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Role modeling is a viable retention strategy for undergraduate women in the geosciences

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ABSTRACT

Gender diversity leads to better science; however, a number of science, technology, engineering, and mathematics (STEM) disciplines, including many geoscience subdisciplines, show a persistent gender gap. PROmoting Geoscience Research, Education, and SuccesS (PROGRESS) is a theory-driven role modeling and mentoring program aimed at supporting undergraduate women interested in geoscience-related degree and career pathways. This study is unique because it is being conducted in a long-term applied setting, rather than as a laboratory exercise. We compare female STEM majors in PROGRESS to a matched control group ($N = 380$) using a longitudinal prospective multisite quasi-experimental design. College women in PROGRESS participated in a mentoring and role-modeling weekend workshop with follow-up support, while women in the control group participated in neither the workshop nor the follow-up support. PROGRESS members identified more female STEM career role models than controls (60% versus 42%, respectively), suggesting that deliberate interventions can develop the networks of undergraduate women. Undergraduate women that participate in PROGRESS have higher rates of persistence in geoscience-related majors (95% versus 73%), although the rates of switching into a geoscience-related major did not differ across groups. More strikingly, we also find that the persistence of undergraduate women in geoscience-related majors is related to the number of female STEM career role models they identify, as their odds of persisting approximately doubles for each role model they identify. We conclude that our ability to retain undergraduate women in the geosciences will depend, in part, on helping them to identify same-gender career role models. Further, the success of PROGRESS points to steps universities and departments can take to sustain their students' interest and persistence, such as hosting interactive panels with diverse female scientists to promote the attainability and social relevance of geoscience careers.

INTRODUCTION

A chorus of national and international stakeholders are calling for growth and increased diversity in the science, technology, engineering, and mathematics (STEM) workforce in order to expand economic prosperity and advance scientific innovation (Al-Gazali et al., 2013; Carnevale et al., 2010; Holdren and Lander, 2012; Larivière et al., 2013; Nentwich, 2010; Okeke et al., 2017; Valentonva et al., 2017). There is increasing recognition that the U.S. and other countries can only meet their national research goals by developing a diverse and inclusive STEM workforce (Al-Gazali et al., 2013; Freeman, 2018; Nielsen et al., 2017; NIGMS, 2015; Okeke et al., 2017), as many types of diversity, such as gender diversity, lead to more innovative science (Campbell et al., 2013; Valantine and Collins, 2015). In the U.S., trends indicate that although 28% of undergraduates start college pursuing a STEM degree, half of these students switch to non-STEM majors or leave college without earning a degree, typically within the first two years (Chen, 2013; Holdren and Lander, 2012). A deeper examination of these trends within the U.S. reveals gender and racial disparities, with women and some racial or ethnic minority groups leaving STEM majors at proportionally higher rates than their male and Caucasian counterparts (Chen, 2013; Hill et al., 2010; NSF, 2017). Although select STEM disciplines have made headway in negating the gender disparity among degree awardees (e.g., biological sciences), many other STEM disciplines (earth, atmospheric, and ocean sciences, physics, computer science, etc.) have shown a persistent or worsening gender gap over the last decade (Bernard and Cooperdock, 2018; NSF, 2017). The problem is particularly acute in the geosciences, as prior progress toward leveling the gender balance at the undergraduate level appears to be slipping. For example, the proportion of women earning baccalaureate degrees in earth, atmospheric, and ocean sciences has dropped since its peak in 2004 from 42.2% to 38.6% (NSF, 2017; Wilson, 2013). Thus, it is critical to create programs, policies, and organizational contexts that attract and retain women in STEM, as well as to identify and reduce factors that act as barriers to retention (Haacker, 2015; NAS, 2011; Nielsen et al., 2017; NIGMS, 2015; Valantine and Collins, 2015).

Barriers to Retention of Women in STEM

Recent advances in the social sciences have identified social and cultural factors that discourage women from continuing to pursue some STEM degrees (Cheryan and Plaut, 2010; Diekman et al., 2015; Yeager and Walton, 2011). Perceptions that certain STEM disciplines have a male-dominated culture is one reason women abandon those degree and career paths (Cheryan et al., 2015). In many male-dominated STEM disciplines, stereotypical expectations of the people, the work, and the values are masculinized (e.g., stereotypes include socially awkward men focused on technology, engaging in work and pursuing interests that are isolating and unrelated to helping others, and valuing inborn brilliance over effort to achieve success; Cheryan et al., 2011; Diekman et al., 2010; Mercier et al., 2006). A lack of counter-stereotypic female role models communicates messages of not belonging or being different or incompatible, which may discourage women from pursuing degrees and careers in these fields (Cheryan et al., 2015; Herrmann et al., 2016). However, with a better understanding of the social perceptions that act as barriers, we can develop intervention strategies that support women in geosciences and other male-dominated STEM fields (Diekman et al., 2015; Yeager and Walton, 2011).

Importance of Female Role Models in STEM

A growing body of evidence indicates that positive and counter-stereotypic female role models in male-dominated STEM disciplines can play an important part in supporting women's motivation and persistence in these disciplines (Herrmann et al., 2016). Role models are defined as figures that inspire others to follow in their footsteps to achieve similar success or motivate others to avoid their path to failure (Lockwood et al., 2002; Lockwood and Kunda, 1997). Role models may be admired from afar or may be known more intimately by the person drawing inspiration from them. Regardless, role models serve as an example of success (or failure), and provide an example of the attitudes and behaviors that are required to achieve similar results (Lockwood et al., 2002).

Role-modeling research has defined the attributes of role models, their aspirants (i.e., individuals inspired by the role model), and the social context that produce inspiration or demoralization. Experimental research in this area has relied upon a biographical methodology, whereby research participants typically read one or more biographies of role models. Early research found that aspirants were most likely to be inspired when role models were *relevant* to themselves (i.e., similar gender, race, or have a shared interest [e.g., science]) and when similar levels of success were perceived to be *attainable* (Lockwood, 2006; Lockwood and Kunda, 1997, 1999). More recent research indicates that role models are most inspirational when they are seen as *highly competent* (Marx et al., 2013; Marx and Roman, 2002), when they are *transparent about their struggles*, and when they show that *effort, rather than inborn brilliance, leads to success in STEM* (Shin et al., 2016). Role models are also inspirational when they show how STEM careers are consistent with helping others, collaboration, and teamwork (i.e., *communal values*; Clark et al., 2016).

The experimental literature has primarily relied upon exposing women in STEM majors to tailored biographies about female role models in a laboratory setting (e.g., Lockwood and Kunda, 1997). For example, a typical lab experiment will have experimental participants read several short biographies of successful same-gender scientists tailored to the participant's field of study (e.g., a female biology major reads six biographies of women succeeding in biological science careers). Laboratory experiments have shown that exposing women to successful and competent female scientific role models can promote more positive attitudes toward science, a deeper feeling of belonging in science, and stronger feelings of commitment to pursue scientific careers (Cheryan et al., 2011, 2013; Clark et al., 2016; Herrmann et al., 2016; Rosenthal et al., 2013; Shin et al., 2016; Young et al., 2013).

The research we present here is unique because little is known about the effects of role modeling in applied and long-term settings. Furthermore, the degree to which programs featuring role models need to be tailored to a participant's field of study within STEM is unclear. That is, laboratory experiments typically tailor role modeling biographies to the exact field of study (e.g., same major or desired career) of study participants. Less is known about what degree of similarity in field of study or career is required to have a positive effect on women's choice of major.

Current Study

The overall goal of the current study is to examine the effects of the PROmoting Geoscience Research, Education, and SuccesS (PROGRESS) program on supporting women's persistence in male-dominated geoscience-related degree and career pathways (Fischer et al., 2018). The present study makes a unique contribution to the degree-of-similarity question, as study participants were drawn from a wide variety of fields of study within STEM while the PROGRESS role models and mentors were drawn only from the geosciences. Our findings are extremely timely in light of recent calls for increased efforts to diversify and broaden participation in the geosciences (Haacker, 2015). Here we extend the role-modeling research by longitudinally tracking (up to 18 months) women in STEM majors who interact with successful female role models working in male-dominated STEM disciplines via an applied quasi-experiment.

PROGRESS was designed as an all-female, co-curricular, informal mentoring and role-modeling program for first- and second-year undergraduate women in STEM majors, with particular focus on the geosciences. PROGRESS is modeled after the Earth Science Women's Network (ESWN), an international peer-mentoring organization devoted to women in the earth sciences, many of whom are early-career scientists (Adams et al., 2016). As described in detail below, PROGRESS was developed by a team that includes geoscientists and social scientists with expertise in educational and gender psychology. The design is rooted in the role-modeling literature, such that PROGRESS participants were connected with successful female role models in geoscience-related disciplines. The current research is part of an ongoing, prospective, longitudinal, multisite propensity-score-matched study comparing the academic journeys of female STEM majors in PROGRESS to a matched control group (Hernandez et al., 2017). Here the propensity-score-matched control group serves as a quasi-experimental *treatment-as-usual* control group (Freedland et al., 2011; O'Connor et al., 2011). Treatment as usual means that control group students did not participate in any PROGRESS-related activities but may have had exposure to role models as typically encountered in a college context.

Here we address four central research questions about the benefits of PROGRESS and role modeling for female STEM majors. (1) Given the intentional design of the program, do PROGRESS members have more female STEM career role models than control-group members? (2) Do PROGRESS members report having a geoscience-related major at higher rates than control-group members? (3) Is PROGRESS more effective for women in geoscience-related majors compared to those in non-geoscience STEM majors? (4) To what degree do female STEM career role models support having a geoscience-related major? Finally, we conducted an exploratory analysis to determine if any of the observed outcomes varied as a function of cohort (i.e., six-month [cohort 2] versus eighteen-month [cohort 1]).

METHODS

Participants

Four-hundred eighty-four (484) college women STEM majors with an expressed interest in the geosciences were recruited into this study. The analytic sample consists of the 380 participants that completed the initial survey (either fall 2015 or fall 2016) and the most recent follow-up survey (spring 2017). Most of the analytic sample self-identified as Caucasian with smaller percentages of multiracial, African-American, Asian, and Hispanic racial and ethnic groups (Table 1). Approximately one-third of the sample was made up of first-generation college students. Approximately one-quarter of the analytic sample was in their first year of college; approximately one-half were in their sophomore year (second year of college), and one-quarter were in their junior year (third year of college) in spring 2017 (Table 1).

Procedure

Students were recruited via email, flyer, and in-person advertisements (Hernandez et al., 2017). Prospective participants completed a screening and matching survey, which included an Institutional Review Board-approved informed consent form, measures of demographic characteristics, academic interests and achievements, and a variety of psychological factors related to persistence in STEM. Participants received a nominal gift ($5 electronic

TABLE 1. SUMMARY OF DESCRIPTIVE STATISTICS OF SAMPLE CHARACTERISTICS BY GROUP (*N* = 380)

Variable		Matched control (*n* = 233) (%)	PROGRESS (*n* = 147) (%)
Current year in school at follow-up survey			
	First year	26.2	29.9
	Second year	48.5	43.5
	Third year	25.3	26.5
Race or ethnicity			
	African American	6.0	6.8
	Asian	6.0	6.8
	Hispanic	6.4	2.7
	Native American	0.9	1.4
	Multiracial	15.0	15.6
	Caucasian	59.2	59.2
	Other	0.9	0.7
	Declined to report	5.6	6.8
Location			
	Colorado-Wyoming Front Range	54.5	58.5
	North Carolina–South Carolina	45.5	41.5
First-generation college student		27.0	25.9
Geoscience-related major at initial survey		20.2	36.1
Geoscience-related major at follow-up		21.0	37.4

Note: The number of female STEM (science, technology, engineering, and mathematics) career role models on the follow-up survey: matched control, mean = 0.55, standard deviation = 0.74; PROGRESS, mean = 0.95, standard deviation = 0.94.

gift card for Starbucks coffee) for completing the screening survey. All students who met the inclusion criteria (i.e., self-identified as female, declared or intended a STEM major, in the first or second year of college, interested in geosciences) received a personalized invitation to participate in a weekend workshop in their area. Students who participated in the weekend workshop formed the PROGRESS (experimental) group. Propensity score matching was used to construct a treatment-as-usual control group of highly similar participants that did not attend the workshop (details in the Propensity Score Matching section below).

PROGRESS members attended an off-campus workshop early in the fall semester in the year in which they had been recruited (i.e., fall 2015 or fall 2016). The multifaceted, two-day workshops were modeled on the ESWN professional development workshops (Adams et al., 2016; Fischer et al., 2018; Glessmer et al., 2012; Hernandez et al., 2017). A central theme of the workshop was exposing participants, in person, to a diversity of highly competent, successful, and local female geoscientists who served as panelists in one of three interactive panel discussions involving four to five scientists each (Fischer et al., 2018). Scientific panel members were recruited from local universities and scientific institutions, with particular emphasis on members of ESWN. The PROGRESS workshops were conducted in two regions (Colorado/Wyoming Front Range and North/South Carolina), and students from multiple universities attended each workshop. The panel members were different for the two regions. Panel discussions highlighted the several key features of inspirational role models identified in the literature: competence and success; being transparent about struggle and emphasizing effort to overcome challenges; women succeeding in counter-stereotypic roles; teamwork and societal context that connected their science to helping others; and autobiographical narratives that identify pathways to achieving similar success. For example, panelists commonly spoke of perceived and real barriers in life and how they overcame or worked around them. The remaining workshop time was used to introduce and discuss concepts that identify stereotypes in science and perceived barriers to success, and to provide skills for expanding academic and career opportunities (Fischer et al., 2018). After the workshop, PROGRESS members were encouraged to continue their engagement with their PROGRESS cohort, with female career role models through locally organized events (e.g., touring research facilities with a volunteer faculty or graduate-student mentor), via emailed announcements and newsletters, and on an ongoing basis through social media (e.g., a closed group on the Facebook social-media website that includes all PROGRESS participants; Fischer et al., 2018).

PROGRESS and matched control participants have participated in biannual (i.e., fall and spring) online follow-up surveys to the present date (fall 2018). Participants self-report on their educational experiences, academic achievements, and career aspirations, as well as their perceptions, beliefs, and motivations about STEM majors and careers. Participants receive a nominal gift ($10 electronic gift card) for their participation in each follow-up survey. The study has maintained a high response rate over time (i.e., average 87% response rate) by using a tailored panel management approach (Estrada et al., 2014).

Propensity Score Matching

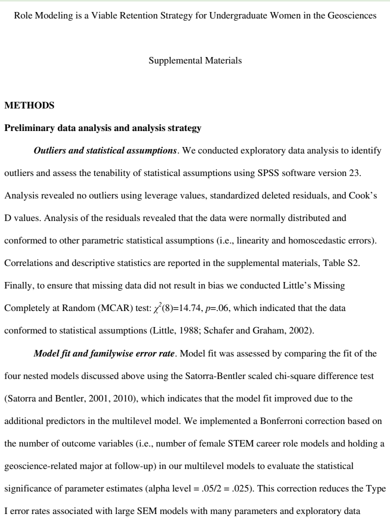
This study used a prospective propensity-score-matching design to minimize the possibility that PROGRESS and control groups were fundamentally different from one another (i.e., selection bias; Rosenbaum and Rubin, 1983; West et al., 2008). Propensity score methods reduce or remove bias when participants are matched based on all relevant confounding variables (i.e., common causes of treatment and outcome). Specifically, we recruited a propensity-score-matched sample of female students in STEM majors from among the participants that completed the screening survey but did not participate in the PROGRESS program. By doing so, the current study followed recommendations to prospectively collect a large amount of information on factors known or hypothesized to predict workshop participation and persistence in STEM in the screening survey (e.g., motivation; Table S1[1] contains a full list of covariates used in matching; Pan and Bai, 2015).

Matched PROGRESS and treatment-as-usual control groups were constructed using a full matching approach in MatchIT software (Ho et al., 2007, 2011; Pan and Bai, 2015; Thoemmes, 2012). The matching procedure resulted in two groups balanced on all covariates and of unequal sizes (N = 380, $n_{progress}$ = 147, $n_{control}$ = 233). The analysis generated propensity score sampling weights to be used in follow-up analysis to account for unbalanced sample sizes. Examination of matching diagnostics revealed balance on the covariates, and the estimate of selection bias dropped by 99% (i.e., mean difference of propensity scores between groups before and after matching). Complete details of the propensity-score-matched analysis are reported in the Supplemental Materials, Table S1 (footnote 1).

Measures

Geoscience-Related Major

Participants were asked to self-report their declared major (or their desired major if none had yet been declared) at initial and follow-up surveys. All participants were in (or desired to be in) a STEM major at the time of the initial survey, but not all were geoscience-related STEM majors. The participant's open-ended responses were recoded into two binary-coded variables that indicated whether or not they had a geoscience-related major at the time of recruitment (*geoscience-related major at the time of the initial survey*) and at follow-up in spring of 2017 (*geoscience-related major at follow-up*). Because the survey question about major was open-ended (i.e., students typed in their major), the text response needed to be translated (i.e., recoded) into the binary variable described above. Two graduate research assistants independently recoded the survey responses and a reliability check showed that they had a high degree of consistency in how they coded majors (Cohen's kappa = 0.92). The few disagreements in how to recode a student's major were resolved in consultation with this study's first author.


Role Modeling is a Viable Retention Strategy for Undergraduate Women in the Geosciences

Supplemental Materials

METHODS

Preliminary data analysis and analysis strategy

Outliers and statistical assumptions. We conducted exploratory data analysis to identify outliers and assess the tenability of statistical assumptions using SPSS software version 23. Analysis revealed no outliers using leverage values, standardized deleted residuals, and Cook's D values. Analysis of the residuals revealed that the data were normally distributed and conformed to other parametric statistical assumptions (i.e., linearity and homoscedastic errors). Correlations and descriptive statistics are reported in the supplemental materials, Table S2. Finally, to ensure that missing data did not result in bias we conducted Little's Missing Completely at Random (MCAR) test: $\chi^2(8)=14.74$, $p=.06$, which indicated that the data conformed to statistical assumptions (Little, 1988; Schafer and Graham, 2002).

Model fit and familywise error rate. Model fit was assessed by comparing the fit of the four nested models discussed above using the Satorra-Bentler scaled chi-square difference test (Satorra and Bentler, 2001, 2010), which indicates that the model fit improved due to the additional predictors in the multilevel model. We implemented a Bonferroni correction based on the number of outcome variables (i.e., number of female STEM career role models and holding a geoscience-related major at follow-up) in our multilevel models to evaluate the statistical significance of parameter estimates (alpha level = .05/2 = .025). This correction reduces the Type I error rates associated with large SEM models with many parameters and exploratory data

[1]Supplemental Materials. Data and readme files containing information on variables used in the analysis. Please visit https://doi.org/10.1130/GES01659.S1 or access the full-text article on www.gsapubs.org to view the Supplemental Materials. All data files are available from the Colorado State University Data Repository (https://hdl.handle.net/10217/192332).

The following majors were coded as geoscience-related majors based on both the U.S. National Science Foundation categories (LSAMP, 2010) and local university categorizations: Atmospheric Science, Climatology, Ecosystem Science and Sustainability, Earth Science, Environmental Chemistry, Environmental Science, Environmental Studies, Environmental Policy, Geology, Geophysics, Geoscience, Hydrology, Marine and Coastal Resources, Marine Science, Meteorology, Oceanic Science, Oceanography, Soil and Crops Science, and Watershed Science.

PROGRESS Membership

Group membership was determined by participation in the PROGRESS workshop. Participation was coded using a binary variable indicating membership in PROGRESS.

Female Role Models

We measured the number and characteristics of STEM career role models using questions developed in prior research (Lockwood, 2006). Participants read the following definition of a career role model: "A career role model is a person who inspires you, someone with whom you identify emotionally, and someone you wish to emulate. A career role model may or may not be aware of your admiration and may not be aware that he or she is a role model for you." With this definition in mind, participants were asked identify up to three STEM career role models by their name, occupation, and gender. Role modeling questions were asked in a follow-up survey (spring semester of 2017). Participants' open-ended responses were recoded into binary variables that indicated whether or not each role model was female. Coding was conducted independently by two graduate research assistants with perfect consistency (Cohen's kappa = 1.00). A summary index variable was created for each participant by summing the number of female STEM career role models (range 0–3).

Preliminary Data Analysis and Analysis Strategy

Prior to testing our research questions, we tested statistical assumptions of multilevel structural equation modeling. Our analyses revealed that the data were consistent with statistical assumptions (more details provided in the Supplemental Materials [footnote 1]). The data were analyzed using propensity-score-weighted multilevel structural equation modeling using maximum likelihood estimation with robust standard errors in M*plus* version 8.00 software (more details are provided in the Supplemental Materials; Muthén and Muthén, 1998–2017).

A series of four nested multilevel models and three nested model comparison tests were conducted to formally test each of our research questions. The four nested models were as follows: model 0—null model (no predictors); model 1—add geoscience major at the time of the initial survey as a predictor (i.e., control variable); model 2—add PROGRESS status and/or number of female STEM career role models (i.e., does PROGRESS and/or number of role models affect the outcome); model 3—add PROGRESS × geoscience major at initial survey interaction term (i.e., does the effect of PROGRESS depend on holding a geoscience-related major). More complex models were compared with simpler models to test the research questions and determine if the more complex models improved prediction.

RESULTS

Prior to conducting our main analyses, we examined the degree to which participant cohort status (i.e., enrolling in the study in 2015 or 2016) directly influenced the outcomes or changed the effect of PROGRESS on the outcomes. Exploratory analyses revealed that cohort status had no effects on the outcomes and did not change (i.e., moderate) any effects of PROGRESS status (p values > 0.25). Thus, cohort status was not considered further in the analyses below.

PROGRESS Members Identify More Role Models than Control Members

We sought to determine if PROGRESS members were able to identify female STEM career role models at higher rates than controls. Results illustrate that women in the PROGRESS group report identifying statistically more female STEM career role models than women in the control group (Tables 1 and 2) (e.g., 60% of PROGRESS members reported having one or more role models compared to 42% in the control group). Formal tests (i.e., a series of nested multilevel models) further indicated that the difference between the PROGRESS and control groups was statistically significant (Table 2) (additional details of nested multilevel models are provided in the Supplemental Materials [footnote 1]).

PROGRESS Membership Supports Persistence in (but Not Recruitment into) Geoscience Majors

Our second analysis sought to examine (1) the degree to which participation in PROGRESS influenced holding a geoscience major at follow-up, (2) the degree to which the PROGRESS effect changed for women with geoscience versus non-geoscience STEM majors at the time of recruitment, and (3) the influence of female STEM career role models over and above the influence of holding a geoscience major at the time of recruitment into the study. The PROGRESS group had a higher proportion of geoscience-related majors than the control group at the time of recruitment into the study and at the follow-up

TABLE 2. SUMMARY OF FIXED EFFECTS FROM MODEL 3 IN PREDICTING THE NUMBER OF FEMALE STEM CAREER ROLE MODELS AND GEOSCIENCE-RELATED MAJOR AT FOLLOW-UP (*N* = 380)

	Number of female STEM career role models at follow-up			Geoscience-related major at follow-up		
Source	b	S.E.	β	*B*	S.E.	O.R.
Intercept	0.78	0.05	N.A.[a]	–0.54	0.17	N.A.[a]
Geoscience-related major at initial survey (Geo)	0.16	0.14	0.09	4.97	0.64	143.93[§]
PROGRESS status (P)	0.33	0.13	0.20*	0.49	0.34	1.63
Geo × P	0.04	0.18	0.01	2.88	1.02	17.87[†]
Number of female STEM career role models	N.A.[b]	N.A.[b]	N.A.[b]	0.77	0.29	2.15[†]

Note: See text for model 3 description. b—unstandardized regression coefficients; S.E.—standard error; β—standardized regression coefficient; *B*—unstandardized logistic regression coefficient (i.e., natural log of the odds ratio); O.R.—odds ratio. N.A.[a]—standardized estimates of the intercept are not applicable in regression models; N.A.[b]—number of female STEM (science, technology, engineering, and mathematics) career role models was the outcome, not the predictor, in this analysis. Number of female STEM career role models was uncentered when used as an outcome, but was grand-mean centered for the analysis. Geo was coded –0.50 for non-geoscience major and 0.50 for geoscience-related major at the time of the initial survey; P was coded –0.50 for the control group and 0.50 for PROGRESS students; Bonferroni correction was applied to evaluation of statistical significance ($\alpha = 0.05 / 2 = 0.025$).

*$p \leq 0.025$.

[†]$p \leq 0.01$.

[§]$p \leq 0.001$.

survey (Table 1). However, multilevel modeling analysis revealed a more nuanced pattern of results.

The modeling analysis revealed no overall effect of PROGRESS on holding a geoscience major at follow-up (Table 2). Rather, the effect of PROGRESS depended on whether or not the participant initially held a geoscience-related major at the time of the initial survey (Table 2). More specifically, our analysis showed that the odds of holding a geoscience major at follow-up were significantly higher for women in PROGRESS who initially held a geoscience major compared to similar controls (18.41-to-1 in PROGRESS and 2.68-to-1 in control; odds ratio = 6.88), whereas the odds of holding a geoscience major at follow-up were essentially the same for PROGRESS and control-group members who initially held a non-geoscience major (0.03-to-1 in PROGRESS and 0.08-to-1 in control, odds ratio = 0.38; ratio of odds ratios = 6.88/0.38 = 17.87). In other words, for participants who initially held a geoscience major, the probability of persisting in geoscience major was significantly higher for PROGRESS versus control-group members (95% versus 73%, respectively), whereas the probability of switching into a geoscience-related major was equally low for PROGRESS and control-group members (3% and 7%, respectively; Fig. 1).

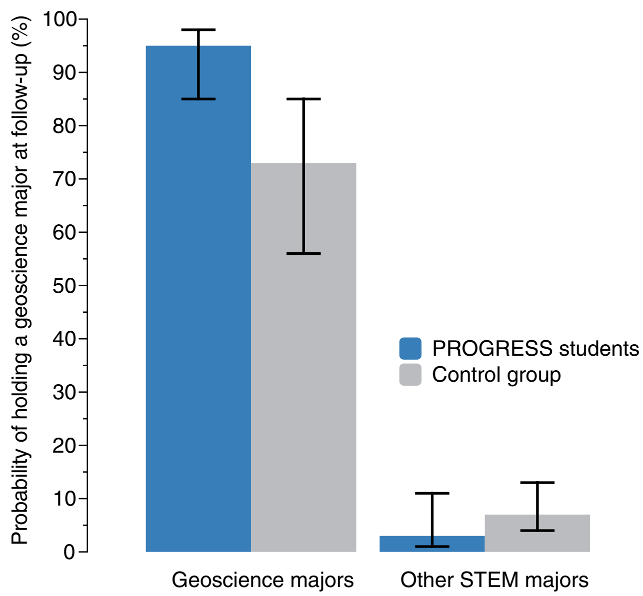


Figure 1. Probability of holding a geoscience-related major at follow-up by PROGRESS status and by geoscience-related major status at the initial survey. Predicted-values and confidence interval error bars are computed from a weighted multilevel model for interaction between PROGRESS status and geoscience-related major status at the time of the initial survey. Error bars represent 95% confidence intervals. STEM—science, technology, engineering, and mathematics.

Female Role Models Support Persistence in Geoscience Majors

In addition, the models indicated that identifying female STEM career role models improved the likelihood of having a geoscience-related major at follow-up. More specifically, the odds ratio indicated that the odds of holding a geoscience major doubled for each additional female role model identified

(Table 2). The probability of holding a geoscience major at follow-up was highest for participants with three female STEM career role models (77%) and progressively less for those with two, one, or no female role models (61%, 42%, and 25%, respectively; Fig. 2).

CONCLUSIONS

Female undergraduates face cultural stereotypes that can discourage their pursuit of degrees and careers in many STEM fields, particularly in the absence of female role models (Cheryan et al., 2015; Herrmann et al., 2016). However, controlled experiments have shown that exposing undergraduate women to inspirational female role models in their field of study can support their motivation to persist in male-dominated STEM fields (Cheryan et al., 2015; Herrmann et al., 2016). Most role-modeling interventions with college women have been conducted in fully controlled experimental settings, and studies of these interventions show that reading biographies of successful female role models can have short-term benefits, such as improved sense of belonging or motivation to persist in STEM (Cheryan et al., 2011, 2013; Clark et al., 2016; Rosenthal et al., 2013; Shin et al., 2016; Young et al., 2013). The present study extends this research in a very important applied direction. We show that having first- and second-year female college students interact with diverse and successful female geoscientists can have a tangible impact on both their identification of female career role models and their persistence in geoscience-related majors (i.e., male-dominated STEM majors). Our analysis indicates that women in PROGRESS identify significantly more female STEM career role models than their matched counterparts. PROGRESS offers two key features: (1) it exposes students to a diverse group of successful female geoscientists during a weekend workshop; and (2) it offers the opportunity for follow-up and new interactions with multiple mentors and other women in STEM. Building a STEM community in this way appears to be an effective way to help college women identify inspirational female career role models. Our analysis also indicates that identifying multiple female career role models increases the persistence of undergraduate women in geoscience majors. By organizing women-only panels, in-person social gatherings, and positive social-media interactions, PROGRESS shows students a variety of inspirational female career role models, and the undergraduate women are more likely to believe that they too can be successful in geoscience careers. Based on our study, we recommend that colleges and universities consider offering similar experiences for their undergraduate women. Female role models and mentors can include successful and enthusiastic faculty, graduate students, research scientists, and working professionals. These women may already exist in a given college or university ecosystem, but they need to be made visible to undergraduate women. We had students and role models meet individually and/or in groups; we were not able to discern a difference in these approaches over the course of the study, but we are continuing to investigate this. From the perspective of implementing PROGRESS or a similar program, it is important that the mentors and role models be engaged; however, the level of engagement can vary. For example, a scientist can be part of a panel (i.e., a one-time commitment) or develop a long-term relationship with a student (e.g., meeting 3+ times a semester for two years). It is much easier to implement a program like PROGRESS with a committed set of women who are connected through a formal or informal network. Students generally are looking for role models that are relevant to their current major. Students may have difficulty understanding all the different ways that mentors can help them; thus, it is important for students to see many different women that they may connect to personally or view as similar to themselves.

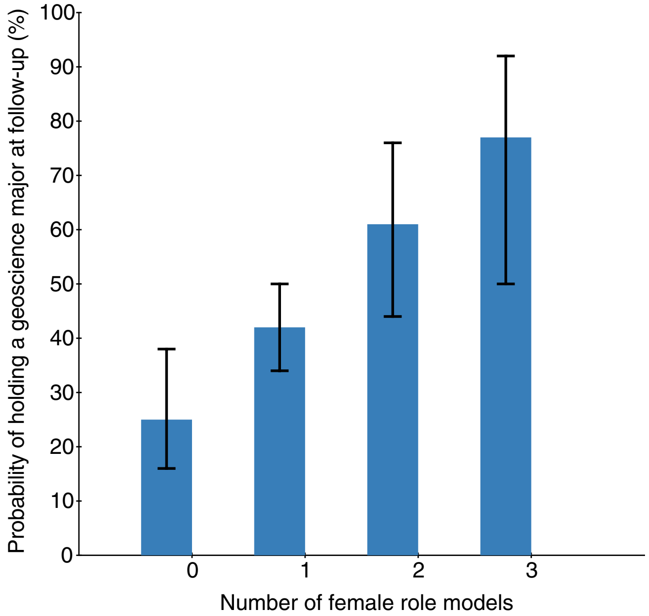


Figure 2. Probability of holding a geoscience-related major at follow-up as a function of the number of female STEM career role models. Predicted values and confidence-interval error bars computed from a weighted multilevel model for the number of role models. Error bars represent 95% confidence intervals.

We also discovered that PROGRESS only influences the persistence of women who started college in a geoscience-related major. This program did little to recruit additional women into geoscience majors from other STEM majors. Therefore, co-curricular programs like PROGRESS, which engage women in workshop activities addressing bias, activities to support skills on how to find and best make use of a diversity of mentors, and panel discussions (Fischer et al., 2018), appear to operate under the principles of *relevance* and *attainability.* Both of these principles have been highlighted in the role-modeling literature (Lockwood and Kunda, 1997, 1999). These principles suggest that co-curricular programs can maximize their impact by ensuring that these activities are tailored to a specific field of study (i.e., the earth sciences versus mathematics versus biology). Students in our program were more satisfied with role models that were in their target field of study. Exposure to a greater diversity of scientists in the geosciences is important because it deepens students' sense of belonging and also broadens their understanding of how the geosciences serve society. Women-only panel sessions, student discussions, and mentor networking events at colleges and universities have the potential to increase retention of undergraduate women.

Although this study advances our understanding of the impact of role modeling and co-curricular informal support programs on women's persistence in geoscience-related STEM disciplines, the limitations of our study point to areas for further research. First, in spite of our best efforts toward inclusive recruitment, our study participants were mostly Caucasian and heterosexual college women interested in STEM. Similar patterns of findings may or may not hold for college women of color or students having diverse sexual and gender identities. Additional research will need to be conducted to have the requisite statistical power to determine benefits for all communities. Second, PROGRESS is a multifaceted co-curricular program for early-tenure undergraduate women compared to a single matched "treatment-as-usual" comparison group. Our study design does not allow us to draw conclusions about the relative important of different features of PROGRESS, such as the key attributes of role models that make them most engaging, the importance of discussing lifestyle and family choices with students, or the optimal timing for implementing mentoring and role-modeling workshops across the undergraduate tenure. Further study will be needed to test which features and what timing are essential to the program and maximize the benefit. For example, in the current study, PROGRESS participation was implemented with a two-day off-campus, women-only workshop and contained several elements: panel discussions, bias-awareness training, mentoring skills development, etc. (Fischer et al., 2018). Future studies will need to disentangle which of these many features are critical for success (e.g., time [two days versus shorter], location [off-campus versus on-campus], all program elements versus panel discussion alone). Identifying the key features of the workshop will greatly aid in scaling PROGRESS-like programs across different institutional contexts. In addition, continued research on the critical elements of PROGRESS is needed to develop a better understanding of how institutions can implement policies that promote gender equity, as well as guide the design of the most cost-effective approach to such policies. Finally, PROGRESS was designed for and implemented at the college level, which limits conclusions we might draw about supporting pre-college women interested in STEM degrees and careers. Further research is needed to investigate the degree to which a PROGRESS-like program could help support women's interest in STEM and success in pre-college coursework required for college-level STEM majors.

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