EXPLORING THE LINKS BETWEEN INSTRUCTORS' NON-CONTENT MESSAGES AND GENDER DISPARITIES IN STEM FIELDS

by

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(Under the Direction of Michael M. Barger)

ABSTRACT

Women are important part of the overall STEM workforce and should have equal access to STEM fields, however, gender gaps exist and differ across STEM fields. The present study explored whether instructors' non-content messages students reported hearing in a survey were related to gender gaps in STEM fields. Results indicated that majors such as biology and chemistry were more gender balanced than majors like computer science and engineering. Gender representation across STEM fields may play a role in students' perceptions of instructors' non-content messages: students in female-dominated STEM fields reported receiving more of these kinds of messages. Instructors' non-content messages were found to be associated to students' motivation and belonging, but in unexpected ways. Existed gender gaps across STEM fields continue to negatively relate to female students' sense of belonging and interest towards STEM careers.

INDEX WORDS: Gender gaps in STEM fields, Instructors' non-content messages, Students' motivation and belonging

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CHAPTER 1

INTRODUCTION

Women should have equal access to STEM (Science, Technology, Engineering and Mathematics) fields. As half of the overall workforce, their potential contributions to STEM fields should not be neglected. However, this is not the case in many STEM fields. Women are underrepresented both in obtaining undergraduate STEM degrees and in the pursuit of STEM careers (Beede, 2011; Noonan, 2017). More notably, the gender gaps are higher in some of the STEM fields like computer science and engineering than other STEM fields like biology and chemistry, and the overall gender gaps have almost stayed the same in recent years (National Science Foundation, 2012; Cheryan et al., 2017; Noonan, 2017; U.S. Bureau of Labor Statistics, 2022).

Previous studies have endeavored to explore the reasons behind the gender imbalance across STEM fields. Gender stereotypes that associate STEM fields with masculine traits, is one of the key factors contributing to the gender gaps in STEM fields, by both decreasing women's willingness to choose a STEM major and preventing them from entering a STEM career (Miller et al., 2018; Makarova, Aeschlimann, & Herzog, 2019). How do gender stereotypes interact with women's STEM development? Studies integrating motivation and belonging constructs have provided further explanations. The stereotypical beliefs (e.g., "brilliance = males") exert a negative effect on females' competence beliefs and interests in fields for the "brilliance," and lower females' sense of belonging to STEM fields, and in turn, negatively influence females' STEM performance and willingness to pursue a STEM-related career (Bian, Leslie, & Cimpian, 2017; Good, Rattan, & Dweck, 2012). Career preferences associated with women's evaluation of utility value, attainment value and cost also contribute to the gender gaps in STEM fields.

Instructors, as one of the professional representations of what it means to work in a STEM field during an important phase of students' academic and career development and having chances to frequently interact with students, may play a role in students' motivation towards STEM fields. Thus, STEM instructors may contribute to an expansion or narrowness of gender gaps in STEM learning and future career development. Much of the previous work has focused on more explicit evidence like the effects of instructors' gender on students' STEM development (Bettinger & Long, 2005; Price, 2010; Kramer, et al., 2016), or how instructional interactions (course syllabus, teaching practices, instructors' feedback) between instructors and students motivate or demotivate students' STEM learning (e.g., Rattan et al., 2012; Fuesting et al., 2019; Canning et al., 2022), however, fewer studies have paid attention on the implicit evidence instructors' may transport to students in class through non-content messages (i.e., statements that are unrelated to the course subject matter) and therefore reinforce those gender stereotypes and reduce feelings of students' motivation and belonging to STEM fields.

This paper sets out to see whether there are differences in students' perceptions of instructors' non-content messages about career between STEM fields that are more dominated by men or women, and whether instructor's non-content messages explain disparities in students' motivation and belonging in STEM fields above and beyond student gender and gender representation of their classmates.

Gender Gaps in STEM Fields

Gender gaps in STEM fields have been a long-standing and hotly studied topic. However, although many efforts have been made to understand and narrow the STEM gender gaps, the situation has not improved significantly, and gender gaps still exist both in academic and career development (Sax et al., 2016; Perez-Felkner, 2018; Delaney & Devereux, 2022). In 2015, women made up 47 percent of the overall U.S. workforce, but the share of women in the STEM workforce was only 24 percent; and nearly half of all employers with bachelor's degrees were women, however, women made up only about 30 percent of all STEM degree holders (Noonan, 2017). Remarkably, the data was similar as what shown six years ago in a survey of 2009 (Beede, 2011). Interestingly, the gender gaps differ across STEM fields. Fields like biological sciences or chemistry are more gender balanced than fields like computer science or engineering. For instance, over 50 percent of the freshmen planning to pursue a major in biological and agricultural sciences were women, however, women made up less than 14 percent of intended computer science majors (National Science Foundation, 2012; Cheryan et al., 2017); and data from the U.S. Bureau of Labor Statistics shows that in 2022 women made up 57.9 percent of biological scientists but 16.1 percent of engineers and architects (U.S. Bureau of Labor Statistics, 2022).

Closing gender gaps and increasing women's participation in STEM fields are beneficial for women's development in careers with good salaries and high status. The majority of the most well-paid and respected jobs are those associated with STEM fields (U.S. News, 2023). The gender wage gap is smaller in STEM jobs than in non-STEM jobs. Women with STEM jobs earned 35 percent more than comparable women with non-STEM jobs and 40 percent more than men with non-STEM jobs (Noonan, 2017). Additionally, women are indispensable for the STEM workforce, especially for those fields which are less gender balanced (e.g., computer science). The STEM labor market has a shortage of positions like materials science engineers, nuclear engineers, systems engineers, software developers and intelligence professionals while has an oversupply of biomedical and chemistry Ph.D.'s (Xue & Larson, 2015). Enough talented women's participation also can contribute to the diversity, collective intelligence, and the sustainable and dynamic development of some STEM fields (Pearl-Martinez & Stephens, 2016).

Understanding what inhibits women from entering STEM fields or cause them to leave is necessary for the narrowness of STEM gender gaps. Gender stereotypes, that traditionally associate STEM fields with masculine traits, have not changed much even though women's representation in STEM fields has gradually increased. In a meta-analysis of 5 decades of Draw-A- Scientist studies, children drew men as scientists more often than women on average and their tendency to depict men as scientists increased as they grow older (Miller, et al., 2018). Gender stereotypes are powerful drivers of gender gaps in STEM fields (Verdugo-Castro, et al., 2022). In a study of three STEM related courses Math, Physics, and Chemistry of secondary school which were perceived as masculine among students, female students regarded these subjects as male domains much more strongly than did male students. These stereotypical beliefs about math and science impede female students' choices towards STEM fields. Among the three subjects, chemistry was reported having the weakest masculinity compared to math and physics, which may partly explain why some STEM fields like chemistry more gender balanced than others (Makarova et al., 2019). Studies integrating motivation and belonging constructs have further explained how these constructs (i.e., sense of belonging, interest, competence beliefs) interact with gender stereotypes to influence women's beliefs and choices about STEM fields. Women are underrepresented in STEM fields valuing giftedness, brilliance, or raw talent, since as an intellectual ability stereotype the trait of giftedness, brilliance, or raw talent has been traditionally associated with men. The stereotypical belief that "brilliance = males" can be endorsed as young as six years old. If women internalize the stereotypical belief, they may categorize the “brilliance” fields as male domains and ultimately undermining female’s sense of belonging to and interest in STEM fields. (Leslie, et al., 2015; Bian, Leslie, & Cimpian, 2017; Deiglmayr, Stern, & Schubert, 2019). Career preferences is another contributor to the gender gaps in STEM fields. Women tend to be more interested in socially oriented occupations which emphasize community or are people oriented. This may explain why women are more likely to pursue biomedical and environmental engineering than mechanical or electrical engineering in STEM fields (Wang & Degol, 2017). From people-oriented jobs, women may obtain higher attainment value (i.e., value that comes from a task being perceived as personally important). As stated in Stein et al. (1971), females gained lower scores on the masculine tasks than those on the feminine and neutral tasks. In addition, women tend to be more willing to pursue a career which can balance family and work than men. Talented occupational women can shift their life focus to family-centered goals after having a baby (Wang & Degol, 2017). Working in high demanding STEM fields may cost them too much energy and time and is not in keeping with their utility value (i.e., value that comes from a task being perceived as useful for one's current or future goals).

The Role of Instructors in Closing the Gender Gaps in STEM Fields

Females’ STEM ability or performance are not the main factors accounted for their underrepresentation in STEM fields. There was no difference in GPA between women who persisted in STEM fields and those who switched to non-STEM fields; however, the support of advisors and mentors was reported as one of the reasons for females’ persistence in STEM fields (Brainard & Carlin, 1997). As a potential contributor to the narrowness of the gender gaps in STEM fields, instructors themselves often ignore their importance. Instructors most frequently utilized gender acknowledgement discourses, which means that they admitted the existence of gender imbalance but indicated that the causes of gender imbalance were outside of their interactions with students (Blair et al., 2017). Obtaining a comprehensive understanding of instructors' roles in closing the gender gaps in STEM fields can both arouse instructors' attention on this problem and provide directions for the improvement.

Much of the previous work has contributed to our understanding of this topic. Studies centered on more explicit evidence as the effects of instructors' gender on students' STEM development have provided inconsistent outcomes. Some studies support the notion that female instructors can serve as role models and have the potential to narrow the gender gaps by increasing female students' interest, competence beliefs, and engagement and improving the STEM enrollment and graduation. (Betting & Long, 2005; Solanki & Xu, 2018; Canaan & Mouganie, 2023; Sansone, 2019). While other studies found the opposite results that female students were less probably to persist in STEM fields with female instructors, and students' performance and effort were improved with instructors having opposite gender but rapport behaviors (Price, 2010; & Kramer et al., 2016).

Except for the research on explicit evidence, implicit evidence also deserves to be investigated. Numerous studies have explored how students being motivated or demotivated in STEM learning by implicit evidence reflecting instructor's mindsets or perceived instructors' mindsets through instructional interactions (e.g., course syllabus, teaching behaviors, instructors' feedback). Students who are taught by instructors bearing more fixed mindsets experience more negative psychological statuses, lower interest, less sense of belonging, lower expectations for their performance and lower performance, and the effects of STEM instructors' mindsets are larger among female students (Rattan et al., 2012; LaCosse, et al., 2021; Canning et al., 2022; Kroeper et al., 2022).

Instructors' Non-content Messages Worth Noting

However, fewer studies have addressed the implicit evidence instructors may deliver to students in class through non-content messages which may bolster gender stereotypical beliefs and erode students' motivation and belonging to STEM fields.

Instructors' non-content messages refer to statements instructors naturally deliver in class that are unrelated to the course subject matter. Although non-content messages are not related directly to students' learning, they may gradually and unconsciously influence students' motivation and academic performance. Suarez-Orozco et al. (2015) studied microaggressions (MAs) (i.e., "brief and commonplace daily verbal, behavioral, or environmental indignities, whether intentional or unintentional, that communicate hostile, derogatory, or negative… slights and insults", Sue et al., 2007) in educational settings. Their findings suggested that MAs eroding students' intelligence and competence were the most frequently types occurring in classrooms and instructors delivered MAs most frequently. In STEM settings, MAs communicating gender stereotypes persist and put women at risk of leaving (Sekaquaptewa, 2019). Although instructors' non-content messages are not necessarily to convey derogating information, they are able to implicitly transport instructors' beliefs to students and generate unexpected impacts on students' motivation and belonging to STEM fields.

Three kinds of instructors' non-content messages have been connected to changes in students' personal theories about intelligence, learning, and knowledge: differential ability messages, conciliatory messages, and help messages. Differential ability messages, for example, "not everyone is going to find this easy", imply that success in some fields depends on talents, which aligns with an entity theory of intelligence that intelligence is a fixed trait (Barger, 2018; Dweck, 2007). Conciliatory messages (e.g., it's ok if you had a bad test) may be perceived as evidence of fixed intelligence but also associated with the theory that knowledge can be personally justified (Barger, 2018). Help messages, for instance, “Ask me for help if you don’t understand,”, may be interpreted as fixed intelligence, and also delivered information that learning takes time (Barger, 2018).

To my knowledge, no previous work has associated the three kinds of instructors’ non-content messages mentioned above with students’ career development. College years are a critical period for students to make decisions about their career path, and instructors are professionals of students’ intended fields of study whom students can easily interact with. A better understanding of the roles of instructors’ non-content messages about careers in different STEM fields may help us to determine whether these non-content messages contribute to the gender gaps across STEM fields in ways such as delivering a fixed view of ability or mindset about STEM careers to students and exerting negative impacts on student motivation and belonging in pursuing a STEM career.

CHAPTER 2

THE CURRENT STUDY

The current study sought to determine whether instructors' non-content messages students report hearing are related to gender gaps prevalent in some STEM fields. Three kinds of instructors' non-content messages were adapted from Barger (2018) into a version towards students' careers. Examples corresponding to differential ability messages, conciliatory messages, and help messages are "Not everyone is going to succeed at careers in this field", "It's ok if you don't know exactly what you want to do with your career", and "If you need help thinking about future careers. I'm happy to help".

Three questions were to be answered through data collected from a survey about student motivation and STEM career pathways. The first was to determine what types of gender imbalance exist across various STEM fields in a modern sample. I hypothesize that there would be varying degrees of gender representation across STEM fields. For example, majors like computer science or engineering would be male-dominated while biology or chemistry would be female-dominated. Next was to see whether there are differences in students' perceptions of instructors' non-content messages about career between STEM fields that are more dominated by men or women. I hypothesize that students in male-dominated STEM fields might receive more messages that indicate a fixed view of ability or mindset. The last was to see whether instructors' non-content messages explain disparities in students' motivation and belonging in STEM fields above and beyond student gender and gender representation of their classmates. I hypothesize that hearing more of these non-content messages bearing a fixed view of ability or mindset might reduce students’ motivation and belonging.

CHAPTER 3

METHODS

Procedures and Participants

Students who were at least 18 years of age and were enrolled in a science, technology, engineering, and mathematics course at the University of Georgia which were identified by STEM instructors were asked to complete an online survey asking about their major, career plans, career motivation, experiences with instructors or role models, etc. Participation was expected to take approximately 15-20 minutes and was voluntary. Some students who participated in the study received a small amount of course extra credit depending on their instructor's preferences. All students who participated in the study would be automatically entered into a drawing to win one of four $100 Amazon.com gift cards.

Participants ($N = 2312$) completed the survey. Since this study focused on gender representation (female versus male) in STEM fields, 208 participants were removed because they reported as other types of gender (i.e., non-binary, prefer not to say, or other) or their reported majors were not STEM majors or did not report majors. The final sample of 2104 students were majority female (65.8%), and White (67.9%; 7.7% Black, 23.2% Asian, 5.7% Latino, 0.4% American Indian, 2.6% Middle Eastern, 0.5% Native Hawaiian, 0.2% Other). Most of them were first year students (47.5%), and 22.5% were 2nd year students, 18.5% were 3rd year students, 8.5% were 4th year students, 2.5% were 5th year students, and 0.1% were other.

Measures

Instructors' Non-content Messages

Barger (2018) associated three kinds of instructors' non-content messages (i.e., differential ability messages, conciliatory messages, and help messages) to changes in students' personal theories about intelligence, learning, and knowledge. This study adapted these three kinds of instructors' non-content messages into a "career" version which may convey instructors' beliefs about students' career development. Taking one conciliatory message as an example, "It's OK if you had a bad test" was adapted as "It's OK if you don't know exactly what you want to do with your career". Instructors' non-content messages were measured using a 7-point Likert-type scale (1 = never hear it to 7 = hear it often). Students were asked to indicate the frequency of hearing five statements about differential ability messages, four statements about conciliatory messages, and three statements about help messages. Sample items include "It is more difficult for some people to succeed at careers in this field than others" (differential ability message), "You don't need to panic if you don't know exactly what you want to do when you graduate" (conciliatory message), and "You should come to me if you have questions about careers in this field" (help message). Exploratory factor analyses were conducted to determine whether these 12 items could be used to reliably assess the three kinds of instructors' non-content messages. Detailed explanation was stated in the Results section.

Students' Motivation and Belonging

Students' motivation and belonging were measured using a 7-point Likert-type scale (1 = not at all true to 7 = very true). Students were asked to indicate how true is for them in terms of 3 statements about belonging (e.g., "I think I would belong in this career"), 4 statements about competence beliefs (e.g., "I think I will be good at this career"), 5 statements about interest (e.g., "I think I will enjoy this career"), 5 statements about attainment value (e.g., "It is important for me to be good at this career"), 4 statements about utility value (e.g., "Pursuing this career will be useful for me later in life"), and 4 statements about cost (e.g., "The career will require too much effort"). Internal consistency in the current sample was satisfying ($\alpha = .85$ for belonging, $\alpha = .81$ for competence beliefs, $\alpha = .91$ for interest, $\alpha = .85$ for attainment value, $\alpha = .76$ for utility value, and $\alpha = .71$ for cost).

Male-dominated-, Female-dominated-, and Neutral-STEM Majors

Students were asked to write in what their major was in the survey. A lab member made a list of all the majors at the University of Georgia (UGA), and then two lab members reached consensus about whether or not each major was STEM by looking at their course requirements and the UGA schools in which they were located. The majors were accordingly coded as STEM or non-STEM. I used Chi-square test to further classify them into female-dominated stem majors, male-dominated stem majors, or neutral stem majors. Although previous studies or national dataset have indicated that some STEM fields are male-dominated while some are female-dominated (e.g., Cheryan et al., 2017; National Science Foundation, 2012), I am not going to directly use the existed categories in this study because there might be idiosyncrasies within our sample, and the gender composition of STEM fields may change over time so I also want to verify those categories with our modern sample.

CHAPTER 4

RESULTS

Preliminary Analysis

I conducted exploratory factor analysis with all 12 items for the measurement of instructors' non-content messages, using a principal axis factoring and varimax rotation. The scree plot suggested a three-dimensional structure. Nonetheless, one item (i.e., "Some of you are going to get a job in this field right away.") failed to load on any dimension significantly. Hence, this item was removed, and I repeated the exploratory factor analysis without this item. Items in the new analysis showed strong loadings on their respective factors (see Table 1) and were retained as our final measure of instructors' non-content messages. Internal consistency for each factor was high ($\alpha = .88$ for differential ability messages, $\alpha = .87$ for conciliatory messages, $\alpha = .85$ for help messages).

Primary Analyses

Research Question one: what types of gender imbalances exist across various STEM fields in our sample?

Chi-square test was conducted to see whether the difference between the number of male and female students is significant within a specific STEM major. The sample of the current study overall is mostly female, which fits with the rise in women participating in select STEM fields and in college more broadly in recent years. Based on the properties of my data and the changing situations of women' participation in STEM fields, using Chi-square test to see the gender distribution across STEM fields might be more suitable for the current study than employing existed categories from previous studies and national dataset. The results (see Table 2) followed a similar pattern as what have been found in the previous studies (Cheryan et al., 2017; National Science Foundation, 2012) that the gender gaps are higher in some STEM fields like computer science and engineering than other STEM fields like biology and chemistry. For example, biology ($\chi^2(1, N = 545) = 140.79, p < .001$) as well as bio-related majors like cellular biology ($\chi^2(1, N = 21) = 5.76, p = .016$), microbiology ($\chi^2(1, N = 37) = 4.57, p = .33$) and genetics ($\chi^2(1, N = 54) = 10.67, p = .0011$) were all female-dominated, while computer science ($\chi^2(1, N = 246) = 31.48, p < .001$) and mechanical engineering ($\chi^2(1, N = 102) = 15.69, p < .001$) were male-dominated. Notably, two engineering majors were female-dominated: biological engineering ($\chi^2(1, N = 55) = 6.56, p = .0104$) and environmental engineering ($\chi^2(1, N = 29) = 4.17, p = .041$). Generally speaking, my first hypothesis was supported. Each field (i.e., female-dominated STEM fields, male-dominated STEM fields, and neutral STEM fields) was then coded in a particular way in the following analyses and this variable was labelled as "gender make-up of field".

Research Question Two: are there differences in students' perceptions of instructors' non-content messages about career between STEM fields that are more dominated by men or women?

A 3×2 ANOVA was conducted to evaluate the effects of gender make-up of field (i.e., female-dominated STEM fields, male-dominated STEM fields, and neutral STEM fields) on students' perceptions of instructors' non-content messages. The descriptive statistics for differential ability messages, conciliatory messages, and help messages were listed in Table 3, Table 4, and Table 5 respectively.

In terms of the differential ability messages, the result indicated no significant main effect for gender, $F(1, 1902) = .47, p = .49$, partial $\eta^2 < .001$, but significant main effect for gender make-up of field, $F(2, 1902) = 20.33, p < .001$, partial $\eta^2 = .021$. Follow-up analysis (Tukey HSD) to the main effect for gender make-up field suggested that students in female-dominated STEM majors heard more differential ability messages than students in both male-dominated STEM majors ($p < .001$) and neutral STEM majors ($p = .01$). There is no significant interaction between gender make-up of field and gender, $F(2, 1902) = 2.11, p = .12$, partial $\eta^2 = .002$. The result was inconsistent with my hypothesis.

Regarding the conciliatory messages, there is no significant main effect for gender, $F(1, 1903) = 1.17, p = .28$, partial $\eta^2 = .001$, but the main effect for gender make-up field was significant, $F(2, 1903) = 7.04, p < .001$, partial $\eta^2 = .007$. Follow-up analysis (Tukey HSD) to the main effect for gender make-up field suggested that students in female-dominated STEM majors heard more conciliatory messages than students in male-dominated STEM majors ($p = .003$). Additionally, students in neutral STEM majors heard more conciliatory messages than students in male-dominated STEM majors ($p = .015$). There is no significant interaction between gender make-up of field and gender, $F(2, 1903) = 0.39, p = .68$, partial $\eta^2 < .001$. The result was also inconsistent with my hypothesis.

The result for help messages indicated no significant main effects for gender make-up of field ($F(2, 1903) = 2.14, p = .12$, partial $\eta^2 = .002$.) and gender $F(1, 1903) = 2.61, p = .106$, partial $\eta^2 = .001$.) , and no significant interaction effect, $F(2, 1903) = 0.18, p = .837$, partial $\eta^2 < .001$. My hypothesis was not being supported.

Research Question Three: do instructors' non-content messages explain disparities in students' motivation and belonging in STEM fields above and beyond student gender and gender representation of their classmates?

Based on the findings from the second research question that students in female-dominated STEM majors heard more differential ability and conciliatory messages, I wanted to examine whether these two kinds of instructors' non-content messages explain disparities in students' motivation and belonging in STEM fields above and beyond student gender and gender representation of their classmates. To examine this question, I conducted a two-step hierarchical regression with student motivation and belonging (i.e., belonging, competence beliefs, interest, attainment value, utility value, and cost) as the dependent variable. Gender, gender make-up of field, and mean centered differential ability messages or mean centered conciliatory messages were entered in the first step. I tried to determine whether hearing more of these instructors' non-content messages than their colleagues is related to lower motivation, so mean centering was used to ruling out the potential effects of a particular field being less motivating and also having more of a particular message. Interactions between gender and gender make-up of field, gender and messages, gender make-up of field and messages were entered in the second step and then removed if not significant in the final model.

Concerning differential ability messages, results are listed in Table 6. Differential ability messages are positively associated with students' sense of belonging and interest ($\beta = .078, p < .001$ for belonging, and $\beta = .093, p < .001$ for interest), which implies that students hearing more differential ability messages reported higher belonging score as well as higher interest score regarding careers within their fields. Students in non-male-dominated STEM fields achieved higher belonging score than students in male-dominated STEM fields; moreover, female students achieved slightly lower belonging score than male students in male-dominated STEM majors (see Figure 1). In non-male-dominated STEM majors, female students felt more interest in careers within their fields (see Figure 2). The association between differential ability messages and factors such as students' competence beliefs, attainment value, utility value and cost remained significant with gender and gender make-up of field included in the model ($\beta = .065, p = .005$ for competence beliefs, $\beta = .154, p < .001$ for attainment value, $\beta = .114, p < .001$ for utility value, and $\beta = .114, p < .001$ for cost), suggesting that students hearing more differential ability messages felt more competent in their career performance within their fields, took pursuing a career within their fields as an important part of who they are as well as practical and useful for them more than those hearing these kinds of messages less frequently, and perceived more cost for pursuing careers within their fields.

As regard to conciliatory messages, results are shown in Table 7. Conciliatory messages are positively associated with students' sense of belonging ($\beta = .137, p < .001$) and interest ($\beta = .125, p < .001$), which implies that students hearing more conciliatory messages reported higher belonging score as well as higher interest score regarding careers within their fields. Students in non-male-dominated STEM fields achieved a little bit higher belonging score than students in male-dominated STEM fields; moreover, female students achieved slightly lower belonging score than male students in male-dominated STEM majors (see Figure 3). In non-male-dominated STEM majors, female students felt more interest in careers within their fields (see Figure 4). The association between conciliatory messages and students' competence beliefs might depends on which STEM environments (i.e., female-dominated, male dominated, or neutral STEM majors) students were in. The interaction between gender make-up of field and conciliatory messages is significant, $\beta = .062, p = .016$. However, since the difference of students' reported competence beliefs between male-dominated fields and non-male-dominated fields is very small (see Figure 5), and only 1 out of 24 interactions for non-content messages is significant, I did not further explore the significant interaction. The association between conciliatory messages and factors such as students' attainment value and utility value remained significant with gender and gender make-up of field included in the model ($\beta = .053, p = .02$ for attainment value, and $\beta = .085, p < .001$ for utility value), suggesting that students hearing more conciliatory messages took pursuing a career within their fields as an important part of who they are as well as practical and useful for them more than those hearing these kinds of messages less frequently. As for cost, neither the main effect nor the interactions for conciliatory messages are statistically significant.

TABLES

Table 1

Factor Loadings for Instructors' Non-content Messages

Items	1	2	3
Differential Ability Messages			
Not everyone is going to succeed at careers in this field.	0.766		
It is more difficult for some people to succeed at careers in this field.	0.772		
Some of you might struggle to have a career in this field.	0.838		
Careers in this field are not for everyone.	0.795		
Conciliatory Messages			
It's ok if you don't know exactly what you want to do with your career.		0.637	
Don't worry if you don't have a career plan yet.		0.745	
Don't worry if you are not sure what you want to do after you graduate.		0.826	
You don't need to panic if you don't know exactly what you want to do when graduate.		0.782	
Help Messages			
If you need help thinking about future careers. I'm happy to help.			0.728
You should come to me if you have questions about careers in this field.			0.799
Ask me for help if you don't have a career plan.			0.740

Table 2

Female-dominated STEM Majors and Male-dominated STEM Majors

STEM Majors	*n* (male)	*n* (female)	χ^2	*df*	*p*
Female-dominated STEM Majors					
Animal Science	5	52	38.75***	1	<.0001
Fisheries and Wildlife	4	12	4*	1	.046
Biological Engineering	18	37	6.56*	1	.0104
Biology	134	411	140.79***	1	<.0001
Cellular Biology	5	16	5.76*	1	.016
Applied Biotechnology	2	12	7.14**	1	.008
Microbiology	12	25	4.57*	1	.033
Genetics	15	39	10.67**	1	.0011
Ecology	9	29	10.53**	1	.0012
Environmental Engineering	9	20	4.17*	1	.041
Chemistry	5	20	9**	1	.003
Health Promotion	4	77	65.79***	1	<.0001
Public Health	1	11	8.33**	1	.004
Pharmaceutical Sciences	13	46	18.46***	1	<.0001
Psychology	14	84	50***	1	<.0001
Exercise and Sport Science	30	105	41.67***	1	<.0001
Nutritional Sciences	6	33	18.69***	1	<.0001
Food Science	3	11	4.57*	1	.033

Dietetics	1	23	20.17***	1	<.0001
Male-dominated STEM Majors					
Civil Engineering	32	13	8.02**	1	.005
Computer Science	167	79	31.48***	1	<.0001
Computer Systems Engineering	32	12	9.09**	1	.003
Management Information Systems	11	3	4.57*	1	.033
Mechanical Engineering	71	31	15.69***	1	<.0001

Note. Assuming that the expected values of male and female students would be 1:1 in Chi-square test if a specific STEM major is gender balanced.

$*p < .05$. $** p < .01$.$*** p < .001$.

Table 3

Means and Standard Deviations for Differential Ability Messages

Variable	Women		Men	
	M	*SD*	*M*	*SD*
Gender make-up of field				
Female-dominated (STEM)	4.33	1.69	4.50	1.56
Male-dominated (STEM)	3.78	1.73	3.72	1.53
Neutral (STEM)	4.16	1.68	3.85	1.54

Note. $N = 1908$.

Table 4

Means and Standard Deviations for Conciliatory Messages

Variable	Women		Man	
	M	*SD*	*M*	*SD*
Gender make-up of field				
Female-dominated (STEM)	4.63	1.55	4.83	1.34
Male-dominated (STEM)	4.31	1.81	4.39	1.48
Neutral (STEM)	4.70	1.49	4.73	1.42

Note. $N = 1909$.

Table 5

Means and Standard Deviations for Help Messages

Variable	Women		Man	
	M	*SD*	*M*	*SD*
Gender make-up of field				
Female-dominated (STEM)	3.90	1.69	4.12	1.46
Male-dominated (STEM)	3.91	1.83	3.99	1.52
Neutral (STEM)	4.13	1.62	4.32	1.59

Note. $N = 1909$.

Table 6

Hierarchical Regression Results for Students' Belonging and Motivation (Differential Ability Messages)

Variable	B	SE	β	B	SE	β
Belonging		Step 1			Step 2	
Constant	5.957***	0.045		5.901***	0.049	
Gender make-up of field	-0.308***	0.06	-.127***	-0.166*	0.077	-.068*
Gender	-0.047	0.049	-.023	0.026	0.055	.013
Mean centered differential ability messages	0.044***	0.013	.078***	0.044***	0.013	.078***
Gender make-up field×Gender				-0.348**	0.121	-.086**
R^2		.021			.025	
ΔR^2					.004**	
Competence Beliefs		Step 1			Step 2	
Constant	5.531***	0.044			No	
Gender make-up of field	-0.238***	0.06	-.099***		interaction	
Gender	-0.171***	0.049	-.085***		statistically	
Mean centered differential ability messages	0.036**	0.013	.065**		significant	
R^2		.016			.017	
ΔR^2					.001	
Interest		Step 1			Step 2	
Constant	6.132***	0.038		6.097***	0.041	

Gender make-up of field	-0.189***	0.051	-.091***	-0.099	0.066	-.048
Gender	0.14***	0.042	.081***	0.186***	0.047	.108***
Mean centered differential ability messages	0.045***	0.011	.092***	0.045***	0.011	.093***
Gender make-up field×Gender				-0.22*	0.103	-.063*
R^2		.03			.032	
ΔR^2					.002*	
Attainment Value		Step 1			Step 2	
Constant	5.774***	0.043			No	
Gender make-up of field	-0.235***	0.058	-.098***		interaction	
Gender	0.194***	0.048	.097***		statistically	
Mean centered differential ability messages	0.086***	0.013	.154***		significant	
R^2		.055			.057	
ΔR^2					.002	
Utility Value		Step 1			Step 2	
Constant	5.79***	0.041			No	
Gender make-up of field	-0.122*	0.055	-.055*		interaction	
Gender	0.124**	0.045	.066**		statistically	
Mean centered differential ability messages	0.06***	0.012	.114***		significant	
R^2		.026			.027	
ΔR^2					.001	

Cost	Step 1			Step 2
Constant	3.702***	0.058		No
Gender make-up of field	-0.167*	0.078	-.051*	interaction
Gender	0.036	0.065	.013	statistically
Mean centered differential ability messages	0.2***	0.017	.263***	significant
R^2		.077		.079
ΔR^2				.002

*$p < .05$. ** $p < .01$.*** $p < .001$.

Table 7

Hierarchical Regression Results for Students' Belonging and Motivation (Conciliatory Messages)

Variable	B	SE	β	B	SE	β
Belonging		Step 1			Step 2	
Constant	5.948***	0.044		5.892***	0.048	
Gender make-up of field	-0.301***	0.059	-.124***	-0.158*	0.077	-.065*
Gender	-0.036	0.049	-.018	0.038	0.055	.019
Mean centered conciliatory messages	0.084***	0.014	.137***	0.085***	0.014	.137***
Gender make-up field×Gender				-0.351**	0.12	-.086**
R^2		.034			.038	
ΔR^2					.004**	
Competence Beliefs		Step 1			Step 2	
Constant	5.522***	0.044		5.523***	0.044	
Gender make-up of field	-0.228***	0.059	-.095***	-0.212***	0.059	-.088***
Gender	-0.16**	0.049	-.08**	-0.161***	0.049	-.081***
Mean centered conciliatory messages	0.08***	0.014	.13***	0.063***	0.015	.103***
Gender make-up field× Mean centered conciliatory messages				0.084*	0.035	.062*

R^2		.027			.03	
ΔR^2					.003*	
Interest		Step 1			Step 2	
Constant	6.127***	0.038		6.091***	0.041	
Gender make-up of field	-0.189***	0.051	-.091***	-0.099	0.066	-.048
Gender	.148***	0.042	.086***	0.194***	0.047	.113***
Mean centered conciliatory messages	0.066***	0.012	.124***	0.066***	0.012	.125***
Gender make-up field×Gender				-0.221*	0.103	-.064*
R^2		.037			.039	
ΔR^2					.002*	
Attainment Value		Step 1			Step 2	
Constant	5.779***	0.044			No	
Gender make-up of field	-0.272***	0.059	-.112***		interaction	
Gender	0.197***	0.049	.098***		statistically	
Mean centered conciliatory messages	0.032*	0.014	.053*		significant	
R^2		.033			.033	
ΔR^2					.001	
Utility Value		Step 1			Step 2	
Constant	5.789***	0.041			No	
Gender make-up of field	-0.138*	0.055	-.062*		interaction	

Gender	0.13**	0.046	.07**	statistically
Mean centered conciliatory messages	0.048***	0.013	.085***	significant
R^2		.018		.017
ΔR^2		<.001		
Cost		Step 1		Step 2
Constant	3.731***	0.06		No
Gender make-up of field	-0.296*	0.081	-.09***	interaction
Gender	0.03	0.067	.011	statistically
Mean centered conciliatory messages	-0.035	0.019	-.042	significant
R^2		.01		.012
ΔR^2				.002

$*p < .05$. $** p < .01$.$*** p < .001$.

FIGURES

Figure 1

Gender Disparities in Students' Belonging (Differential Ability Messages)

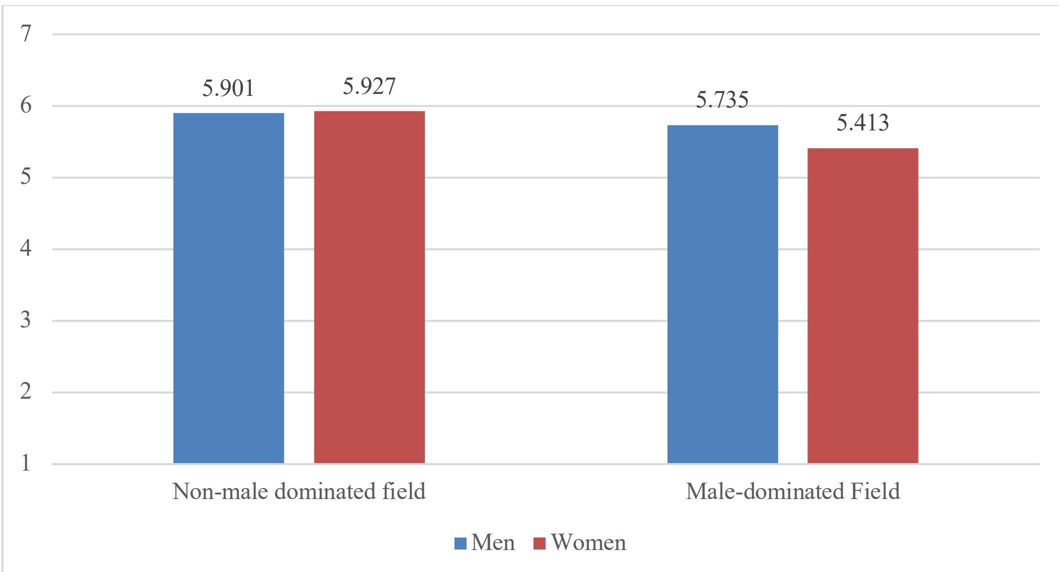


Figure 2

Gender Disparities in Students' Interest (Differential Ability Messages)

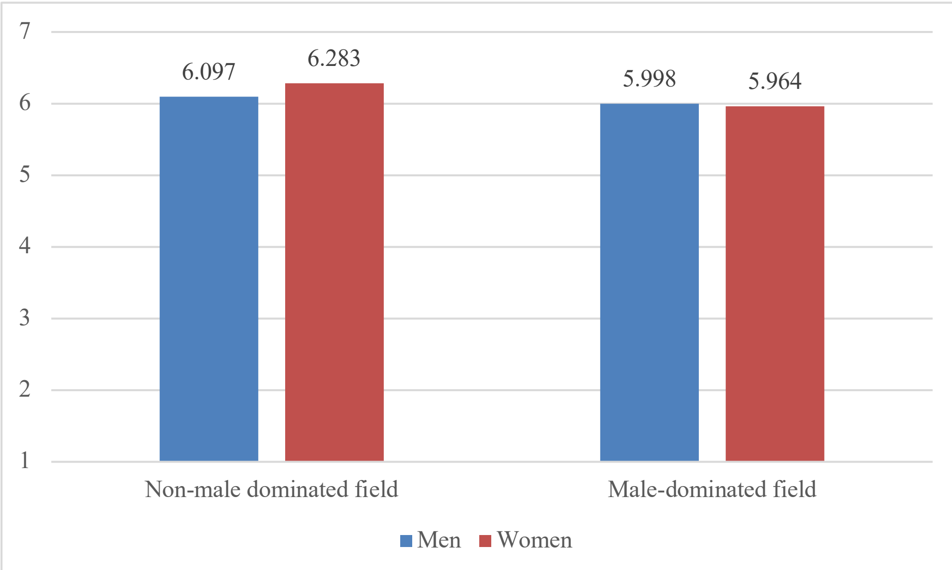


Figure 3

Gender Disparities in Students' Belonging (Conciliatory Messages)

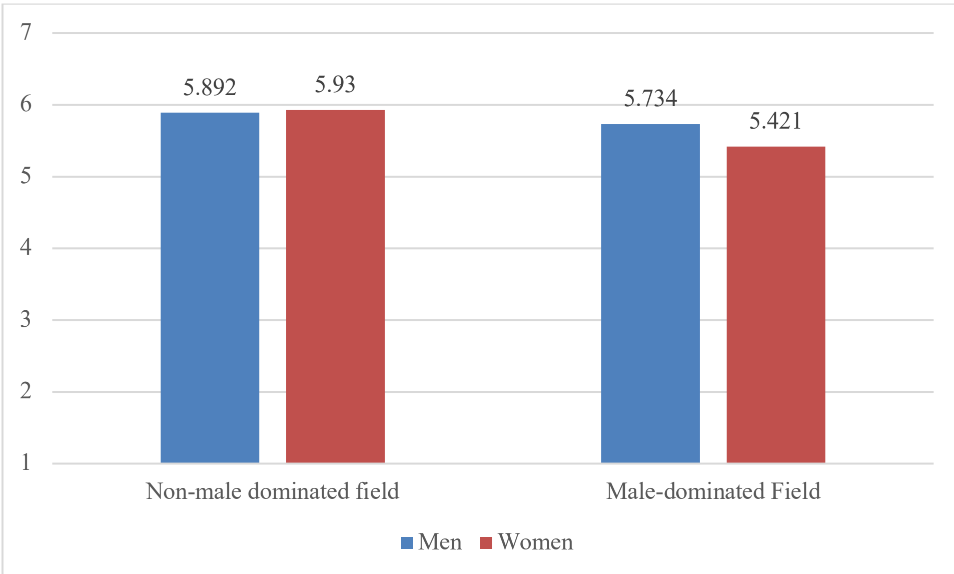


Figure 4

Gender Disparities in Students' Interest (Conciliatory Messages)

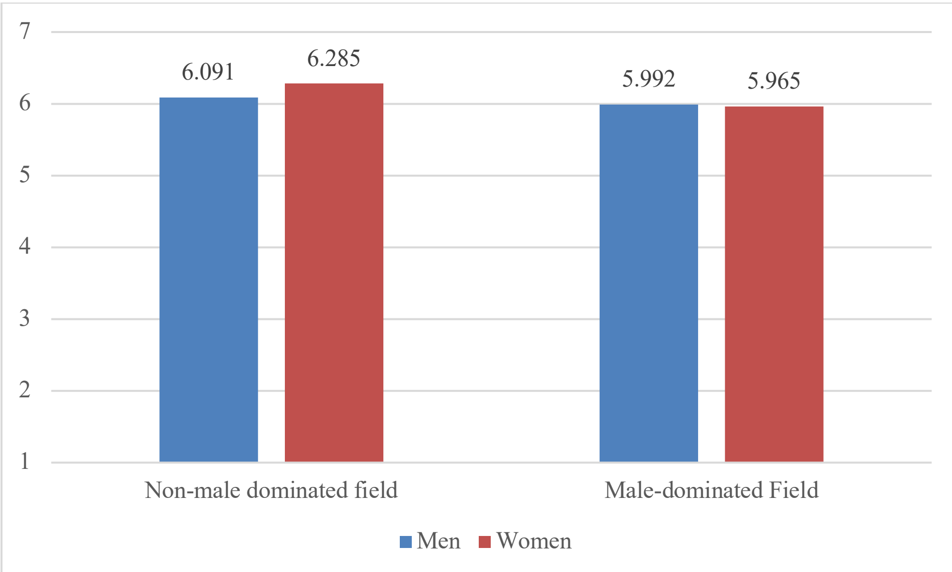
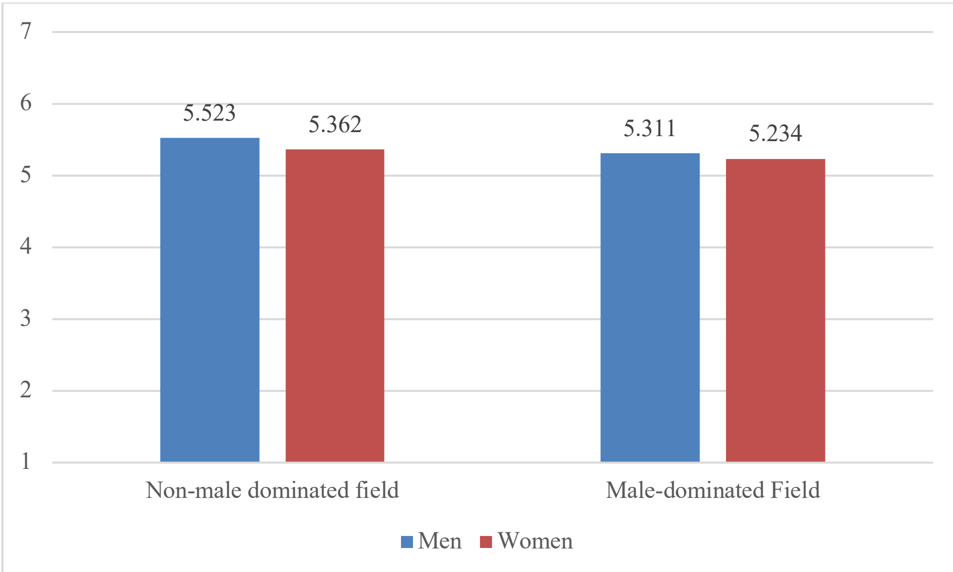


Figure 5

Gender Disparities in Students' Competence Beliefs (Conciliatory Messages)



CHAPTER 5

DISCUSSIONS

General Discussion

The present study provided more evidence with a modern sample to the imbalanced gender distribution across STEM fields. Results in our research are generally consistent with the previous findings: women participate more in majors like biology or chemistry than majors like engineering or computer science.

The gender imbalances coincide with different types of instructors' non-content messages. However, it does not appear that these messages explain gender imbalances in the predicted way. I expected that students in male-dominated STEM fields would report hearing more differential ability messages, conciliatory messages, and help messages which might indicate a fixed view of ability or mindset since that STEM fields are stereotypically associated with masculine traits (Leslie et al., 2015; Bian, Leslie, & Cimpian, 2017; Miller, et al., 2018). However, my results indicated that students in female-dominated STEM majors reported hearing more differential ability messages and conciliatory messages than students in male-dominated STEM majors. As to the help messages, the results were not statistically significant. Female students and male students did not differ on their perceptions of instructors' differential ability messages and conciliatory messages, so the difference was not about students' gender but something about the gendered context around them. One possible explanation is that instructors of female-dominated context may deliver differential ability and conciliatory messages more often than those of male-dominated context because of gender biases. Moss-Racusin et al. (2012)

found that faculty members rated male applicants for a lab manager position as more competent than female applicants even if their application materials were similar. Instructors viewing women's STEM ability through a biased lens may unconsciously stress the importance of "brilliance" to succeed in STEM (i.e., differential ability messages) when they look out at classrooms of mostly women. Also, instructors' underestimated evaluation of women's ability may result in lower expectations for women's success in STEM and thus instructors might express more conciliatory messages in female-dominated context. Furthermore, instructors might be more interested in emotionally supporting women students by providing more positive feedback like praise and encouragement to female students than male students (Jampol & Zayas, 2021; Charousset & Monnet, 2022), so instructors of female-dominated majors might provide more conciliatory messages since the majority of students were women. However, there could be unintended consequences of these conciliatory messages like perceptions of instructors' entity theory and low expectations and lower motivation and lower self-expectations for performance (Rattan et al., 2012). Although the results did not explain the gender gaps across STEM fields as I expected, they do have a potential consequence, in that instructors' non-content messages indicating a fixed view of ability or mindset are being given more often in female-dominated STEM fields and therefore could have a disproportionate impact in terms of creating a fixed mindset environment for women who are pursuing careers in STEM.

Instructors' non-content messages did connect to student motivation, but not completely in a predicted way. I expected that hearing more of those instructors' non-content messages bearing a fixed view of ability or mindset might reduce students' motivation and belonging, but I only find this pattern in students' perceived cost for STEM careers within their fields. Students hearing more differential ability messages from instructors reported higher cost score. Some of the other motivational constructs linked to instructors'' non-content messages in the opposite way. Students heard more differential ability and conciliatory messages achieved higher attainment value and utility value and felt more competent than those hearing these kinds of messages less frequently. One possibility is that STEM fields are associated with qualities like highly competitive and full of talented people, so students in STEM fields may tend to consider themselves as gifted people with strong abilities and skills. Hence, the messages communicate a fixed view of ability or mindset about careers within their fields may strengthen students' confidence both in themselves and those careers. Entity beliefs might be motivating, for example, Mendoza-Denton et al. (2008) found that in favorably stereotyped groups, members' performance was enhanced when their in group's advantage was confirmed and they were told that ability is fixed, but fixed mindsets can lead to negative outcomes (e.g., avoiding challenges, giving up easily and seeing effort as fruitless) over the long term (Dweck & Molden, 2017). Future studies can examine this research question by measuring mindsets which I was unable to do here to see whether the results are similar to mine, and if so, the reasons behind the positive association between instructors' non-content messages and students' attainment value and utility value should be further explored to see whether fixed mindsets can be beneficial in selective environments. Furthermore, although I did not find obvious evidence for the moderate effects of students' gender or different gender dominated environments on the association between instructors' non-content messages and student motivation and belonging, the impact of gender gaps across STEM fields on female students' sense of belonging and interest towards STEM careers is presented. In male-dominated STEM majors, female students felt slightly less sense of belonging to careers within their fields than male students. Additionally, in non-male dominated STEM majors, female students felt more interest in careers within their fields. Numerous studies have found that concepts indicating gender stereotypical beliefs such as “male domains” or “brilliance = males” are still prevalent and can lower women’s interest in and sense of belonging to STEM fields (e.g., Bian, Leslie, & Cimpian, 2017; Good, Rattan, & Dweck, 2012; Miller, et al., 2018). My findings added more evidence to the gender stereotypical issues among STEM fields and suggested that more endeavors ought to be made to improve gender gaps in STEM fields since it is still an issue worthy of attention.

Limitations

Although this study provides useful information by looking at hundreds of students across 62 different college STEM majors, there are some limitations that should be noted. First, I used a convenience sample, and the sample disproportionately represents females, which may impact the generalizability of the findings to the overall population. Future studies may employ more representative sample to control the potential bias. Second, this is a cross-sectional study. All correlations I found only tell us that they coincide with each other at a single point in time rather than one causes another. Future studies may further explore the cause-and-effect relationships between these variables by studying their development over time or using experimental methods. Third, this study found positive relationships between messages delivering a fixed belief of ability or mindset and student motivation but was unable to provide explanations for these unexpected findings. Future work may further explore whether a fixed belief of ability or mindset can booster motivation in selective or competitive environments.

Conclusion

Gender gaps still exist and differ across STEM fields. Gender representation across STEM fields may play a role in students’ perceptions of instructors’ non-content messages. Students in female-dominated STEM fields reported receiving more of these kinds of messages, which deserves attention since by this way a fixed mindset environment may be created for women who are pursuing careers in STEM and thus hinder their development in STEM fields. Instructors' non-content messages are found to be associated to student motivation and belonging, but in unexpected directions. Students reporting hearing more differential ability and conciliatory messages achieved higher attainment value and utility value and felt more competent than those reporting hearing these kinds of messages less frequently. How these variables interact with each other need to be further explored. Existed gender gaps across STEM fields continue to negatively relate to female students' sense of belonging and interest towards STEM careers, potentially perpetuating these trends for years to come.

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