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Role With It: Examining the Impact of Instructor Role Models in Introductory Mathematics Courses on Student Experiences

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Role with it: Examining the impact of instructor role models in introductory mathematics courses on student experiences

Abstract: *Contributing to the effort to diversify the demographics in STEM disciplines, we examined the effect of role models in students' perceptions of precalculus and calculus courses. Drawing from Dasgupta's stereotype inoculation model (2011a) in which ingroup experts can serve as "social vaccines" to protect against negatively stereotyped groups, we tested the impacts of four different social markers instructors might share with their students: gender, race, sexual identity, and First-Generation College Student status (FGCS). Data from this study comes from student survey responses (n=19,191) on the Student Post-Secondary Instructional Practices Survey as part of the NSF-funded Progress Through Calculus project, which examined student reports of introductory mathematics programs across the United States. We analyzed the data using a cumulative link mixed model on the survey items related to instructional practice, academic performance, and affective beliefs to determine which items exhibited a minoritized role model effect. Out of the 58 survey items, 25 items exhibited a statically significant minoritized role mode effect: seven for gender, nine for race, three for sexuality, and fourteen for FGCS. Our results indicate impacts of a minoritized role model effect that varied based on social markers, and while most were consistently a positive predictor, there were some instances of a role model contributing a negative predictor. More studies are needed to further understand the complex phenomenon of role models in calculus courses. However, it is clear that if you want to support a large variety of students, you need a diverse group of instructors.*

Keywords: role-models, diversity, STEM, calculus, race, gender, sexuality, first-generation college students, quantitative analysis

Introduction

There has been a concerted effort both nationally and at the local level to diversify the science, technology, engineering, and mathematics (STEM) disciplines and broaden participation for individuals with a minoritized identity within each field (Basile & Lopez, 2015; National Science Foundation, 2020). Such efforts have permeated all educational levels starting in early elementary (e.g., enrichment programs) all the way into higher education and industry (e.g., hiring practices, identity-affirming professional organization). Yet one of the well-documented barriers to diversifying the STEM discipline is the current and historical lack of diversity or representation existing within STEM spaces, especially among STEM instructors who serve as representatives of their field of study (National Science Foundation, 2019). In an effort to address these barriers, one innovation is the use of targeted programs such as role model interventions that leverage peers or faculty who identify with an underrepresented identity in STEM to provide students with concept images of scientists who may share that identity (González-Pérez et al., 2020). The impact of role models for students with marginalized gender and racial identities has generally been shown to be effective in STEM environments to broaden participation and bolster STEM identities (Gladstone & Cimpian, 2020). Yet, one aspect that is often missing from studies of role models is an examination of shared identities or social markers beyond the more visible constructs such as race and gender to account for less visible social markers such as sexuality or First-Generation College Student (FGCS) status. Additionally, most studies examine pre-determined macro-level output constructs such as persistence, academic performance and beliefs, and fail to examine in situ descriptions of interactions and classroom practices. In this paper, we examine, through quantitative methodologies, the following research question: *What is the potential minoritized role model effect (MRME) of having a matched-identity instructor along the social markers of gender, race, sexuality, and First-Generation College Student on students' reports of their experiences in undergraduate introductory mathematics courses?*

Literature Review

The impact of role models is widely studied as a mechanism to diversify STEM disciplines. By role models, following previous studies, we refer to individuals who serve as exemplars within the field and share a matched-identity, social marker, or cultural background with students. Through these shared social markers, research has shown that role models can impact students by countering negative stereotypes held about their identity group, such as women in STEM. The majority of the role model studies to date focus on issues of gender (e.g., Bagès et al., 2016; Cheryan et al., 2011; Drury et al., 2011; Herrmann et al., 2016; Lawner et al., 2019; Lockwood, 2006; Marx & Roman, 2002; Stout et al., 2011) and, to a lesser extent, race (e.g., Zirkel, 2002; Evans, 1992). To our knowledge, no studies have analyzed the impact of role models in regard to less visible characteristics, such as First-Generation College Student (FGCS) status and sexuality. As for the outcomes, the existing research has identified the benefits role models can have on students' academic performance (Bagès et al., 2016; Herrmann et al., 2016; Marx & Roman, 2002; Zirkel, 2002;), persistence (Drury et al., 2011; Lawner et al., 2019), and affect and beliefs (Lin-Siegler et al., 2016; Lockwood, 2006; Stout et al., 2011). In these studies, students were exposed to role models through a variety of means, including letters written by an exemplar (e.g., Hermann et al., 2016), reading a story about exemplars (e.g., Bagès et al., 2016; Lin-Siegler et al., 2016; Lockwood, 2006), or through personal instruction by the exemplar (e.g., Stout et al., 2011).

In a study comparing academic performance, girls and boys were given a math test to complete. When the person administering the tests was a competent woman experimenter, girls' academic performance was protected and they performed at the same level as equally talented men (Marx & Roman, 2002). Participants exposed to story-based instruction which modeled how scientists achieve through failures and struggles, improved their science learning post-intervention (Lin-Siegler et al., 2016). In a field experiment with sixth graders, Bagès et al. (2016) exposed the students to a description of a woman or man role model before a difficult test in which the role model's success was described as either being achieved through exerted effort, being gifted or no explanation given. For this experiment, they were more interested in the shared similarities of a role model's success than that of the social marker of gender, although they were still curious as to the effect the role model would have on girls. The results suggest that when exposed to a hardworking role model, girls scored as well as boys on a difficult math test (Bagès et al., 2016). While the previous studies have focused primarily on academic achievement, Drury et al. (2011) found that maximizing a sense of perceived similarity is key to a role model's impact on students and women role models can greatly benefit the retention of women in STEM. In a longitudinal study of young adolescents, Zirkel (2002) administered a pre/post survey to the student participants. Results from the survey indicate that students with race- and gender- matched role models performed better academically than peers without a race- and gender- matched role model.

When examining affective beliefs, Cheryan and colleagues' (2011) study consisted of all women role models of which one group embodied stereotypes and the other did not. In this study, the "stereotypicality of role models were manipulated using pretesting clothing, hobbies, and preferences" that were either associated with the stereotypical computer science major, or with an average college student, the non-stereotype (Cheryan et al., 2011, p. 657). It was seen that women who interacted with non-stereotypical role models believed that they could be more successful in computer science than those who interacted with stereotypical role models (Cheryan et al., 2011). Relatedly, Hermann et al. (2016) conducted an online intervention which consisted of having students read a letter from a woman role model after the first examination in the course via a survey platform. This letter was sent from a woman graduate student who discussed the benefits of a college degree, feelings of not belonging, and discussion of poor academic performance. This cultivated, in the students, a sense of belonging and a desire to overcome future challenges. Those in the intervention group had higher grades and lower failing and withdrawal rates compared to the control group (Hermann et al., 2016). In another study, women reading about a successful graduate of their university in their major rated themselves higher on success-related traits when the role model was a woman (Lockwood, 2006). In a longitudinal naturalistic study, taking a calculus course with a female professor enhanced women's implicit math self-concept and improved their implicit attitudes toward math compared to taking a calculus course with a professor who was a man (Stout et al., 2011).

Theoretical Framing

Multiple theories have been used to explain the impact of role models in education settings, including Social Cognitive Theory (Bandura, 1977), Expectancy Value Theory (Eccles & Wigfield, 2002), and the Stereotype Inoculation Model (Dasgupta, 2011). Social Cognitive Theory places emphasis on self-efficacy, people's beliefs on what they themselves can do. In developing their self-efficacy, learners can adjust their own efficacy in numerous ways such as observing the outcomes of others' actions, particularly if the model is perceived as being similar (Cook & Artino, 2016). Expectancy Value Theory (EVT) examines the expectation of success and perceived value of accomplishing the task (Cook & Artino, 2016). The expectancy of success is shaped by motivational beliefs. Role models represent who can be successful and help students to hold the expectation of their own success. Instructors possessing shared psychological similarities can help marginalized students change their perceptions of external barriers and stereotypes (Gladstone & Cimpian, 2020). While both of the previously discussed models have theoretical utility to examine role models and have been highly utilized in prior research, for this study, we needed a theoretical model to capture the impact of role models on in situ descriptions of classroom practices, persistence, and affect. As such, we leverage the Stereotype Inoculation Model in this manuscript, a multidisciplinary theoretical model developed for the purpose of understanding efforts to increase equity and inclusion in high-achievement settings. The stereotype inoculation model proposes a theoretical account for how ingroup experts and peers can serve as facilitators to increase social belonging, attitudes, and identity in a given academic field.

Dasgupta (2011a) developed the stereotype inoculation model to respond to the fact that past proposed solutions to diversify academic fields tend to focus on the individual being the one to make a change to their perceptions of themself. If we consider negative stereotypes as a disease and those in a disadvantaged group as the patients, the past strategies mentioned are akin to patients fighting off a virus by themselves without any assistance. Instead, the Stereotype Inoculation Model focuses on the situation, placing antibodies, which are ingroup members, in the necessary settings to combat against the virus, which are negative stereotypes of the individual (Aronson & McGlone, 2011; Dasgupta, 2011b). For this model, the "social vaccines" of ingroup members and peers applies to groups that are negatively stereotyped in a particular achievement domain. The focus of the model, therefore, does not necessarily refer to groups that are a numeric minority who are not stereotyped as lacking ability in the given domain (Dasgupta, 2011b). For example, in science and engineering in the US, negative stereotypes are mostly applied to women, minoritized non-Asian ethnic individuals, and working-class students. For members of a negatively stereotyped group, seeing successful ingroup experts defies the negative stereotype, thereby enhancing students' own self-efficacy and motivation to succeed (Blanton, Crocker, & Miller, 2000; Brewer & Weber, 1994).

Exposure to ingroup peers and experts goes hand in hand with the timing of this exposure, which is of particular importance. In the early stages of academic or professional development, such as for the transition to college, belonging and self-doubt are likely to be potent (Dasgupta, 2011a). When novices don't believe that they belong or see a 'possible self' within the domain, they may leave to find an ingroup in which they do. In reference to the medical analogy, the patients have neither combatted nor cured the virus. Instead, they have put themselves in quarantine, separating themselves from the situation(s) where the virus was present. This may come in the form of switching majors away from science, technology, engineering, and mathematics, to changing departments, universities, or even jobs. To prevent this attrition, ingroup experts and peers inoculate one's self-concept by creating environments that foster social belonging (Tse, Logel, & Spencer, 2011). In fact, "recruitment and retention of underrepresented groups who are newcomers at entry level is closely dependent on the visibility" of ingroup members (Dasgupta, 2011a). A stronger and more stable sense of belonging is only one benefit these 'social vaccines' can have. Exposure to ingroup experts and peers in high-achievement environments strengthens individuals' sense of achievement, activates motivation to affiliate, inoculates self-concept, and reduces imposter feelings (Dasgupta, 2011b). Furthermore, the presence of ingroup experts impacts the entire educational ecosystem by signaling that the ingroup identity is both valued and deemed an important contribution (Laurin, Fitzsimmons, & Kay, 2011), which can enhance collaborative relationships with both in- and out-group members (Dasgupta, 2011b). We view this model as highly compatible with our research goals, though remain aware of the necessity of this model on visible markers for being ingroup or not (i.e. perceived gender and race and ethnicity), which are not necessarily present among students and instructors who share the identities of being the first generation of their families to go to college or identify as LGBTQ+.

Methods

The data from this study comes from the NSF-funded Progress through Calculus project, which examined introductory mathematics programs across the United States. As part of this project, instructor and student surveys (Apkarian et al., 2019) were administered over three academic terms at 12 universities selected from a national sample of mathematics programs. The survey was composed of multi-item sections asking about the frequency of instructional practices (30 items), the helpfulness of instructional practices (12 items), equitable perceptions of inclusive instructional practices as compared to other students (6 items), mathematical affective beliefs at the start and end of the course (8 items), and two questions related to persistence asking about expected course grade and STEM major. The survey also asked about social markers such as gender, race, sexual identity, and First-Generation College Student status.

To aid in interpretability and to ensure large enough grouping sizes, responses to the demographic questions were condensed into binary dummy variables indicating a marginalized identity. Additionally, we chose this option to ensure that those with marginalized identities that are often removed from quantitative analysis due to small sample sizes were included in our analysis. For gender, this meant responses of Women, Transgender, and Gender Non-binary were combined as a category of Woman+ and students who indicated Man were categorized as (cis)Man. For race, Alaskan Native or Native American, Black or African American, Hispanic or Latinx, Middle Eastern or North African, and Native Hawaiian or Pacific Islander were categorized as Underrepresented and Racially Minoritized (URM). Non-URM consisted of students who identified as Central Asian, East Asian, Southeast Asian, South Asian, and White. For sexuality, Asexual, Bisexual, Gay, Lesbian, and Queer were categorized as Queer, and Straight (Heterosexual) students were categorized as Straight. The First-Generation College Student (i.e., neither parent nor guardian completed a Bachelor's degree) was already designed as a binary option and was categorized as FGCS or Non-FGCS.

After removing individuals who did not consent and those under the age of 18, data from 19,191 students and 437 instructors remained. Data for instructors and students were matched using R software version 4.0.3 (R core team, 2019), resulting in 17,912 survey responses from students, as seen in Table 1.

Table 1 Count of survey responses broken down by the gender, race, sexuality, and First-Generation College Student status of the student and instructor.

Social Marker	**Student**	**Instructor**	**Matched survey responses**	**Grouping Size for MRM**	
Gender	(cis)Man	(cis)Man	4391		
	(cis)Man	Woman+	3209	gender MRM	2,678
	Woman+	(cis)Man	3406	gender non-MRM	11,006
	Woman+	Woman+	2678		
Race	Non-URM	Non-URM	8455		
	Non-URM	URM	1077	race MRM	947
	URM	Non-URM	2920	race non-MRM	12,452
	URM	URM	947		
Sexuality	Straight	Straight	10189		
	Straight	Queer	484	sexuality MRM	60
	Queer	Straight	1208	sexuality non-MRM	11,881
	Queer	Queer	60		
FGCS	Non-FGCS	Non-FGCS	10266		
	Non-FGCS	FGCS	2802	FGCS MRM	1050
	FGCS	Non-FGCS	3794	FGCS non-MRM	16,862
	FGCS	FGCS	1050		

Using the cumulative link mixed model from the ordinal package of R software (version 2019.12-10), we fitted logistic models for each of the 58 ordinal outcome variables with a random effect of the institution via the Laplace approximation. We included course level (precalculus, calculus 1, and calculus 2) as a predictor variable, with calculus 1 as the reference group since course level was significantly related to several of the social markers for instructors and students. The remaining predictor variables were related to the social markers of students, instructors, and their interaction effect as dummy coded predictor variables. The fitted logistic model is presented in equation 1, where j is the response option for the survey, i is i^{th} student, and the boldface text are the interaction effects. The interaction effect represents the potential additive impact of a matched-identity role model. The identity markers used included gender, race, sexuality, and First-Generation College Student status. These markers were selected as they represent both visible and less-visible identities to unpack the effect of role models in this context. The interaction effect of the instructor and student social marker represented the MRME.

$$logit\big(P(Y_i \leq j)\big) = \theta_j + \beta_1(precalculus) + \beta_2(calculus\ 2) + \beta_3\,(Woman\ student) + \beta_4\,(Woman\ instructor) + \beta_4\,(URM\ student) + \beta_5\,(URM\ instructor) + \beta_6\,(Queer\ student) + \beta_7\,(Queer\ instructor) + \beta_8\,(FirstGen\ student) + \beta_9(FirstGen\ instructor) + \boldsymbol{\beta_{10}(Woman\ student)\!:\!(Woman\ instructor)} + \boldsymbol{\beta_{11}(URM\ student)\!:\!(URM\ instructor)} + \boldsymbol{\beta_{12}(Queer\ student)\!:\!(Queer\ instructor)} + \boldsymbol{\beta_{13}(FirstGen\ student)\!:\!(FirstGen\ instructor)} \mid University$$

After fitting the cumulative link mixed model for each of the survey items, we identified whether the particular survey response items had a statistically significant ($p < .05$) predictor for any of the minoritized role model effects, which was determined by the interaction effect depicted in the model above. Because the aim of this analysis is novel and exploratory in nature, we purposefully did not adjust our cut-off scores for the significant threshold. Instead, we wanted to guard against Type II errors and identify possible evidence of a minoritized role model effect for the various social markers. Furthermore, this exploratory approach allows us to determine future composite items or primary outcome variables to conduct confirmatory analysis (Feise, 2002).

Results

Out of the 58 survey items, 25 items (see Appendix) exhibited a MRME for at least one of the social markers of gender, race, sexuality, and FGCS status. The full results of the model are available here (http://bit.ly/3bo5tgd), but we present in-depth those survey items which showed an MRME for the four social markers we examined. By examining the items which exhibit a MRME for each population, we acknowledge and explore the ways in which different axes of marginalization, and different visibility of identities, are differently impacted in the event of a student and instructor sharing aspects of minoritized identities. Following the presentation of the results, we discuss limitations on the interpretation and generalizability of these findings, particularly in regard to sample sizes, visibility of identities, and the collapsing of multiple identities into binary social markers. We refer to items based on how they were initially clustered in the survey in five groups: (1) instructional practices; (2) helpfulness of instructional practices; (3) perceived equity of instruction; (4) mathematical affect; and (5) persistence indicators.

We focus on the odds ratio (OR) as the value of interest, which in this study can be interpreted thusly: for [outcome of interest], students with an MRM are [OR] times as likely to report a value higher than those without an MRM; this effect is above and beyond the effect of any non-interaction variables. An OR value ≥ 1 indicates that the MRME predicts a greater likelihood of a higher score on an item, and an OR value ≤ 1 indicates that the MRME predicts a lower likelihood of a higher score on the item; if the confidence interval includes 1 then we cannot detect an MRME.

Gender MRME

A detectable MRME for Woman+ students with Woman+ instructors occurred for seven of the items on the survey, including one describing instructional practices, three for the helpfulness of instructional practices, two for the perceived equity of instruction, and STEM major (Table 2). That is, the gender MRME was found to significantly contribute to the model of response outcomes for these seven items.

	B	SE	Wald z	OR [95%CI]
Instructional practices				
PIPS_ShareIdeas	0.15	0.07	2.16*	1.16 [1.01, 1.33]
Helpfulness of instructional practices				
Helpful_Feedback	0.19	0.09	2.12*	1.21 [1.01, 1.44]
Helpful_InstantFeedback	0.20	0.09	2.16*	1.22 [1.02, 1.46]
Helpful_WorkIndiv	0.25	0.08	3.16**	1.29 [1.10, 1.50]
Perceived equity of instruction				
Included_Contribute	0.24	0.004	66.67***	1.27 [1.25, 1.28]
Included_Help	0.20	0.09	2.26*	1.22 [1.03, 1.45]
Persistence indicators				
STEM_major	-0.18	0.09	-2.00*	0.84 [0.70, 1.00]

*Table 2. MRME statistics from models of the seven survey items for which the gender MRME was significant at the 0.05 level. *p<0.05, **p<0.01, ***p<0.001. Values may have been rounded to two decimal places*

The seven items which showed evidence of a gender MRME relate to a few aspects of student experience, but we note that several are (or may be) related to student-instructor interactions or instructor-facilitated interactions. For example, students with a gender MRM are more likely to rate general instructor feedback (OR=1.21) and immediate instructor feedback (OR=1.22) more highly than peers without a gender MRM. These students are also 1.27 times as likely as their peers to report receiving more help than their peers, which may be related to them finding individual work time more helpful (OR=1.22). While the positive gender MRME on sharing their ideas during class (OR=1.16) and opportunities to contribute to whole-class discussions (OR=1.27) does not explicitly connect to the instructor, we note that instructors generally facilitate such activities by calling on students or inviting particular students to participate. While not definitive, these patterns suggest that the positive gender MRME is at least somewhat related to students' interactions or relationships with their instructor. It is somewhat surprising, in light of the previously reviewed literature, the students with a gender MRM were 0.84 times as likely as their peers to report majoring in a STEM field.

Race MRME

A detectable (and positive) MRME for underrepresented racially minoritized (URM) students with a URM instructor occurred for nine of the items on the survey, including six describing the instructional practices, one mathematical affect item, and both STEM major and expected course grade (Table 3). That is, the race/ethnicity MRME was found to significantly contribute to the model of response outcomes for these nine items.

The nine items which showed evidence of a race/ethnicity MRME relate to a few different aspects of student experience, but we note that several are related to student-student interactions in class and several are related to factors associated with persistence in STEM. When considering the instructional practice items, recall that the MRME is an interaction effect above and beyond individual students or instructors having a URM identity. As shown in Table 3, students with a race/ethnicity MRM are more likely to report working in small groups (OR=1.71), talking about course topics (OR=1.45), and discussing difficulties (OR=1.38) with classmates during class; they also are 1.58 times as likely as peers without a race/ethnicity MRM to report sharing their ideas (or their group's ideas) during whole-class discussions. These results suggest that students with a race/ethnicity MRM perceive student-student class activities as more present than their peers. A positive race/ethnicity MRME was detected for two other aspects of instructional practice, which do not clearly relate to peer-to-peer engagement: students with a race/ethnicity MRM are 1.65 times as likely to report working individually during class time and 1.38 times as likely to report that exams focus on important facts and definitions from the course as compared to students without a race/ethnicity MRM. The positive race/ethnicity MRMEs on reporting a STEM major (OR=1.48), expecting a higher grade (OR=1.28), and feeling confident in mathematical abilities at the beginning of the term (OR=1.32) align with factors that support persistence in STEM majors (Chen & Weko, 2009; Zirkel, 2002).

	B	SE	Wald z	OR [95% CI]
Instructional practices				
PIPS_DiscussDifficulty	0.32	0.11	2.90**	1.38 [1.11, 1.71]
PIPS_ShareIdeas	0.45	0.11	4.01***	1.58 [1.26, 1.97]
PIPS_TalkStudent	0.37	0.11	3.34***	1.45 [1.16, 1.80]
PIPS_WorkGroups	0.54	0.12	4.64***	1.71 [1.37, 2.15]
PIPS_WorkIndividual	0.50	0.11	4.40***	1.65 [1.32, 2.06]
PIPS_TestFocus	0.32	0.12	2.74**	1.38 [1.10, 1.73]
Mathematical affect				
Attitude_BeginConfident	0.28	0.11	2.58**	1.32 [1.07, 1.64]
Persistence indicators				
STEM_major	0.39	0.14	2.77**	1.48 [1.12, 1.96]
ExpectedGrade	0.25	0.11	2.17*	1.28 [1.02, 1.61]

*Table 3. MRME statistics from models of the nine survey items for which the race/ethnicity MRME was significant at the 0.05 level. *p<0.05, **p<0.01, ***p<0.001. Values may have been rounded to two decimal places*

Sexuality MRME

A detectable MRME for Queer students with a Queer instructor occurred for only three items on the survey. The sexuality MRME was found to significantly contribute to the model as a negative predictor for one instructional practice item, one level of perceived equity of instruction item, and one helpfulness of instructional practice item (Table 4).

	B	SE	Wald z	OR [95% CI]
Instructional practices				
PIPS_DiscussDifficulty	-0.66	0.26	-2.54*	0.52 [0.31, 0.86]
Helpfulness of instructional practices				
Helpful_Lecture	-0.62	0.30	-2.11*	0.54 [0.30, 0.96]
Perceived equity of instruction				
Included_Encourage	-0.68	0.34	-2.02*	0.51 [0.26, 0.98]

*Table 4. MRME statistics from models of the three survey items for which the sexuality MRME was significant at the 0.05 level. *p<0.05, **p<0.01, ***p<0.001. Values may have been rounded to two decimal places*

The three items which showed evidence of a sexuality MRME all showed a negative effect, and they are not obviously related to each other in their content. Compared to their peers, students with a sexuality MRM are half as likely as their peers to report discussing mathematical difficulties with their peers in class as descriptive of their experience (OR=0.52); half as likely to report instructors' content lectures as helpful (OR=0.54); and half as likely to report that they receive more encouragement than their peers (OR=0.51). We discuss possible interpretations in the following sections but note here that the wide confidence intervals (and their proximity to a null effect) suggest additional work is needed to confirm the presence and size of these effects.

First-Generation College Student MRME

A detectable MRME for First-Generation College Students (FGCS) with a FGCS instructor occurred for fourteen of the items on the survey: five related to instructional practices, three related to the perceived equity of instruction, five related to mathematical affect, and expected grade in the course (Table 5). That is, the FGCS MRME was found to significantly contribute to the model of response outcomes for these fourteen items – three negative effects, and eleven positive effects.

	B	SE	Wald z	OR [95%CI]
Instructional practices				
PIPS_ShareIdeas	0.21	0.09	2.42*	1.24 [1.04, 1.47]
PIPS_AdjustStudent	0.22	0.09	2.49*	1.25 [1.05, 1.48]
PIPS_Feedback	-0.24	0.09	-2.72**	0.79 [0.66, 0.94]
PIPS_OutsideInstructor	-0.20	0.09	-2.21*	0.82 [0.69, 0.98]
PIPS_OutsidePeer	-0.22	0.09	-2.53*	0.80 [0.68, 0.96]
Perceived equity of instruction				
Included_Contribute	0.07	0.00	20.73***	1.07 [1.07, 1.08]
Included_Help	0.23	0.11	2.10*	1.26 [1.02, 1.56]
Included_Opportunity	0.29	0.12	2.41*	1.34 [1.06, 1.69]
Mathematical affect				
Affect_BeginConfident	0.24	0.09	2.81**	1.28 [1.08, 1.51]
Affect_BeginInterest	0.18	0.09	2.06*	1.20 [1.01, 1.45]
Affect_NowEnjoy	0.23	0.09	2.62**	1.26 [1.06, 1.50]
Affect_NowInterest	0.31	0.09	3.48***	1.36 [1.14, 1.62]
Affect_NowLearn	0.19	0.09	2.03*	1.21 [1.01, 1.45]
Persistence indicators				
ExpectedGrade	0.25	0.09	2.81*	1.29 [1.08, 1.54]

*Table 5. MRME statistics from models of the fourteen survey items for which the First-Generation College Student MRME was significant at the 0.05 level. *p<0.05, **p<0.01, ***p<0.001. Values may have been rounded to two decimal places*

The fourteen items which showed evidence of a FGCS MRME relate to several different aspects of student experience. Due to the number of items, it is possible to construct a variety of overlapping interpretations, and we describe one. One possible cluster relates to out-of-class activities, as the FGCS MRME indicates lower rates of feedback from the instructor (OR=0.79) – but not immediate feedback (*not significant*) – as well as lower rates of interacting with the instructor (OR=0.82) and peers (OR=0.80) *outside* of class time. That lack of out-of-class interaction does not seem to correspond to feelings of exclusion during class. Students with a FGCS MRM were 1.24 times as likely to report sharing their ideas in class as descriptive of their experience, and more likely to report more opportunities to contribute to class discussions

(OR=1.07) and to ask questions in class (OR=1.34); they also were more likely to report receiving more help from the instructor (OR=1.26). One other FGCS MRME related to the course itself is more reporting of the instructor adjusting teaching based on what students do (not) understand. The FGCS MRME has a positive effect on several affective outcomes and students' expected grade in the course. They are 1.28 times as likely as their peers to report that they began the course confident in their mathematical abilities, 1.21 times as likely to report that they feel able to learn mathematics, and 1.29 times as likely to expect a higher grade. In addition to these items related to mathematical ability and confidence, students in this group indicated being more interested in mathematics at the beginning (OR=1.20) and toward the end (OR=1.36) of the course; they also reported higher levels of enjoyment of the subject than their peers (OR=1.26).

Discussion

As described in Dasgupta (2011a), the four main tenets of the Stereotype Inoculation Model are: (1) contact with successful experts and peers in high-achievement settings can act as a "social vaccine" to inoculate against negative self-efficacy, and that this is critical at times when students are especially susceptible to self-doubt, such as in early college; (2) this role model effect is especially impactful for populations whose identities are numerically in the minority (such as Black students attending predominantly white institutions) and/or who are negatively stereotyped against in the achievement setting (such as women in STEM); (3) these effects are heightened if the student feels a connection to the role model; and (4) the impact of the negative stereotypes on students' self-concept is often subtle and unconscious, so role-models likely have more clear effects on students implicit self-concept compared to their explicit self-concept.

To better understand the impact of role models serving as social vaccines, we have examined the effects on students of having a matched-identity expert who is an introductory college mathematics instructor. Specifically, we analyzed student survey responses to questions related to various instructional practices. In total, there were four social markers that we highlighted in our analysis: Woman+, URM, Queer, and First-Generation College Student. Our findings indicated that these role models *do* serve as "social vaccines," but these minoritized role model effects are varied based on the social marker. The Stereotype Inoculation Model was developed by Dasgupta (2011a) and has been used to explain the effect that visible identity group connections have on students - specifically related to perceived gender and perceived race and ethnicity. Given that history, it is not surprising to have found differences in how the MRMs affect the four populations we studied. In this section, we explore the nuances of those effects and potential causes. We also discuss limitations and needs for future research stemming from our findings, and conclude with implications from our work and emphasize non-implications.

Nuanced findings from each social marker

Gender

For the students that identified as Woman+ and were enrolled in a class with an instructor that identified as Woman+, the results indicate seven positive MRMEs related to instructional practices and one negative MRME related to persistence in STEM. Of the seven positive aspects, we call attention to the possibility of a strengthened or heightened sense of a MRME related to student-instructor interactions. As mentioned previously, the existing literature has highlighted the positive effect that gender-matched role models can have for Woman+-identifying students. What is not as clear are the reasons attributing to the negative MRME that arose in our findings.

That is, why is it that the Woman+-identifying students in our data are reporting a negative MRME related to reporting a STEM major? We offer two hypotheses as a consideration but suggest that future work focuses on this aspect of gender-matched role models for Woman+ students. One possible explanation for the negative MRME is that students are self-selecting instructors during course enrollment for their calculus courses. If true, it could be that Woman+ students are self-selecting to enroll in the courses taught by Woman+ instructors (in search of a gender-matched role model) due to an already-developed sense of mathematics anxiety and/or previous negative experiences with non-gender-matched instructors. This would then likely contribute to higher rates of Woman+ students reporting "unsure/undeclared" when asked about their intended major. An alternative hypothesis is that Woman+ students maybe witness to hostile climates and microaggression perpetrated against their instructors, motivating them not to pursue a STEM major.

Race

The results related to the race and ethnicity MRME indicate that URM students with a URM instructor perceive more interactions with other students during class compared to their peers. We highlight two possible interpretations of this finding. First, URM students may feel safer interacting with students more when a URM instructor is facilitating these interactions. More student-student interaction increases the potential of both good interactions and bad interactions, including microaggressions and negative stereotype affirming behavior from other students towards URM students (Leyva, et al., 2021). It is possible that URM students either implicitly or explicitly believe that a URM instructor will create a class environment where these bad interactions will be minimized. An alternative perspective draws on the "spotlight effect," in which students of underrepresented groups feel as though they are the center of attention when there is a discussion in their group (Crosby, King, and Savitsky, 2014). For example, a Black student may feel the spotlight effect when the US history of the enslavement of African people is discussed. We posit that by having a teacher of color in an introductory mathematics class, URM students may experience the spotlight effect and increase their *perception* of their class contributions and peer interactions.

Sexuality

As we cautioned in the results related to Queers students' MRME, the confidence intervals are fairly wide, and so we do not want to draw any strong conclusions based on these findings. However, it is striking that this population experienced the fewest MRMEs, and that the only ones that were experienced were negative. Queer students with a MRM were less likely to discuss mathematical difficulties, experience helpful lectures, and receive encouragement compared to their peers. These items may indicate a level of disengagement or perceived unsafe environment for the Queer student, and point to the potential vulnerability of discussing difficulties or feeling encouraged, and may indicate hostile environments in the classroom for Queer students. It is unclear why these negative experiences are slightly heightened by having a Queer instructor, though it is not clear if students were aware they had a Queer instructor. Like First-Generation College Student status discussed next, sexuality is often a less visible individual trait that may be communicated to students but is up to the instructor to choose to disclose (or not). Perhaps the effect of the "social vaccine" are undermined if the ingroup expert does not feel comfortable disclosing their shared identity status. Similar to our hypothesis on gender MRME, Queer students may be witness to transgressions and hostility to Queer instructors and internalize that discomfort as students, thus minimizing their willingness to discuss difficulties or feel encouraged. More research in this area is needed.

First Generation College Student

While disclosing oneself as a First General College Student (FGCS) is becoming more prevalent among instructors (with encouragement from programs and initiatives such as the Center for First-Generation Student Success), it is still unlikely that the FGCS students involved in our study were explicitly aware that their instructors were also a FGCS. As such, it is surprising that a positive MRME was present for so many items among FGCS, and such a wide array of items, including expected grade and ability to learn mathematics and mathematical confidence, interest, and enjoyment. These findings are incredibly positive. Further, this indicates that there may be subtle behaviors of the instructor related to their own experiences as FGCS that are beneficial to students that are FGCS - further research is needed to identify these behaviors so that they can be more purposefully enacted by FGCS and non-FGCS instructors.

Limitations and Future Studies

We recognize and acknowledge a number of limitations in this current study, each of which presents opportunities for further inquiry. A major limitation of this work stems from a broader limitation of quantitative studies on social identities; to perform the tests we did, we needed to categorize students into binary markers of identity. This becomes especially problematic for social markers comprised of many varying identities, such as grouping Black students, Latinx students, Indigenous students, and Mixed-Race students together into the URM category or grouping together LGBTQ+ students together as Queer. Does an Indigenous student recognize a shared racial identity with a Black instructor? Perhaps there is a shared connection related to being racially marginalized, but it is not clear if this connection rises to the level needed for the "social vaccine" to be effective. Future work targeting the MRME within one broader identity group (e.g, race and ethnicity) can explore this question and add nuance to our understanding.

An additional major limitation of this work is that it is not intersectional - does a Black woman feel a connection to her white woman instructor and benefit from the MRME? Future work will explore such questions and help to identify how multiple social markers work in concert through the social inoculation model. Further, the Dasgupta (2011a) model emphasizes the role that both expert and *peer* role models can have on students' self-concept - in this work, we have narrowed our focus to only the role of the expert role-model (as the instructor), but future work will expand this and investigate how our findings hold or expand in relation to peers. Dasgupta (2011b) posits that a critical mass of roughly ⅓ of the class sharing a social marker is necessary for the positive effects of the "social vaccine" to hold; while this is currently in existence for Woman+ in some introductory mathematics classes, we will need to explore the MRME for social markers that have not and likely will not (e.g., Queer students are 10% of the undergraduate population) meet this threshold.

A final major limitation of this work relates to the confounding systemic barriers affecting who is teaching introductory mathematics and which courses and how they are teaching those courses. For instance, recent research has found that teachers whose teaching is evaluated primarily through student evaluations are less likely to implement active learning, and this sensitivity is heightened among populations who received biased student evaluations (e.g., women and instructors of color) (Apkarian et al., 2021). Our analyses here cannot tease out such detail, and to do so will require future qualitative research.

Lastly, our work faces a number of limitations due to its design as a large quantitative study based on voluntary surveys examining components of students identities: student participation was voluntary, meaning we were most likely to hear from students who had less neutral experiences and who were still engaged in the course near the end of the term. There are small sample sizes in some groups, and thus we need to treat the effects with care, and the survey asked students to reflect back to the beginning of the term.

Implications and Non-Implications

We end by emphasizing some implications of this work, and perhaps more importantly, some non-implications of this work. First, we see an important implication in the hiring of more diverse faculty. In order for students to experience positive MRMEs, there is a need for more faculty that can serve as role models based on a variety of social markers and personal identities. To draw on the vaccine metaphor, we emphasize that while increasing instructor diversity among multiple identity dimensions can help serve as "social vaccines" for marginalized populations of students, "one dose" is not enough. Rather, a changed culture explicitly focused on valuing students' personal identities in conjunction with their STEM identities is necessary to support the inclusion of students from marginalized populations. To be clear, what we are not implying is that mathematics departments can use a diverse instructor pool as an excuse not to change the culture. Instead, our work is meant to highlight the value-added of hiring and retaining diverse instructors to build and sustain an environment that has the potential to positively impact all students in every course offered by the department. To some extent, we can think about the positive effect of hiring diverse faculty and supporting these faculty to thrive at the university as the establishment of "herd immunity." That is, by creating an environment where students are able to experience multiple and sustained positive MRMEs throughout their mathematics career, the presence of stereotype threat may be mitigated. Taking this analogy one step further, we see a relationship between members of a department that do not believe personal identity has anything to do with mathematics and the existence of "anti-vaxxers" in the community that choose to not acknowledge the threat of specific illnesses.

A second major implication stems from the findings related to the less-visible matched identities of sexuality and FGCS status. Ultimately, additional research needs to be done to learn more about why the Queer students reported negative MRMEs and the students that identified as FGCS reported primarily positive MRMEs. However, given these results, we see the implication that whenever possible, instructors are open with their students and provide the opportunity to serve as a matched-identity instructor for their students. It could be the case that FGCS instructors are more likely to talk about their FGCS status in class whereas Queer students are less likely to learn about their instructor's matched identity, leaving them without a role model and/or creating a hostile environment to learn mathematics. In any case, we would like to be explicit and state that we are not suggesting that hiring LGBTQ+ faculty is a harmful practice for students. In fact, we believe that having a diverse group of instructors *and* changing the cultural environment where instructors are encouraged to feel comfortable bringing their identity to the classroom is the best thing we can do for students.

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Appendix

Inclusion Items: Consider your regular course meetings and primary instructor of the course. As compared to other students in class… (1: A lot less than other students … 5: A lot more than other students)	
Included_Contribute	How much opportunity do you get to contribute to class discussions?
Included_Help	How much help do you get from the instructor?
Included_Opportunity	How much opportunity do you get to answer questions in class?
Included_Encourage	How much encouragement do you receive from the instructor?
Instructional Practices: Indicate the degree to which the following statements describe your experience in regular course meetings. (1: Does not occur … 5: Very descriptive)	
PIPS_ShareIdeas	I share my ideas (or my group's ideas) during whole class discussions
PIPS_DiscussDifficuty	I discuss the difficulties I have with math with other students during class
PIPS_TalkStudents	I talk with other students about course topics during class
PIPS_WorkGroups	I work with other students in small groups during class
PIPS_WorkIndividual	I work on problems individually during class time
PIPS_TestFocus	The test questions focus on important facts and definitions from the course
PIPS_AdjustStudent	The instructor adjusts teaching based upon what the class understands and does not understand
PIPS_Feedback	I receive feedback from my instructor on homework, exams, quizzes, etc.
PIPS_Outside_Instructor	I see my instructor(s) outside of class for help
PIPS_Outside_Peer	I work with peers outside of class on math problems
Helpfulness Items: For each of the following activities, please indicate how much each helps your learning in the course. (1: Not helpful … 3: Very helpful)	
Helpful_Feedback	I receive feedback from my instructor on homework, exams, quizzes, etc.
Helpful_InstantFeedback	I receive immediate feedback on my work during class
Helpful_WorkIndividual	I work on problems individually during class time
Helpful_Lecture	I listen as the instructor guides me through major topics
Affect Items: Please indicate your level of agreement for the following statements from the beginning of the course and now. (1: Strongly disagree … 6:Strongly agree)	
Affect_BeginConfident	At the beginning of course, I am confident in my mathematical abilities
Affect_BeginInterest	At the beginning of course, I am interested in mathematics
Affect_NowEnjoy	Now, I enjoy doing mathematics
Affect_NowInterest	Now, I am interested in mathematics
Affect_NowLearn	Now, I am able to learn mathematics
Persistence Items	
STEM_Major	Have you declared, or do you intend to declare, a STEM major? (1: No, 2: Unsure, 3:Yes)
ExpectedGrade	What grade do you expect to get (1: F, 2:D, 3:C,C+,C-, 4:B,B+B-, 5: A, A+, A-)

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