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: *χ2*(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 approaches (e.g., decisions guided by model improvement tests – modification indices; Cribbie, 2000; Green and Babyak, 1997).

***Analytic strategy***. Structural equation modeling (SEM) describes a family of statistical methods and computational algorithms designed to model the associations or links between phenomena (Kline, 2016). Most relevant for the present study, SEM allows for prediction of continuous or categorical outcomes from a set of predictors or covariates (i.e., similar to multiple regression or the generalized linear model). In addition, SEM allows for formally testing or the comparison of data-model fits of simple models (fewer predictors) versus more complex models (more predictors). The present study used an SEM framework to predict a) the number of female science career role models (continuous variable) and b) the holding a geoscience-related major at the follow-up survey.

In addition to the goals of prediction, two features of the present study’s design needed to be taken into account in the SEM model. First, the data were collected from students attending different colleges (i.e., students nested within schools). This is a familiar problem to educational researchers, as nesting of students within schools can cause a violation of the statistical assumption of independence of errors (Stapleton, 2006). In practical terms, students within a given school are more similar to one another (and more likely to respond similarly) compared to students across different schools; and this similarity manifests in a correlation between scores within schools (i.e., intra-class correlation or ICC). Statistical models that are not sensitive to or do not account for an ICC may have severely biased estimates of standard error, resulting in severe threats to statistical conclusion validity (i.e., inferences based on these tests will be wrong). Multilevel SEM is one method of statistically controlling for the ICC (Muthén and Santora, 1995; Stapleton, 2006).

Second, the propensity score methodology used in this study balanced the two samples on a set of observed covariates and generated a set of weights to be used in the analysis. SEM allows for implementation of weights in data analysis to account for PSM method of the study’s design (Pan and Bai, 2015). The weighted analysis incorporated propensity score-generated sampling weights to balance groups on matching variables and account for unequal sample sizes in the matched groups (Pan and Bai, 2015).

**RESULTS**

**PROGRESS members identify more role models than control members**

A series of four nested multilevel models and three nested model comparison tests were conducted to formally address our research question (i.e., do PROGRESS members identify more female role models). The four nested models were as follows: Model 0 – null model (no predictors); Model 1 – add predictor *geoscience major at the time of the initial survey* (i.e., control variable); Model 2 – add *PROGRESS status* (i.e., does PROGRESS affect role model identification); Model 3 – add *PROGRESS × geoscience major at initial survey* moderation (i.e., does the effect of PROGRESS depend on holding a geoscience-related major). The series of nested model comparisons showed that only Model 2 (PROGRESS status) improved model fit: Model 0. vs. 1. *Δχ2*(1) = 1.49, *p* = .22; Model 1. vs. 2. *Δχ2*(1) = 2.23, *p* = .01; Model 2. vs. 3. *Δχ2*(1) = 0.05, *p* = .82.

**PROGRESS membership supports persistence in Geoscience majors**

Concerning overall recruitment into and persistence in geoscience-related majors, a descriptive cross-tabulation analysis revealed that nearly ten percent of participants switched their major into or out of geoscience-related majors between the initial survey and follow-up (i.e., 19 [5%] switched into a geoscience-related major; 15 [4%] switched out of geoscience-related major; 85 [22%] persisted in geoscience-related majors; and 261 [69%] persisted in a non-geoscience STEM major).

A series of four nested multilevel models and three nested model comparison tests were conducted to formally address our research question. The analysis of nested model comparisons was identical to that described above, with the exception that the number of female STEM career role models was included as a predictor in Model 2. The series of nested model comparisons showed that model fit improved at each step in the analysis: Model 0 vs. 1: *Δχ2*(1) = 248.34, *p* < .001; Model 1 vs. 2: *Δχ2*(2) = 9.07, *p* = .01; Model 2 vs. 3: *Δχ2*(1) = 32.81, *p* < .001.

Not surprisingly, the analysis indicated that having a geoscience-related major at the time of the initial survey had the strongest effect on holding a geoscience-related major at follow-up (i.e., the odds-ratio showed that the odds of having a geoscience major at follow-up were ~144 times higher for women who initially reported holding a geoscience major compared to those who initially reported holding a non-geoscience STEM major), Table 2.

Supplemental Table 1. SUMMARY OF PRE- AND POST-MATCHING DIFFERENCES BETWEEN PROGRESS AND CONTROL GROUPS ON ALL COVARIATES IN PROPENSITY SCORE MATHCING ANALYSIS (*N* = 380)

|  | *MPROGRESS* | | *MControl* | | *Standardized Difference*  *(Cohen’s d)* | |
| --- | --- | --- | --- | --- | --- | --- |
| *Source* | *Before* | *After* | *Before* | *After* | *Before* | *After* |
| Propensity | 0.50 | 0.50 | 0.32 | 0.50 | 0.94 | 0.01 |
| Cohort | 0.50 | 0.50 | 0.50 | 0.48 | 0.00 | 0.03 |
| Heterosexual status | 0.20 | 0.20 | 0.18 | 0.20 | 0.03 | -0.02 |
| Parental Status | 0.55 | 0.55 | 0.56 | 0.52 | -0.02 | 0.05 |
| Do you plan to have children (or more children) in the future? | 2.81 | 2.81 | 2.87 | 2.81 | -0.04 | 0.00 |
| U.S. or Foreign national status | 0.54 | 0.54 | 0.52 | 0.55 | 0.03 | -0.03 |
| U.S. national (European decent) | 0.74 | 0.74 | 0.73 | 0.76 | 0.02 | -0.07 |
| U.S. national (African) | 0.10 | 0.10 | 0.10 | 0.07 | -0.01 | 0.08 |
| U.S. national (Asian) | 0.08 | 0.08 | 0.08 | 0.05 | -0.02 | 0.09 |
| U.S. national (Latina) | 0.05 | 0.05 | 0.08 | 0.04 | -0.16 | 0.06 |
| U.S. national (Native American/Pacific Islander/First Nation) | 0.12 | 0.12 | 0.11 | 0.09 | 0.03 | 0.10 |
| U.S. national (Other) | 0.03 | 0.03 | 0.02 | 0.02 | 0.06 | 0.06 |
| Is English your first language? | 1.44 | 1.44 | 1.42 | 1.45 | 0.03 | -0.02 |
| Do you identify as having a physical disability? | 0.50 | 0.50 | 0.51 | 0.49 | -0.01 | 0.03 |
| Are you a veteran or currently in the military? | 0.50 | 0.50 | 0.51 | 0.49 | -0.02 | 0.03 |
| Parental highest level of education | 6.16 | 6.16 | 6.01 | 6.17 | 0.11 | 0.00 |
| Has anyone in your family completed a degree in the geosciences? | 0.61 | 0.61 | 0.63 | 0.58 | -0.03 | 0.05 |
| Total annual income of the family that raised you. | 4.40 | 4.40 | 4.46 | 4.59 | -0.05 | -0.14 |
| Financial resources for college: School scholarship | 0.61 | 0.61 | 0.59 | 0.68 | 0.04 | -0.14 |
| What kind of financial resources support your college studies? Job off campus | 0.18 | 0.18 | 0.26 | 0.19 | -0.21 | -0.04 |
| What kind of financial resources support your college studies? External scholarship | 0.29 | 0.29 | 0.38 | 0.33 | -0.18 | -0.08 |
| What kind of financial resources support your college studies? Parental or other family support | 0.65 | 0.65 | 0.67 | 0.64 | -0.03 | 0.02 |
| What kind of financial resources support your college studies? Work-study | 0.12 | 0.12 | 0.10 | 0.07 | 0.04 | 0.14 |
| What kind of financial resources support your college studies? Residence assistantship | 0.01 | 0.01 | 0.02 | 0.00 | -0.03 | 0.09 |
| What kind of financial resources support your college studies? Partner’s employment | 0.01 | 0.01 | 0.01 | 0.00 | -0.02 | 0.04 |
| What kind of financial resources support your college studies? Loans | 0.52 | 0.52 | 0.49 | 0.51 | 0.06 | 0.02 |
| What kind of financial resources support your college studies? Other job on campus | 0.12 | 0.12 | 0.08 | 0.18 | 0.12 | -0.21 |
| What kind of financial resources support your college studies? Savings | 0.35 | 0.35 | 0.41 | 0.41 | -0.12 | -0.12 |
| What kind of financial resources support your college studies? Other | 0.11 | 0.11 | 0.05 | 0.12 | 0.20 | -0.04 |
| Full-time student status | 1.02 | 1.02 | 1.00 | 1.00 | 0.11 | 0.13 |
| College-1 | 0.91 | 0.91 | 0.95 | 0.91 | -0.13 | -0.01 |
| College-2 | 0.09 | 0.09 | 0.05 | 0.09 | 0.13 | 0.01 |
| College-3 | 0.18 | 0.18 | 0.16 | 0.19 | 0.07 | -0.02 |
| College-4 | 0.06 | 0.06 | 0.05 | 0.03 | 0.06 | 0.12 |
| College-5 | 0.03 | 0.03 | 0.04 | 0.02 | -0.07 | 0.07 |
| College-6 | 0.10 | 0.10 | 0.14 | 0.09 | -0.16 | 0.02 |
| College-7 | 0.15 | 0.15 | 0.19 | 0.16 | -0.11 | -0.04 |
| College-8 | 0.14 | 0.14 | 0.12 | 0.14 | 0.04 | 0.00 |
| College-9 | 0.84 | 0.84 | 0.85 | 0.83 | -0.01 | 0.04 |
| First year of college | 1.46 | 1.46 | 1.48 | 1.47 | -0.04 | -0.01 |
| Are you attending college in-state or out of state? | 0.92 | 0.92 | 0.83 | 0.88 | 0.14 | 0.05 |
| Major=Agricultural Science | 0.03 | 0.03 | 0.03 | 0.02 | -0.02 | 0.07 |
| Major =Biological / Life Sciences (e.g. Biology, Pre Medicine, Veterinary, etc..) | 0.35 | 0.35 | 0.46 | 0.33 | -0.23 | 0.03 |
| Major =Engineering | 0.20 | 0.20 | 0.20 | 0.19 | 0.01 | 0.03 |
| Major =Mathematics Or Computer Science | 0.00 | 0.00 | 0.00 | 0.00 | . | . |
| Major =Natural / Geological Sciences (e.g., Chemistry, Atmospheric Sciences, etc..) | 0.05 | 0.05 | 0.05 | 0.04 | 0.01 | 0.08 |
| Have you decided on a major (or double major)? | 1.39 | 1.39 | 1.35 | 1.38 | 0.06 | 0.01 |
| Most recent GPA for matching | 3.62 | 3.62 | 3.64 | 3.61 | -0.07 | 0.01 |
| SAT combined / ACT Equiv. for matching | 1.33 | 1.33 | 1.36 | 1.28 | -0.05 | 0.08 |
| Did you take an AP or IB course in science? | 1.05 | 1.05 | 1.07 | 1.06 | -0.04 | -0.01 |
| Home=Urban | 1285.04 | 1285.04 | 1262.65 | 1290.68 | 0.18 | -0.05 |
| Home=Rural | 1.27 | 1.27 | 1.26 | 1.24 | 0.01 | 0.04 |
| Participated in a summer science program | 0.14 | 0.14 | 0.17 | 0.09 | -0.07 | 0.16 |
| Been a member of an honor society | 0.21 | 0.21 | 0.23 | 0.26 | -0.05 | -0.11 |
| Participated in a science competition, a science fair, or professional research conference | 0.35 | 0.35 | 0.28 | 0.34 | 0.14 | 0.01 |
| Interest in having a mentor on your campus? | 0.72 | 0.72 | 0.74 | 0.71 | -0.05 | 0.02 |
| Interested in participating in long-term study? | 0.40 | 0.40 | 0.37 | 0.44 | 0.06 | -0.09 |
| Science is funa | 1.42 | 1.42 | 1.40 | 1.43 | 0.05 | -0.01 |
| I am good at scienceb | 4.07 | 4.07 | 3.95 | 4.00 | 0.14 | 0.08 |
| It would be thrilling to make a scientific discoveryc | 4.63 | 4.63 | 4.56 | 4.64 | 0.11 | -0.02 |
| I enjoy mathd | 4.18 | 4.18 | 4.12 | 4.23 | 0.09 | -0.07 |
| Mathematics is one of my best subjectse | 4.79 | 4.79 | 4.73 | 4.77 | 0.13 | 0.05 |
| Being a woman is an important part of my identityf | 3.51 | 3.51 | 3.58 | 3.60 | -0.06 | -0.08 |
| I like being a womanf | 3.29 | 3.29 | 3.35 | 3.42 | -0.05 | -0.10 |
| My ethnicity is an important part of my identityg | 4.35 | 4.35 | 4.29 | 4.36 | 0.08 | -0.01 |
| I can see how majoring in the geosciences relates to my future education and occupational goalsh | 4.32 | 4.32 | 4.30 | 4.36 | 0.02 | -0.05 |
| How much do you know about the geosciences? (e.g., have taken courses)i | 3.32 | 3.32 | 3.40 | 3.24 | -0.08 | 0.08 |
| How much do you know about OCCUPATIONS in the geosciences?i | 4.03 | 4.03 | 3.86 | 3.93 | 0.17 | 0.11 |
| People who are good at science are [feminine -- masculine]j | 3.01 | 3.01 | 2.91 | 2.87 | 0.09 | 0.12 |
| Science is a domain that is [feminine -- masculine]j | 2.66 | 2.66 | 2.57 | 2.59 | 0.07 | 0.06 |
| When I think of people who are very good at science, I think of [feminine -- masculine]j | 2.87 | 2.87 | 2.87 | 2.92 | 0.00 | -0.13 |
| The field of geoscience is [feminine -- masculine]j | 2.60 | 2.60 | 2.61 | 2.66 | -0.02 | -0.10 |
| Everyone (male or female) has a fair shot at educational opportunitiesk | 2.62 | 2.62 | 2.57 | 2.67 | 0.06 | -0.06 |
| Having a social impact is important to my choice of majorl | 2.74 | 2.74 | 2.77 | 2.79 | -0.05 | -0.09 |
| Mastering tasks is what I value in my educationm | 2.93 | 2.93 | 3.08 | 2.87 | -0.14 | 0.05 |
| I am drawn to majors that require hands-on, physical workn | 4.13 | 4.13 | 4.15 | 3.97 | -0.02 | 0.18 |
| I am an outdoorsy personn | 4.12 | 4.12 | 4.21 | 4.17 | -0.12 | -0.07 |
| I am confident that I can use technical science skills (use of tools, instruments, and/or techniques)o | 4.13 | 4.13 | 3.98 | 4.09 | 0.18 | 0.05 |
| I consider myself to be a people personp | 4.12 | 4.12 | 3.94 | 4.15 | 0.18 | -0.03 |
| Discrimination against women is no longer a problem in the United Statesq | 4.16 | 4.16 | 4.16 | 4.12 | 0.00 | 0.06 |
| Women are just as capable of thinking logically as menq | 3.80 | 3.80 | 3.77 | 3.73 | 0.03 | 0.08 |
| How interested are you in taking courses in the geosciences?r | 4.91 | 4.91 | 4.88 | 4.92 | 0.10 | -0.04 |
| How interested are you in pursuing a GEOSCIENCE DEGREE? r | 1.77 | 1.77 | 1.78 | 1.66 | -0.02 | 0.14 |
| How interested are you in pursuing a GEOSCIENCE GRADUATE DEGREE?r | 3.88 | 3.88 | 3.68 | 3.75 | 0.17 | 0.12 |
| How likely are you to pursue a GEOSCIENCE OCCUPATION?r | 3.33 | 3.33 | 3.09 | 3.17 | 0.17 | 0.11 |
| If you do poorly on a test people will assume that it is because you are a womans | 2.93 | 2.93 | 2.68 | 2.88 | 0.18 | 0.04 |
| Note: *MPROGRESS* = mean in the PROGRESS group; *MControl* = mean in the matched control group. It is standard practice to flag Cohen’s d difference values > .20 as indicating imbalance across groups, but none of the values exceeded this limit after matching.  aIndicator of positive attitude toward science (adapted from original source) (Scott and Martin, 2013).  bIndicator of science self-concept (Marsh et al., 2013).  cIndicator of science community values (Estrada et al., 2011).  dIndicator of positive attitude toward mathematics (Scott and Martin, 2013).  eIndicator of mathematics self-efficacy (Walton et al., 2011).  fIndicator of gender identity (Schmader, 2002).  gIndicator of ethnic identity (Schmader, 2002).  hIndicator of science utility values (Hulleman et al., 2010).  iIndicator of geoscience career path knowledge.  jIndicator of stereotypes about geoscience (Stout et al., 2011).  kIndicator of gender-specific system justification (Jost and Kay, 2005).  lIndicator of communal values (Diekman et al., 2011).  mIndicator of mastery goal orientation (Elliot and Church, 1997).  nIndicator of outdoors behavioral interest.  oIndicator of science self-efficacy (Chemers et al., 2011).  pIndicator of communal goal attainment values (Diekman et al., 2011).  qIndicator of perceptions of sexism (Swim et al., 1995).  rIndicator of deep interest in geosciences (Hulleman et al., 2010).  sIndicator of gender-based stereotype threat (Woodcock et al., 2012). | | | | | | |

Supplemental Table 2. CORRELATION MATRIX AND DESCRIPTIVE STATISTICS OF KEY VARIABLES IN THE MULTILEVEL MODELS (N = 380)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | 1. | 2. | 3. | 4. |
| 1. Geoscience-related major at initial survey (Geo) | - |  |  |  |
| 2. PROGRESS status (P) | .18\*\* | - |  |  |
| 3. # of female STEM career role models | .14\*\* | .23\*\* | - |  |
| 4. Geo × P | .67\*\* | .51\*\* | .19\*\* | - |
| *M* | .26 | .39 | .70 | .14 |
| *SD* | .44 | .49 | .85 | .35 |
| *Skew* | 1.08 | .47 | .98 | 2.09 |
| *Kurtosis* | -.84 | -1.79 | .07 | 2.38 |
| Notes: Geo = Geoscience major; Geo is a binary coded at the time of the initial and follow-up surveys for the correlation matrix shown above (0 = nonGeoscience-related STEM major, 1 = Geoscience-related major), PROGRESS status binary coded for the correlation matrix shown above (0 = matched control group, 1 = PROGRESS group).  \**p* < .05, \*\**p*<.01 | | | | |

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