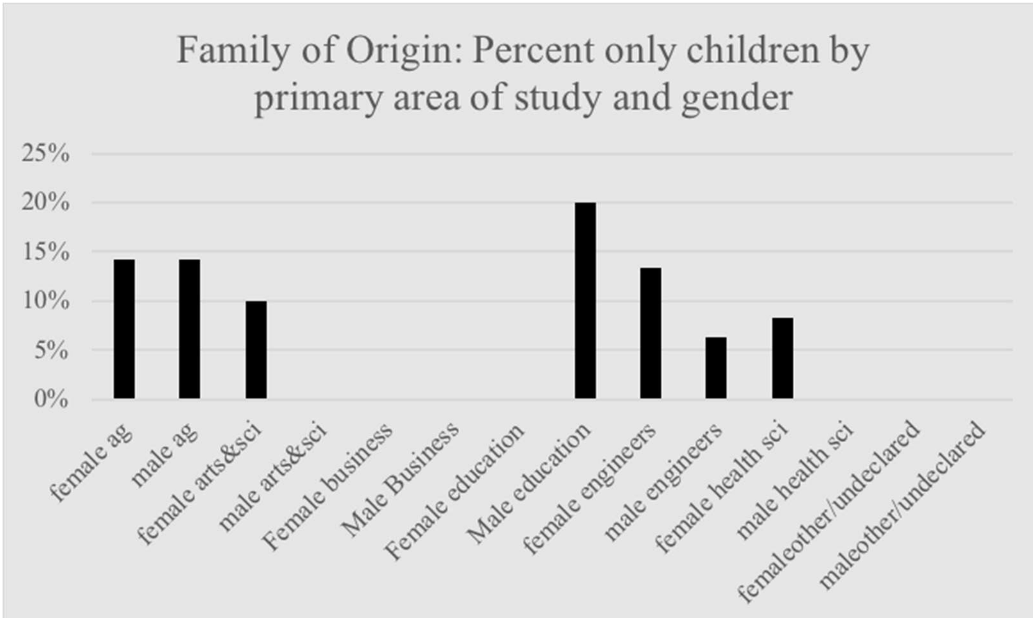

FIGURE 7
FOCUS ON STUDENTS WITH BROTHERS, PRIMARY AREA OF STUDY, AND GENDER

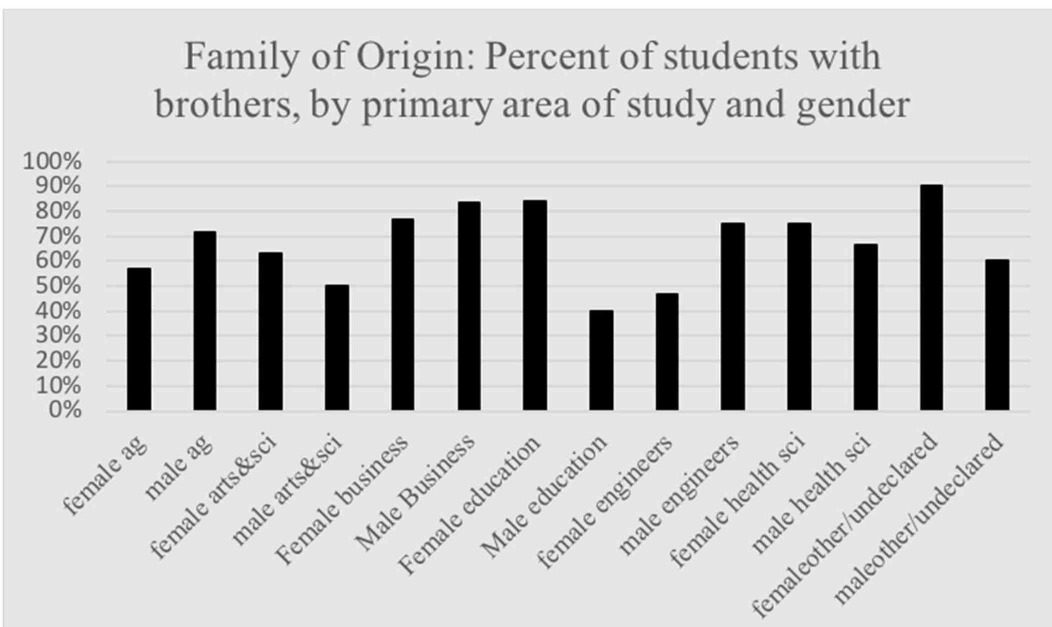

FIGURE 8
FOCUS ON STUDENTS WITH SISTERS, PRIMARY AREA OF STUDY, AND GENDER