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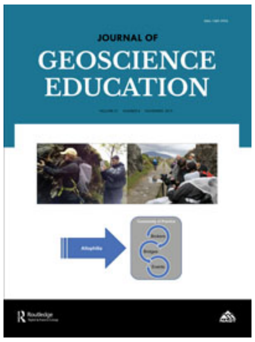

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Probing the National Geoscience Faculty Survey for reported use of practices that support inclusive learning environments in undergraduate courses

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ABSTRACT

What is the extent to which college and university geoscience faculty report using education practices that contribute to more inclusive learning environments and engage a diverse population of students? In the 2016 National Geoscience Faculty Survey, faculty answered questions about their practices in a specific introductory or major course they had taught in the previous two years, and about how they share and learn about the content and methods used in their teaching. Based on factor analysis, 22 of the survey questions divided into four categories associated with inclusive teaching practices: geoscientist representations, curricular choices, learning strategies, and career pathways. The self-reported use of practices across these four categories varies greatly, with some used by as many as 71% of faculty respondents whereas others by only 8%. These data provide new information on the current state of teaching practices in the geosciences with regard to inclusive practices, and establish a baseline to which responses from future surveys may be compared. Univariate general modeling combined with ANOVA tests on the responses to the questions shows that education practices differ based on variables such as teaching style, communication with colleagues, years of teaching experience, faculty type, institution type, class size, and course type (introductory or major). These differences suggest opportunities for focused geoscience faculty development around education practices that support the success of a diverse population of undergraduate students and the enhancement of inclusive learning environments in the geosciences.

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Introduction

Attracting and supporting a diverse population of geoscientists is a critical issue. In particular, recent studies have reported that racial, ethnic, and gender diversity in the geosciences is disproportionate when compared to other STEM fields and to national demographics (Huntoon & Lane, 2007; National Center for Science and Engineering Statistics, 2015; National Science Foundation [NSF], 2010; Sidder, 2017). This persistent lack of diversity in the geosciences is influenced in part by students' undergraduate experiences in geoscience and the choices educators make that contribute to broadening or limiting the participation and success of students from historically untapped groups (Bernard & Cooperdock, 2018; Huntoon, Tanenbaum, & Hodges, 2015; Killpack & Melon, 2016; Wolfe & Riggs, 2017). Recent research has recommended the adoption of a variety of inclusive and equitable education practices. However, to date, there has been little to no documentation as to which of these practices geoscience faculty are currently using or not using in their courses. Such documentation is valuable to suggest directions for focused faculty development and to benchmark future progress.

To learn what teaching practices faculty use and how faculty learn about teaching, the National Survey of Geoscience Faculty has been conducted four times: in 2004, 2009, 2012, and 2016. Previous analyses of survey data have elucidated the teaching practices used in undergraduate courses (Macdonald, Manduca, Mogk, & Tewksbury, 2005; Manduca et al., 2017) and the effectiveness of geoscience professional development programs (Manduca et al., 2017). Recognizing the potential of such a rich data set, a community-based research team was assembled through an application process to

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"explore the results of the geoscience faculty survey administered over 12 years" (Manduca et al., 2018, ED11B-04). The establishment of such a research team is building the capacity of the geoscience community to effectively use large-scale survey datasets (Manduca et al., 2018) and has resulted in several distinct research efforts, including this investigation.

As members of the community-based research team, we sought to document faculty members' reported use of practices contributing to inclusive learning environments, and the predictors for faculty use of these practices. To do so, we took advantage of new items added to the 2016 survey that were not included in previous surveys such as these: Considering the images and stories of individual geoscientists in your course, what percentage included people of color? Did you develop strategies to support less successful groups of students based on data from the course? Do you frequently communicate with your colleagues about how to meet the needs of groups that traditionally have been underserved and/or underrepresented? (New survey questions are marked with * in Table 1.)

These new items, combined with a few relevant ones repeated from previous iterations of the survey, provide an opportunity to probe the survey to investigate the extent to which college and university faculty self-report using practices that contribute to inclusive and equitable teaching and learning. We envision that our analysis of this new data set has multiple audiences, including (a) faculty who are introduced to new instructional strategies by learning what practices others are employing (Macdonald et al., 2005), (b) leaders of geoscience faculty development programs who may be better able to focus future programming based on documentation of what faculty are currently doing, and (c) geoscience education researchers for whom this analysis provides a baseline from which to compare future surveys of geoscience faculty and potentially document progress with regard to the incorporation of inclusive practices.

Evidence-based educational practices

The 2012 Engage to Excel report stated that the "underrepresented majority" of "women and members of minority groups" (p. i) now represent approximately 70% of undergraduate students, yet only 45% of undergraduate STEM degrees. The report urged the adoption of evidence-based educational practices to more effectively attract students from these groups and to support their success (Olson & Riordan, 2012). Evidence-based practices documented by recent education and geoscience education research have specified practices that contribute to creating inclusive and equitable learning communities. Examples of such practices described in the literature include those that remove barriers, such as those barriers that impede the learning of students with differing abilities (Atchison & Libarkin, 2016; Carabajal, Marshall, & Atchison, 2017; Cooke, Anderson, & Forrest, 1997; McCarthy, 2005), and practices that provide support and entry ramps, such as those related to leveraging undergraduate research (Carpi, Ronan, Falconer, & Lents, 2017; Pandya, Henderson, Anthes, & Johnson, 2007; Wechsler et al., 2005), engaging in mentoring (Pyrtle, Powell, & Williamson-Whitney, 2007; Serpa, White, & Pavlis, 2007), using multicontextual and culturally responsive approaches (Bang & Medin, 2010; Chávez & Longerbeam, 2016; Ibarra, 1999; Semken & Morgan, 1997), and increasing course structure (Eddy & Hogan, 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011). Additional inclusive instructional practices relate to the affective domain with regard to how learning is influenced by emotions, attitudes, and biases (Krathwohl, Bloom, & Masia, 1964). Examples include increasing students' sense of belonging (Strayhorn, 2012; Walton & Cohen, 2007), avoiding microaggressions (Harrison & Tanner, 2018), addressing implicit biases (Grunspan et al., 2016), and minimizing stereotype threat (Steele, 1997). Within the context of these many beneficial practices, limited documentation exists as to the frequency with which they are employed by science faculty.

To document the frequency with which some of these practices are used by geoscience faculty, we analyzed items from the 2016 National Survey of Geoscience Faculty that correspond with inclusive practices as enumerated in the science education and social science literature. Selected items relate to four broad groups associated with inclusive teaching practices that are derived from the factor analysis results presented later in the article: geoscientist representations, curricular choices, learning strategies, and career pathways (see Table 1).

Geoscientist representations—for example, in images and stories—can be significant to developing students' science identity and increasing their sense of belonging, perhaps especially for students who have infrequently seen themselves represented in the geosciences or other sciences (King & Domin, 2007; Rosser, 1993; Schinske, Perkins, Snyder, & Wyer, 2016; Stout, Dasgupta, Hunsinger, & McManus, 2011).

The curricular choices faculty make to incorporate content and issues of societal relevance can positively impact students' attraction to and connection with the geosciences and environmental sciences (Pandya, 2012; Pelch & McConnell, 2017). Examples of content and issues of societal relevance include addressing environmental justice issues (Darby & Atchison, 2014; Villalobos, 2016), emphasizing connections between science and society (McConnell, 2018; Pelch & McConnell, 2017), and incorporating service learning projects (National Research Council, 2012; 2000).

Intentional incorporation of learning strategies that promote metacognition (Cook, Kennedy, & McGuire, 2013; Dang, Chiang, Brown, & McDonald, 2018; Mynlieff, Manogaran, St Maurice, & Eddinger, 2014) and study skills (Sebesta & Speth, 2017) have been shown to improve learning for many students in science courses; and some strategies, such as an increase in course structure, have been found to close the achievement gap for black students and first-generation students (Eddy & Hogan, 2014).

Practices related to providing information about careers, as well as support for career exploration and the job search, are grouped together under career pathways. Describing a range of career opportunities (Huntoon & Lane, 2007), discussing career plans (Lundberg, Kim, Andrade, & Bahner, 2018; MacLachlan, 2006), and promoting internships and research opportunities (Maton & Hrabowski, 2004) have been shown to positively influence historically underrepresented students' interest in STEM (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009).

Although the frequency with which science faculty employ various practices generally has not been well documented, the incorporation of active learning is one practice that has been documented for prior iterations of the National Survey of Geoscience Faculty (Manduca et al., 2017). As such, we sought to explore whether the use of active learning approaches might be a predictor for geoscience faculty incorporating other practices that foster inclusive learning environments. Active learning is a student-centered approach that involves students interacting with the material being learned and often with each other, as well; it has been shown to increase motivation for diverse student populations (Huguet et al., 2019) and improve learning (Freeman et al., 2014; McConnell et al., 2017). Examples of such approaches reported in the survey include small-group and class discussions, in-class exercises, and think-pair-share opportunities (Manduca et al., 2017). Active learning approaches are seen by some to be an effective inclusive teaching strategy, because they tend to create learning environments in which more students feel comfortable taking risks (Johnson & Johnson, 1999), they have the potential to reduce the achievement gaps observed between populations of students (Beichner et al., 2007; Haak et al., 2011; Roberts et al., 2018), and they often encourage the active participation of many students "not just those who are already engaged" (Tanner, 2013, p. 322).

Given the importance of undergraduate geoscience instruction for attracting and developing future geoscientists, we sought to document not only faculty's use of active learning techniques but also additional practices relevant to developing a diverse and inclusive geoscience community. This documentation of current practices may be used to suggest new initiatives and will serve as a benchmark for future progress. Frequency charts, exploratory factor analysis, statistical tests, and modeling are applied to categorize the practices faculty self-report and to determine predictors for the variances in the reported practices. The large number of respondents to the 2016 National Survey of Geoscience Faculty ($n = 2{,}615$; approximately 25% of geoscience faculty in the United States) allows for robust conclusions about the practices faculty currently employ.

Research methods

The research questions we sought to address were these: (a) What is the extent to which college and university faculty report using educational practices that contribute to creating and fostering more inclusive learning environments with the potential to engage a more diverse population of students? (b) How might these practices be categorized? (c) How does use of these practices differ across the variables of teaching style, communication with colleagues, years of teaching experience, faculty type, institution type, class size, and course type (introductory or major)?

Survey

The 2016 National Geoscience Faculty Survey was developed by leadership of On the Cutting Edge, InTeGrate, and SAGE 2YC, with support from their grants from the NSF, and with expertise from Greenseid Consulting Group, LLC, and Professional Data Analysts, Inc. The survey was previously administered three times—in 2004, 2009, and 2012—by On the Cutting Edge, an NSF-funded professional development program sponsored by the National Association of Geoscience Teachers. The surveys asked about "teaching practices as well as levels of engagement in education research, scientific research, and professional development related to teaching" (Manduca et al., 2017). Each iteration of the survey preserved core items from previous surveys, while adding, deleting, and revising items to collect information to address new areas of interest. For example, items related to course goals were added to the 2009 survey, sustainability and using a systems approach to the 2012 survey, and supporting students' career pathways and using images and stories of geoscientists to the 2016 survey. The items for each of the four iterations of the survey are posted at https://serc.carleton.edu/NAGTWorkshops/about/evaluation.html.

The methodologies of the surveys have been described in prior publications (Macdonald et al., 2005; Manduca et al., 2017). In all four survey administrations, after determining if respondents taught any undergraduate courses, respondents were asked whether they taught introductory courses, majors courses, or both introductory and majors courses. The answers to these questions served as a branch point that divided respondents into three groups. Respondents who taught only introductory courses were presented with questions about the most recent introductory course they had taught. Respondents who taught only majors courses were presented with questions about the most recent majors course they had taught. Respondents who indicated that they taught both introductory and majors courses were assigned to answer questions either about the most recent introductory or the most recent majors course they had taught.

Participants

The 2016 survey was sent by email to 10,910 individual geoscience faculty members in the United States. A total of 2,615 faculty completed one or more questions to the survey. Excluding 18 retirees to whom the survey was sent, the survey response rate was 24% (2,615 out of 10,892 eligible contacts). Excluding these retirees and survey contacts who had invalid or bad email addresses (1,296), the survey response rate was 27.3% (2,615 out of 9,596). Out of the 2,615 respondents, 2,581 indicated they were at U.S. institutions, with at least one respondent from each state, Washington D.C., and Puerto Rico. Twenty-two percent of respondents had seven or fewer years of teaching experience, 27% had eight to 15 years of experience, and 50% had more than 16 years of experience teaching at the undergraduate level. Of the respondents, 15% were assistant professors, 21% associate professors, 42% full professors, 8% instructors, 6% adjunct professors, and 8% other respondents. Sixty percent taught at doctoral degree-granting institutions, 18% at master's degree-granting institutions, 9% at bachelor's degree-granting institutions, and 13% at associate degree-granting institutions.

Analysis

Twenty-six items were selected from the 2016 National Geoscience Faculty Survey based on practices that correspond to those that have been described in the existing literature as broadening participation and fostering inclusive and equitable learning environments. The three authors independently assessed the available items, selected ones that mapped to inclusive instructional practices, and then engaged as a group in discussions about each of their selections. Once consensus was achieved, selected survey items were included in the research study. The 26 items initially examined in this study are listed in Table 1; the full set of survey items is listed at https://serc.carleton.edu/NAGTWorkshops/about/evaluation.html.

The seven predictor variables for statistical testing were selected, in part, based on results from Manduca and colleagues (2017; Table 2). In our analysis, we employ two variables based on categories established in previous iterations of the survey: teaching style and faculty type. For teaching style, faculty were categorized into three groups "on the basis of decreasing levels of student engagement" (Manduca et al., 2017, p. 3): traditional lecture, active lecture, and active learning (Manduca et al., 2017). For faculty type, Manduca et al. (2017) used cluster analysis to categorize faculty into education-focused faculty, who invested in activities "related to improving teaching" (p. 3); geoscience research-focused faculty, who invested in "geoscience research activity" (p. 3); and teaching faculty, who were less likely to invest in activities related to improving teaching or to geoscience research.

Descriptive statistics were used to examine the frequency of responses on raw survey data. Frequency plots include all 26 items selected for the study. The SPSS version 25 software package was used for all statistical analyses and tests (statistical tests and terminology are explained in Supplementary Material A).

Factor analysis was used as a data-reduction technique to interpret the large dataset and to group related survey items. Variables were extracted through the use of a Varimax rotation and Kaiser normalization. Four of the originally selected 26 items were removed from the initial factor analysis due to weak factor loadings ($<.3$). The factor analysis was rerun with the remaining 22 items (see Table 3). Factors were selected based on parsimony: finding the fewest possible variables to represent the most variance of

Table 1. Original 26 survey items for factor analysis organized by factors (in bold).

Item code	Survey question	Response options
	Geoscientist representations	
Q17a*	In your course, please indicate how frequently you include photos and stories of individual geoscientists and their work?	1 Never, 2 Sometimes, 3 Frequently
Q17b*	Considering the images and stories of individual geoscientists you included in your course, what percentage of the geoscientists included are female?	0 Never, 1 Less than 30%, 2 Between 30% and 70%, 3 More than 70%
Q17c*	Considering the images and stories of individual geoscientists you included in your course, what percentage of the geoscientists included are people of color?	0 Never 1 Less than 30% 2 Between 30% and 70% 3 More than 70%
	Curricular choices	
Q18.2	In your most recent course, did your students address a problem of national or global interest?	0 Not selected, 1 Yes
Q18.3	In your most recent course, did your students work on a problem of interest to the local community?	0 Not selected, 1 Yes
Q18.6*	In your most recent course, did your students address environmental justice issues?	0 Not selected, 1 Yes
Q21.7*	Do you ask students in your class to make explicit connections from course content to their lives?	0 Not selected, 1 Yes
Q25.6	Which of the following content changes did you make in your course in the past two years? Increased emphasis on environmental issues.	0 Not selected, 1 Yes
Q25.7	Which of the following content changes did you make in your course in the past two years? Added content linking geoscience to societal issues.	0 Not selected, 1 Yes
Q35.4	Do you frequently communicate with your colleagues about the following? How well we are preparing students for life on a finite planet.	0 Not selected, 1 Yes
	Learning strategies	
Q21.1	Do you ask students in your class to reflect on the effectiveness of their study skills or time management strategies?	0 Not selected, 1 Yes
Q21.3	Do you ask students in your class to reflect on their success in learning a concept or skill during the course?	0 Not selected, 1 Yes
Q21.4	Do you ask students in your class to reflect on the strategies they used to solve a problem as part of the course?	0 Not selected, 1 Yes
Q21.5*	Do you ask students in your class to reflect on effective study strategies?	0 Not selected, 1 Yes
Q21.6*	Do you ask students in your class to form student study groups?	0 Not selected, 1 Yes
Q22.9*	In your most recent course, which of the following did you do? Develop strategies to support less successful groups of students based on data from the course.	0 Not selected, 1 Yes
	Career pathways	
Q22.1*	In your most recent course, which of the following did you do? Include information about geoscience and STEM careers and career pathways in your course.	0 Not selected, 1 Yes
Q22.3*	In your most recent course, which of the following did you do? Highlight alumni from your program who are working in geoscience.	0 Not selected, 1 Yes
Q22.5*	In your most recent course, which of the following did you do? Promote internship and research opportunities to all students.	0 Not selected, 1 Yes
Q22.6*	In your most recent course, which of the following did you do?: Publicize job search and career resources available on your campus	0 Not selected, 1 Yes
Q22.7*	In your most recent course, which of the following did you do? Help students with applications for internships, research experiences, and/ or jobs.	0 Not selected, 1 Yes
Q22.8*	In your most recent course, which of the following did you do? Make explicit connections between skills needed in the geoscience workforce and course assignments and outcomes.	0 Not selected, 1 Yes
	Questions that had weak loading (< .3)	
Q18.5	In your most recent course, did your students work on a community-inspired research or service project?	0 Not selected, 1 Yes
Q19.13*	In your most recent course, how often did your students work as part of a team?	1 Never, 2 Once or twice, 3 Three or more times
Q35.3	Do you frequently communicate with your colleagues about the following? How well we are preparing students for careers?	0 Not selected, 1 Yes
Q22.4*	In your most recent course, which of the following did you do? Give an assignment in which students explore geoscience careers.	0 Not selected, 1 Yes

Note. * indicates question new to 2016 survey.

the dataset, using factors with eigenvalues greater than 1, and detecting dominate factors with scree plots.

Cronbach's alpha testing was used to determine reliability of the items in each factor, which were then normalized to a scale of 0 to 1 and summed to generate a total score for each factor. This score was then used as the dependent (outcome) variable in univariate general modeling statistical analysis, in which the seven variables

Table 2. List of predictor variables.

Variable	Survey description	Response options
Teaching style	Designated by cluster analysis (Manduca et al., 2017)	0 Traditional lecture only, 1 Active lecture, 2 Active learning
Communication with colleagues	Do you frequently communicate with your colleagues about the following? How to meet the needs of groups that traditionally have been underserved and/or underrepresented.	0 Not selected, 1 Yes
Experience	Years of teaching experience	1 New: 7 years or less, 2 Mid-level: 8 to 15 years, 3 Senior: 16+ years
Faculty type	designated by cluster analysis (Manduca et al., 2017)	1 Education focused, 2 Geoscience focused, 3 Teaching faculty
Institution type	2010 Carnegie classification	1 Associate's, 2 Baccalaureate, 3 Master's, 4 Research and/or doctoral
Course type	Introductory or major course	1 Intro, 2 Major
Class size	How many students were in your most recent [intro/major] course?	1 Small: 30 or less, 2 Medium: 31–80, 3 Large: Greater than 80

Table 3. Factor loadings for the 22 items that had acceptable loadings (>.3).

Item	Geoscientist representations (10.04%)	Curricular choices (11.17%)	Learning strategies (10.75%)	Career pathways (10.78%)
Q17a	.812	.112	.056	.117
Q17b	.838	.114	.062	.090
Q17c	.817	.130	.069	.092
Q18.2	−.014	.637	.042	.030
Q18.3	.101	.464	−.031	.170
Q18.6	.082	.684	.019	−.069
Q21.1	.044	.121	.759	−.011
Q21.3	.013	.083	.589	.166
Q21.4	−.026	.062	.520	.219
Q21.5	.061	.094	.736	−.073
Q21.6	.082	.072	.438	.099
Q21.7	.148	.485	.203	.016
Q22.1	.227	.167	.222	.427
Q22.3	.227	−.027	.103	.474
Q22.5	.040	.081	.091	.727
Q22.6	−.009	.139	−.003	.683
Q22.7	.087	.072	.087	.666
Q22.8	−.041	.013	.248	.545
Q22.9	.050	.041	.467	.190
Q25.6	.062	.638	.041	.031
Q25.7	.127	.650	.028	.082
Q35.4	.074	.392	.135	.142

Note. Total variance shown in parentheses. Organized by item number. Shading represents factor that item loaded most strongly.

Table 4. Univariate model output for geoscientist representations.

Variable	Degrees of freedom	Type III sum of square	Mean square	F	Sig. ($p < .05$)
Corrected model	11	295.6	26.88	9.914	**.000**
Intercept	1	1606	1606	592.6	**.000**
Class size	1	54.18	54.18	19.99	**.000**
Years of teaching experience	1	2.204	2.204	.8130	.367
Communication with colleagues	1	64.07	64.07	23.63	**.000**
Faculty type	2	39.22	19.61	7.234	**.001**
Intro or major course	1	5.689	5.689	2.099	.148
Institution type	3	44.31	14.77	5.448	**.001**
Teaching style	2	3.395	1.698	.6260	.535
Error	1805	4893	2.711		
Corrected total	1816	5188			
Adj. R^2			.051		

of interest were further examined for their ability to predict the outcome variables (see Tables 4–7).

Variables of interest were considered continuous. However, ordinal data were examined using contrasts and reference variables in the univariate modeling process based on theoretical assignments. ANOVA tests were then deployed to examine mean score differences among predictor variables (see Table 8). The ANOVA results were also used to verify model performance by comparing results to the model-reported contrasts; ANOVA results are reported herein for simplicity. Normality of the dataset was satisfied. Homogeneity of variance was not assumed and the nonparametric Tamhane's interactions test was used as a more conservative interactions test. Radar graphs were constructed using the mean scores from Table 8 normalized to a common score range of 0 to 100.

Table 5. Univariate model output for curricular choices.

Variable	Degrees of freedom	Type III sum of square	Mean square	F	Sig. ($p < .05$)
Corrected model	11	792.0	72.00	23.07	**.000**
Intercept	1	489.8	489.8	157.0	**.000**
Class size	1	32.30	32.30	10.35	**.001**
Years of teaching experience	1	14.94	14.94	4.789	**.029**
Communication with colleagues	2	216.5	216.5	69.37	**.000**
Faculty type	1	35.19	17.60	5.639	**.004**
Intro or major course	1	153.1	153.1	49.07	.525
Institution type	3	6.971	2.324	.7450	.525
Teaching style	2	62.44	31.22	10.00	**.000**
Error	1809	5645	3.121		
Corrected total	1820	6437			
Adj. R^2			.118		

Table 6. Univariate model output for learning strategies.

Variable	Degrees of freedom	Type III sum of square	Mean square	F	Sig. ($p < .05$)
Corrected model	11	694.7	63.15	23.48	**.000**
Intercept	1	492.7	492.7	183.2	**.000**
Class size	1	23.81	23.81	8.852	**.003**
Years of teaching experience	1	2.416	2.416	.898	.343
Communication with colleagues	2	145.7	145.7	54.18	**.000**
Faculty type	1	86.91	43.45	16.16	**.000**
Intro or major course	1	6.83	6.826	2.538	.111
Institution type	3	159.9	53.29	19.81	**.000**
Teaching style	2	102.1	51.05	18.98	**.000**
Error	1809	4866	2.690		
Corrected total	1820	5560			
Adj. R^2			.120		

Table 7. Univariate model output for career pathways.

Variable	Degrees of freedom	Type III sum of square	Mean square	F	Sig. ($p < .05$)
Corrected model	11	799.1	72.64	25.55	**.000**
Intercept	1	465.1	465.1	162.6	**.000**
Class size	1	13.85	13.85	4.871	**.027**
Years of teaching experience	1	27.46	27.46	9.656	**.002**
Communication with colleagues	2	218.5	218.53	76.86	**.000**
Faculty type	1	46.65	23.32	8.203	**.000**
Intro or major course	1	293.2	293.2	103.1	**.000**
Institution type	3	27.58	9.193	3.233	**.022**
Teaching style	2	85.97	42.99	15.12	**.000**
Error	1809	5143	2.843		
Corrected total	1820	18208			
Adj. R^2			.129		

Survey results

Descriptive statistics were used to examine the frequency of faculty responses to items selected from the survey for this study. The items were grouped by geoscientist representations, curricular choices, learning strategies, and career pathways for the frequency charts (see Figures 1, 2, 3, and 4) and the description of results (below).

Frequency of responses

Geoscientist representations

Eighty-four percent of faculty respondents reported that they included "photos and stories of individual geoscientists and their work" (Item 17a, Table 1). The frequency with which they include these photos and stories during a course varies from once or twice (23%), several times (39%), weekly (11%), or nearly every class (11%; see Figure 1a). Fifty-two percent of faculty respondents report that less than 30% of the "geoscientists included are female," and 48% of faculty report that more than 30% are female (see Item 17b in Table 1 and Figure 1b). Eighty-two percent of faculty respondents report that less than 10% of the "geoscientists included are people of color" (Question 17c, Table 1 and Figure 1c).

Curricular choices

Faculty were asked to select items to respond to a variety of questions related to what students do, or are asked to do, in a course. In response to the question, "Did you ask students in your class to … ?" 71% of

Table 8. Means, standard deviations, and ANOVA results for each factor.

	Sum of geoscience representation mean	Sum of curricular choices mean	Sum of learning strategies mean	Sum of career pathways mean
Score range	0–9	0–7	0–6	0–6
Teaching style				
Traditional lecture	4.06 (1.68)	**2.09 (1.81)**	**1.48 (1.55)**	**1.89 (1.68)**
Active lecture	4.27 (1.66)	2.63 (1.81)	2.09 (1.69)	2.58 (1.80)
Active learning	4.37 (1.73)	2.84 (1.87)	2.49 (1.76)	2.67 (1.83)
N	2018	1978	1980	1980
F - statistic	3.591	16.14	37.66	18.05
Sig. ($p < .05$)	.028	**.000**	**.000**	**.000**
Communication with colleagues				
Not selected	4.10 (1.74)	2.06 (1.82)	1.99 (1.66)	2.28 (1.74)
Yes	**4.62 (1.70)**	**2.77 (2.07)**	**2.73 (1.82)**	**3.05 (1.86)**
N	2021	2445	2039	2039
F - statistic	41.34	77.87	87.36	86.71
Sig. ($p < .05$)	**.000**	**.000**	**.000**	**.000**
Years of teaching experience				
7 or less	4.32 (1.76)	**2.01 (1.84)**	2.26 (1.74)	2.40 (1.75)
8–15	4.29 (1.79	2.48 (1.95)	2.32 (1.82)	2.43 (1.87)
16+	4.25 (1.74)	2.34 (1.97)	2.17 (1.73)	2.61 (1.83)
N	2119	2489	2092	2092
F - statistic	.292	9.616	1.503	3.052
Sig. ($p < .05$)	.746	**.000**	.223	.047
Faculty type				
Education focused	**4.74 (1.52)**	**3.23 (1.93)**	**2.91 (1.78)**	**3.00 (1.78)**
Geoscience focused	4.25 (1.78)	2.63 (1.89)	2.06 (1.68)	2.59 (1.84)
Teaching focused	4.19 (1.68)	2.74 (1.82)	2.22 (1.72)	2.39 (1.76)
N	1997	2010	2010	2010
F - statistic	14.42	15.30	31.63	15.22
Sig. ($p < .05$)	**.000**	**.000**	**.000**	**.000**
Institution Type				
Associate	**4.69 (1.50)**	2.85 (1.94)$^{+}$	**3.06 (1.83)**	2.42 (1.78)
Bachelor's	4.25 (1.82)	2.63 (1.95)*	2.13 (1.59)	2.91 (1.77)$^{+}$
Master's	4.28 (1.79)	2.49 (1.90)	2.23 (1.74)	2.55 (1.82)
Doctoral	4.17 (1.76)	2.07 (1.93)$^{+*}$	2.03 (1.72)	2.45 (1.85)$^{+}$
N	2015	2365	1989	1989
F - statistic	6.760	18.26	26.44	4.058
Sig. ($p < .05$)	**.000**	**.000**	**.000**	**.007**
Class size				
<30	**4.16 (1.75)**	**2.50 (1.86)**	2.17 (1.72)	2.62 (1.84)
31–80	4.49 (1.65)	2.97 (1.84)	**2.54 (1.81)**	2.56 (1.80)
81+	4.74 (1.56)	3.21 (1.83)	2.13 (1.69)	**2.14 (1.71)**
N	2096	2062	2064	2064
F - statistic	17.08	23.21	9.337	7.844
Sig. ($p < .05$)	**.000**	**.000**	**.000**	**.000**
Course type				
Intro	**4.50 (1.61)**	**3.09 (1.84)**	2.33 (1.77)	2.13 (1.71)
Major	4.12 (1.81)	2.28 (1.84)	2.17 (1.72)	**2.91 (1.83)**
N	2105	2085	2074	2074
F - statistic	55.56	279.25	15.84	54.88
Sig. ($p < .05$)	**.000**	**.000**	.209	**.000**

Note. Standard deviations are included in parentheses. Bold = variable is significantly different than all others in group ($p < .01$). $^{+}$ or * = indicates variables are significantly ($p < .01$) different from one other variable in group but not all in group.

faculty respondents selected "make explicit connections from course content to their lives" (Table 1 and Figure 2). In response to the question, "In your most recent course, did your students … ?" faculty respondents selected items that indicated that their students "address a problem of national or global interest" (62%), "work on a problem of interest to the local community" (30%), "address environmental justice issues" (25%), and "work on a community-inspired research or service project" (8%; see Table 1 and Figure 2). Note that for these questions, and the ones in the following paragraph, faculty could select more than one response.

Faculty who responded that they had changed the content of their course also were asked questions related to these changes and to their communication with colleagues. In response to the question, "Which of the following content changes did you make in your course in the past two years?" 40% of faculty respondents selected, "Added content linking geoscience to societal issues," and 35% selected, "Increased emphasis on environmental issues" (Table 1 and Figure 2). Thirty-eight percent indicated that they "frequently communicate with … colleagues about … how well we are preparing students for life on a finite planet" (Table 1 and Figure 2).

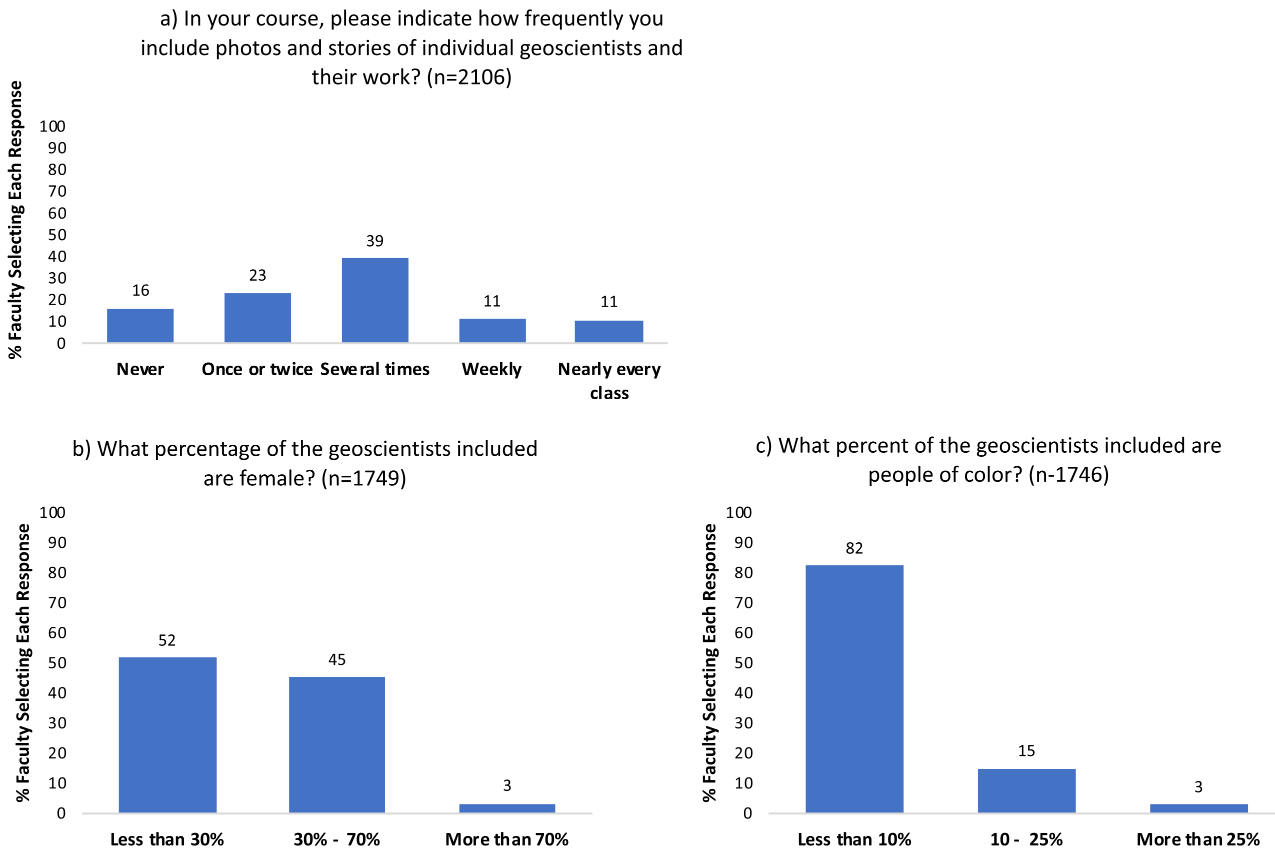

Figure 1. Frequency charts for survey questions loading on the geoscientist representations factor (Q17a, b, and c). Percentage of faculty respondents selecting each response is noted above the bars.

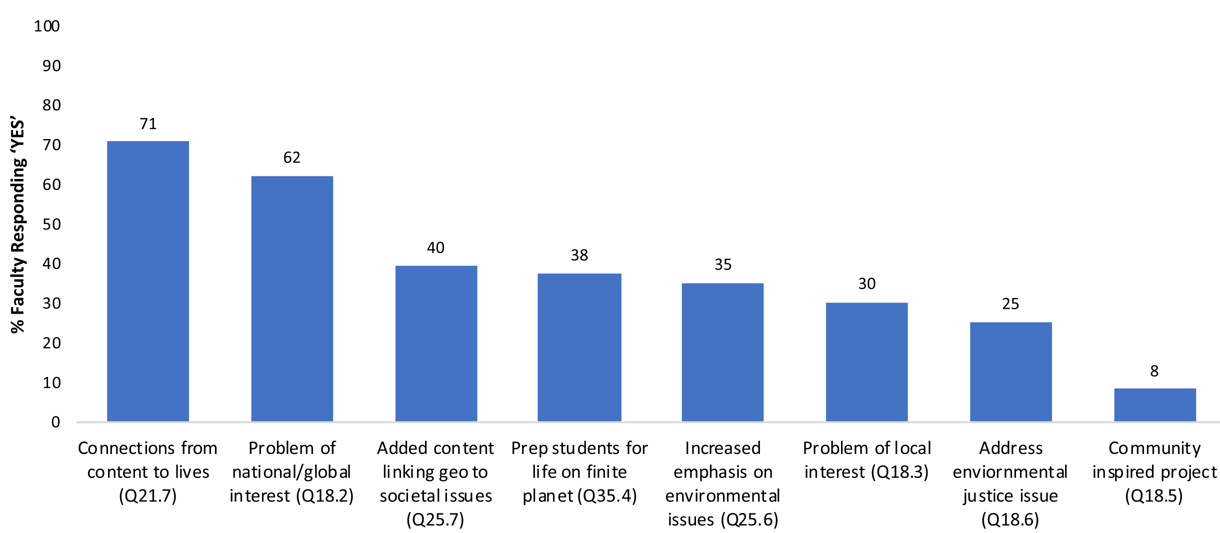

Figure 2. Frequency chart for survey questions loading on the curricular choices factor. Percentage of faculty respondents selecting "yes" for each question is noted above the bars.

Learning strategies

Faculty respondents were asked to select one or more items in response to the question, "Do you ask students in your class to … ?" Respondents selected items that indicated they ask students to "reflect on their success in learning a concept or skill during the course" (47%), "form student study groups" (45%), "reflect on effective study strategies" (43%), "reflect on the strategies they used to solve a problem as part of the course" (42%), and "reflect on the effectiveness of their study skills or time management strategies" (41%; see Table 1 and Figure 3). In response to a question asking what faculty themselves did in their most recent course, 21% indicated they "develop[ed]

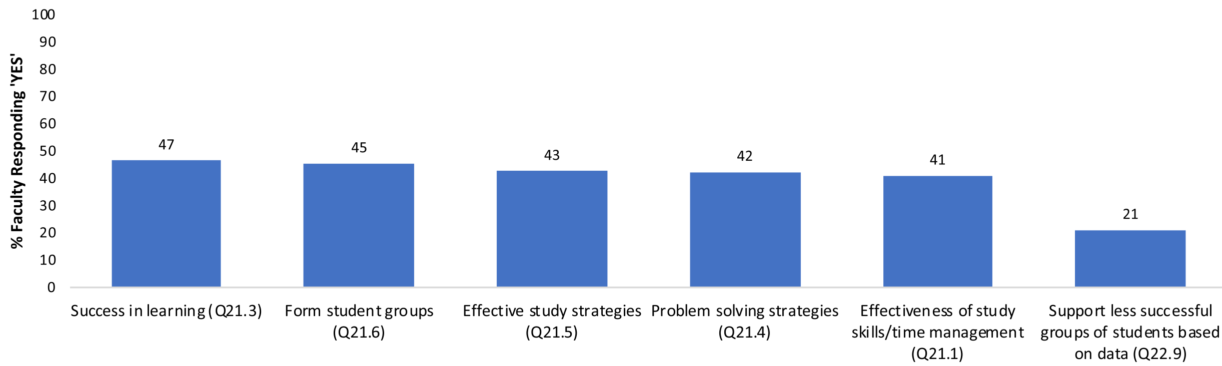

Figure 3. Frequency chart for survey questions loading on the learning strategies factor. Percentage of faculty respondents selecting "yes" for each question is noted above the bars.

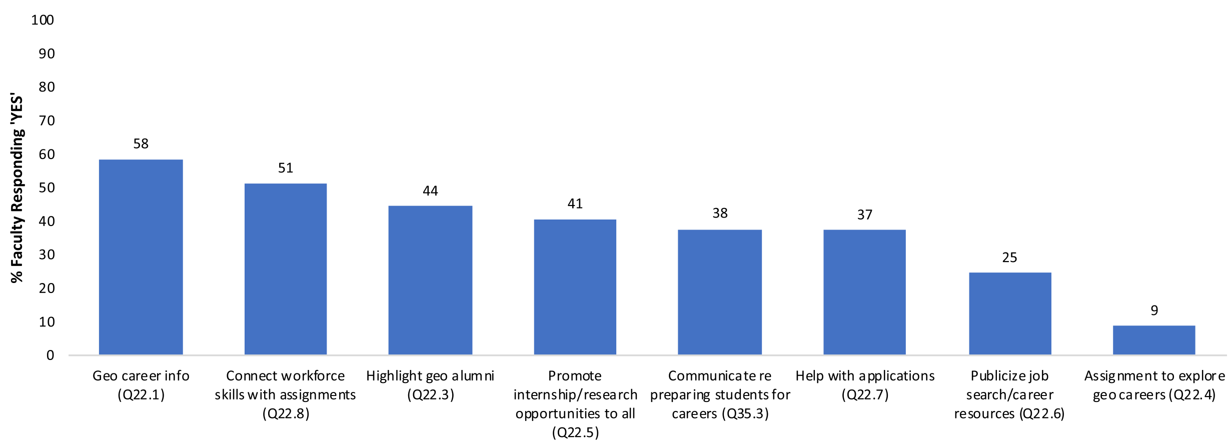

Figure 4. Frequency chart for survey questions loading on the career pathways factor. Percentage of faculty respondents selecting "yes" for each question is noted above the bars ($n = 2056$).

Table 9. Summary of predictors for each outcome variables.

Variable	Geoscience representations	Curricular choices	Learning strategies	Career pathways
Teaching style	No	Yes**	Yes**	Yes**
Predictors:		Active learning		
Communicate with colleagues	Yes**	Yes**	Yes**	Yes**
Predictors:	Faculty communicating how to meet needs of underserved/underrepresented students			
Years of teaching experience	No	Yes	No	Yes*
Predictors:		More experience		More experience
Faculty type	Yes**	Yes*	Yes**	Yes**
Predictors:	Education-focused faculty			
Institution type	Yes**	No	Yes**	Yes
Predictors:	Associate		Associate	Baccalaureate
Course type	No	Yes**	No	Yes**
Predictors:		Intro courses		Major courses
Class size	Yes**	Yes**	Yes*	Yes
Predictors:	Large courses		Medium courses	Small courses

Note. Yes = variable was a significant predictor ($p < .05$). No = variable was not a significant predictor ($p > .05$). *was significant predictor at .01 level; **was significant predict at .001 level. Interpretation of predictors based on regression and ANOVA modeling results.

strategies to support less successful groups of students based on data from the course" (Table 1 and Figure 3).

Career pathways

Faculty respondents were asked to select one or more items in response to the question, "In your most recent course, which of the following did you do?" Respondents selected items that indicated they "include information about geoscience and STEM careers and career pathways" (58%), "make explicit connections between skills needed in the geoscience workforce and course assignments and outcomes (51%), "highlight alumni … who are working in geo-science" (44%), "promote internship and research opportunities to all students" (41%), "help students with applications" (37%), "publicize job search and career resources available" (25%), and "give an

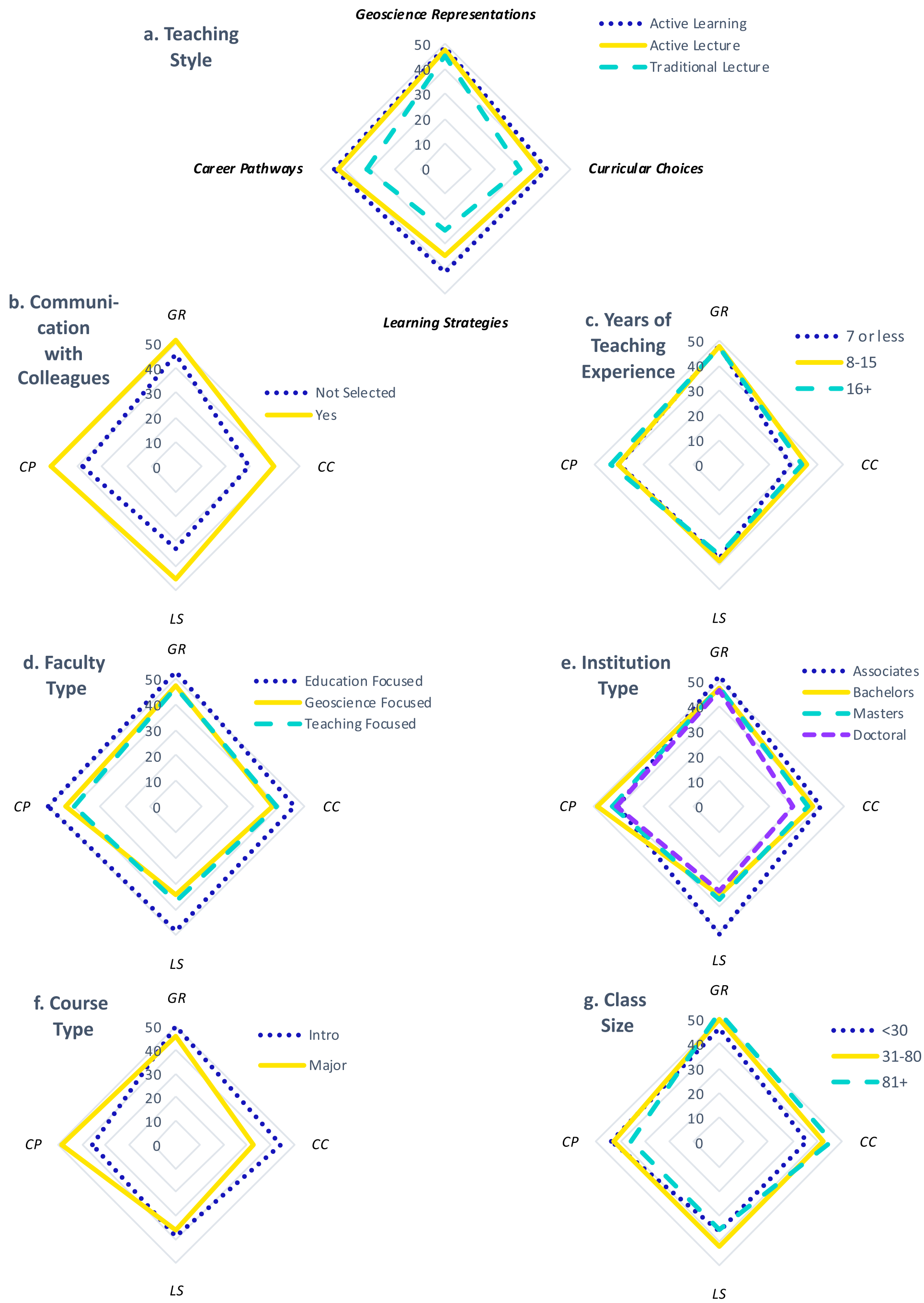

Figure 5. Radar graphs were constructed for the predictor variables using the mean scores from Table 5 normalized to a common score range of 0–100. Note that plots shown are constructed with axes from 0 (center) up to 50 (outer), given that normalized scores were at or below 50. The four variables plotted are the same on all graphs. The four corners correspond to the four factors: geoscience representations (GR, top), curricular choices (CC, right), learning strategies (LS, bottom), and career pathways (CP, left). Predictor variables plot further out on the radar graphs when they more strongly correspond with reported use of practices that support inclusive learning environments.

For example, in the Figure 5a radar graph, the three categories of teaching style—active learning, active lecture, and traditional lecture—are plotted against the four factors. Overall, the larger the area outlined, the more faculty with that teaching style report using practices that are connected with supporting diversity and inclusion; such that we can interpret that these practices were generally more frequently reported for courses with active learning than for those dominated by traditional lecture. In addition, we can look at how each of the teaching styles plots with regards to the four factors. The three teaching styles plot close together at the apex of the graph, so we can interpret that there is relatively little difference across the teaching style categories for use of geoscience representation. In contrast, at the bottom of the graph, active learning plots furthest out on the radar graph; thus, we can interpret that active learning is more of a predictor for incorporation of learning strategies than active lecture or traditional lecture.

assignment in which students explore geoscience careers" (9%; see Table 1 and Figure 4).

Factor analysis

A four-factor solution was used based on parsimony and eigenvalues greater than 1. Twenty-two of the 26 survey items (Table 1) formed four components with loading scores > .3: geoscientist representations, curricular choices, learning strategies, and career pathways (Table 3). In total, these four factors represented 43% of the total variance. Three items loaded on the geoscientist representations factor, seven on the curricular choices factor; six on the learning strategies factor, and six on career pathways. Once the factor groups were identified, reliability testing was conducted using Cronbach's alpha. Reliability analysis of the four factors indicated moderate Cronbach's alpha scores of .818 for geoscientist representations, .675 for curricular choices, .591 for learning strategies, and .687 for career pathways. These reliability scores were considered acceptable based on previous studies that show that a Cronbach's alpha score between .5 and .6 is acceptable for exploratory research (Ravid, 1994).

Univariate modeling and analysis of variance

The univariate linear modeling showed multiple significant predictors for each of the four factors (Table 4–7). Four variables of interest were significant predictors for the geoscientist representations factor, five for the curricular choices factor, five for the learning strategies factor, and seven for the career pathways factor. The R^2 values were lowest for the geoscience representations ($r^2 = .051$), showing the model did not fit this factor as well as the other factors, which all had r^2 values ranging from .118 to .129, indicating a stronger model fit for these factors (Tables 4–7). Tests of contrasts conducted during univariate modeling indicated that several groups were statistically different within the same variable for each factor. Tests of contrasts results were aligned with ANOVA results, verifying model performance; ANOVA results revealed several significant differences among variables of interest (Table 8). For a simplified summary of these results, see Table 9 and Figure 5, which show the predictor variables for each outcome variable and factor. The most notable differences among the variables of interest included the following points.

1. In terms of teaching style (Manduca et al., 2017), instructors with a traditional lecture teaching style had statistically significant lower means in three of the four factors than those with active learning or active lecture teaching styles (Table 8 and Figure 5a).
2. Instructors who reported that they frequently communicate (Q35.5) with colleagues about "how to meet the needs of groups that traditionally have been underserved and/or underrepresented" had statistically significant higher means for all four factors than those who did not report communicating with other faculty (Table 8 and Figure 5b).
3. Faculty experience was not a significant variable. The only occurrence of statistical significance was observed among less experienced faculty, who had a lower mean than more experienced faculty in the curricular choices factor (Table 8 and Figure 5c).
4. In terms of faculty type (Manduca et al., 2017), education-focused faculty had statistically significant higher means for all four factors than the geoscience research-focused faculty and the teaching faculty (Table 8 and Figure 5d).
5. Institution type varied in regard to where statistical differences between means were observed (Table 8 and Figure 5e). Associate degree-granting institutions had higher means than all other institution types for learning strategies and geoscience representation factors. Doctoral degree-granting institutions had lower means than associate and bachelor's degree-granting institutions for curricular choices. Bachelor's institutions had higher means than doctoral degree-granting institutions for the career pathways factor.
6. Class size showed significant differences between means for all four factors, but the statistically different group varied (Table 8 and Figure 5f). For geoscience representations and curricular choices, small class sizes showed lower means than all other class sizes. For learning strategies, the medium-sized classes showed significantly higher means than all other class sizes. For career pathways, large class sizes showed lower means than all other class sizes.
7. Significant differences between introductory and major courses were also observed, with introductory courses having higher means in the geoscience representation and curricular choices factors, and the courses for majors displaying higher means in the learning strategies and career pathways factors (Table 8 and Figure 5g).

Discussion

In the discussion, we first focus on reported use of practices by geoscience faculty that correspond with practices described in the literature to broaden participation and foster inclusive and equitable learning environments for diverse learners. We then discuss the ways in which these practices differ across the variables of teaching style, communication with colleagues, years of teaching experience, faculty type, institution type, class size, and course type (introductory or major).

Faculty's reported use of practices

This discussion is organized by the four groups of items as determined through the factor analysis: geoscientist representations, curricular choices, learning strategies, and career pathways.

Geoscientist representations

Although the majority of faculty respondents reported including photos and stories of individual geoscientists in their course, only 22% reported including them at least weekly. More frequent and repeated exposure to geoscientists and their work may be needed to better communicate to students what geoscientists do and to help students better develop a (geo)science identity. The percentage of geoscientists included who are female or people of color may be roughly in line with the current percentages for geoscientists (Sidder, 2017), but they are far lower than the percentages of undergraduate students and the percentages in the U.S. population. For example, 70% of undergraduate students are women and "members of minority groups" (Olson & Riordan, 2012), and yet slightly over half of faculty reported that less than 30% of the "geoscientists included are female," and most faculty reported less than 10% of the "geoscientists included are people of color." Increasing the percentage would be a step toward increasing students' sense of belonging, helping students to develop a science identity, and shifting stereotypes of (geo)scientists (Schinske et al., 2016). Furthermore, when choosing which geoscientists to include in images and stories, faculty may want to consider the demographics of their region and their student population.

Curricular choices

Although the majority of faculty reported including connections of course content to their students' lives and incorporating problems of global/national interest, less than a third include problems of local interest or address environmental justice issues (Figure 2). An increased emphasis on socioscientific issues has been demonstrated to positively influence students' attitudes about science (Pelch & McConnell, 2017). Furthermore, Pandya (2012) suggested that citizen science has the "potential to broaden participation not only in citizen science but also in science more generally" (p. 317). Thus, increased emphasis on citizen science (such as through working on problems of local interest in courses) and on socioscientific issues (such as environmental justice) may attract more students, and a greater diversity of students, to the geosciences. We are encouraged that nearly 40% of faculty responding to the survey reported recently adding content linking geoscience to societal issues (this study); this result may reflect the recent emphasis on these topics by the NSF-funded InTeGrate program (Pelch & McConnell, 2017).

Learning strategies

Nearly half of faculty reported using one or more research-based strategies that support student learning including student self-reflection and forming study groups (Figure 3). Self-reflection and other metacognitive strategies have been shown to improve students "self-evaluation skills" and "may preferentially help lower-performing students" even over the course of a single semester (Dang et al., 2018, p. 8). We look forward to future research that may provide evidence as to the differential impact of the use of various metacognitive strategies in science courses with regard to student diversity and demographics.

Less than a quarter of faculty survey respondents indicated that they "develop strategies to support less successful groups of students based on data from [their] course." Data on student performance may be useful for identifying "achievement gaps for certain groups of students" (Rachford, Coffey, & Sambolin, 2018, p. 45) and may motivate faculty to incorporate "equity-minded" (Rachford et al., 2018, p. 48) approaches in their STEM courses. One example of such an approach is shown by the AACU Transparency in Learning and Teaching (TILT) Framework; Winkelmes et al. (2016) found that "transparently designed, problem-centered assignments may help to provide more equitable educational experiences and increase retention and completion rates, especially for underserved students" (p. 36). We note that although a few course structure and learning strategy approaches have been shown to be more beneficial for certain groups of students than others (Beichner et al., 2007; Eddy & Hogan, 2014), overall there is not yet sufficient documentation of the "relative effectiveness of different student-centered strategies" for particular groups of students (Olson & Riordan, 2012, p. 137).

Career pathways

Many faculty reported employing strategies that support students' career pathways in some way (Figure 4). This is encouraging, because career information and exploration have been shown to be an important influence on students' attraction to the geoscience major (Hoisch & Bowie, 2010). Relatively few faculty reported that they publicize job search and career resources or that they give an assignment in which students explore careers; these would be reasonable next steps for faculty to take to further students' interest in geoscience careers. Another step would be for faculty to promote and engage students in science internships and research, which has been demonstrated to attract historically underrepresented students to science and to science research careers (Hurtado et al., 2009; Villarejo, Barlow, Kogan, Veazey, & Sweeney, 2008).

Variables predicting faculty use of teaching practices

In the previous section, we discussed the practices geoscience faculty employ. In this section, we discuss the ways in which these practices differ across the variables of teaching style, communication with colleagues, years of teaching experience, faculty type, institution type, class size, and course type (introductory or major).

Teaching style

In the survey, self-reported practices were used to categorize faculty into three groups "on the basis of decreasing levels of student engagement": active learning, active lecture, and traditional lecture (Manduca et al., 2017, p. 3). The more faculty members engage students in class, the more likely they also are to respond to questions related to curricular choices, career pathways, learning strategies, and geoscience representations in ways that are consistent with supporting diversity and inclusion in geoscience courses (Figure 5a). The most noticeable differences are related to the incorporation of strategies that support student learning, whereas there is relatively little difference across the teaching style categories for use of geoscience representations. Faculty respondents who reported using traditional lectures were far less likely to provide information on career strategies, incorporate societally relevant content and issues, or incorporate metacognition and other strategies that have been shown to support student learning. A professional development strategy, then, might be to continue the focus on moving geoscience faculty from traditional lecture methods toward active learning methods, and at the same time to provide faculty with specific examples of strategies that also support diversity and inclusion in the geosciences.

Communication with colleagues

Faculty respondents who reported frequently communicating with colleagues about how to meet the needs of students from groups that traditionally have been underserved and/or underrepresented were much more likely to respond to questions related to curricular choices, career pathways, learning strategies, and geoscience representations in ways that are consistent with creating and supporting inclusive learning environments in geoscience courses. This result might suggest professional development strategies that encourage talking about these approaches with colleagues within and beyond one's institution. One such approach would be to support faculty change agents going back to their institutions or regional communities to facilitate these types of discussions with materials provided via the web or distributed during professional development (Macdonald et al., 2019).

Years of teaching experience

The number of years of experience faculty had teaching geoscience made little difference in how they responded to questions related to geoscience representations, learning strategies, or career pathways (Figure 5c). Faculty respondents with less experience were less likely to report making curricular choices related to incorporating socially relevant content and issues in their classes. Overall, there seems to be an opportunity to share effective classroom strategies that support broadening participation with both new and experienced faculty.

Faculty type

Manduca et al. (2017) used cluster analysis to categorize faculty into education-focused faculty, who invested in activities "related to improving teaching" (p. 3); geoscience research-focused faculty, who invested in "geoscience research activity" (p. 3); and teaching faculty, who were less likely to invest in activities related to improving teaching or related to geoscience research. They found that "faculty who invest in learning about teaching are more likely to use practices that support student engagement" (Manduca et al., 2017, p. 3).

Similarly, this study found that education-focused faculty who invest in improving teaching are also most likely to respond to questions related to curricular choices, career pathways, learning strategies, and geoscience representations in ways that are consistent with supporting diversity and inclusion in geoscience courses (Figure 5d).

Institution type

Faculty respondents who teach at two-year colleges (schools that offer an associate degree) are more likely than faculty at other institution types to respond to questions related to geoscience representations, curricular choices, and learning strategies—but not career pathways—in ways that are consistent with supporting a diverse population of students in geoscience courses. This result might reflect a positive response of faculty at two-year colleges to the demographics of their student bodies. Two-year colleges enroll a more diverse student population than other institution types (National Center for Education Statistics, 2017). The diversity of the student body might result in a campus culture that places greater emphasis on inclusive practices.

Course type

Faculty respondents who reported on an introductory course they taught were more likely to make curricular choices related to incorporating societally relevant content and issues in their courses than those who reported on a majors course. The incorporation of socioscientific content in introductory courses may be important to initially attract students (Pandya, 2012), and continued incorporation in courses for majors may be necessary to sustain student interest in geoscience. We suggest that ways to accomplish this for geoscience majors might be an important curricular discussion point for departments.

In contrast to curricular choices, faculty respondents who reported on an introductory course were far less likely than faculty teaching majors courses to report supporting students' career pathways using various strategies. Introductory courses reach a large proportion of the students taking geoscience courses. The number of students enrolled in the introductory courses represented in the survey responses was calculated from numbers entered by respondents and totaled 70,198 for the 2016 survey, or approximately 20% to 25% of students enrolled in geoscience courses (Egger, 2019). Given the large number of students in introductory geoscience courses, and the demonstrated value of career information to attracting students to the sciences (Hoisch & Bowie, 2010), introductory courses may be a key place to provide information and support to students related to geoscience careers.

Class size

Class size (Figure 5f) was not a consistent predictor for the four factors. In general, there are a variety of strategies that may be employed related to geoscience representation, curricular choices, learning strategies, and career pathways, such that a faculty member's decision to incorporate some of the beneficial practices need not be limited by the number of students in his or her class.

Limitations

We acknowledge that the four factors we detail—geoscientist representations, curricular choices, learning strategies, and career pathways—do not cover all of the practices recent research has shown to be important to supporting diversity, equity, and inclusion in education; our analysis of questions and responses was limited to items in the National Geoscience Faculty Survey. We draw your attention to the recent *Journal of Geoscience Education* special issue on "Synthesizing Results and Defining Future Directions of Geoscience Education Research," which has several articles summarizing other important factors, such as mentoring, peer support, research experiences, and institutional culture (Wolfe and Riggs, 2017); instructional practices that address barriers to students with different abilities (Carabajal et al., 2017); and self-efficacy, identity, microaggressions, and stereotype threat (Callahan et al., 2017). The geoscientist representation questions in the survey were limited to the broad category of "people of color" and to binary gender categories; they are limited in the sense that they do not address all aspects of diversity. Furthermore, the survey was not originally designed to only describe inclusive practices among geoscience faculty, and instead had multiple aims. By not having as many replicate items that examined each of the four factors identified in this research, our factor reliability is limited, but within the range considered acceptable.

The study design is limited by the absence of randomized assignment. The population for the study is based on responses to a national survey that was administered as a census sample to all identifiable geoscience faculty (Manduca et al., 2017). A response-bias analysis conducted by Professional Data Analysts compared 2016 survey responders to the full 2016 sample on two variables that were available for the majority of the sample: faculty rank (recorded for 72%) and institution type (recorded for 93%). A higher percentage of full, associate, and assistant professors contacted responded (28%) than instructors, lecturers, and adjuncts (21%; Chi-square = 33.338, $df = 1$, $p < .001$). A lower percentage of contacted faculty from doctoral degree-granting institutions responded (23%) than contacted faculty from master's, bachelor's, and associate degree-granting institutions, or other institution types (28%; Chi-square = 36.64, df = 1, $p < .001$). We acknowledge that the respondents who chose to respond may be more interested in professional development and adoption of teaching strategies than those who chose not to respond, such that there is a possibility that the use of strategies may be overreported.

Implications and recommendations

Our study of the 2016 National Geoscience Faculty Survey responses showed that faculty's self-reported use of practices across the four categories of geoscientist representations, curricular choices, learning strategies, and career pathways varied, with some practices employed by many faculty and others by only a few. When designing a course, faculty members make many choices about how and what they teach. We do not expect them to incorporate all of the surveyed options. Instead, we suggest they incorporate a range of the research-based practices that will serve in the construction of inclusive learning environments, and that will further improve and foster existing learning environments. From this study, we specifically recommend that faculty do the following:

- Include more photos and stories of geoscientists and a higher percentage of geoscientists from groups historically underrepresented in the science. Resources to draw from include the SACNAS Biography Project (http://sacnas.org/biography-project/) and the SAGE 2YC project (https://serc.carleton.edu/sage2yc).
- Incorporate socioscientific issues in geoscience courses. Modules developed through the NSF-funded InTeGrate program (https://serc.carleton.edu/integrate; Pelch & McConnell, 2017) and opportunities through AGU's Thriving Earth Exchange (https://thrivingearthexchange.org/) offer some examples.
- Move from traditional lecture-based classes toward classes that regularly engage students in active learning. Several outstanding resources are available that offer faculty suggestions for active learning practices. Tanner's (2013) article offers specific strategies to cultivate equity in science classrooms.
- Teach students learning strategies that promote metacognition, self-reflection, and study skills, as increasing students' awareness of the learning process significantly improves student learning (National Resource Council, 2000). Information and specific strategies for geoscience courses are available through NAGT's *Teach the Earth* site on metacognition (https://serc.carleton.edu/NAGTWorkshops/metacognition).
- Provide information and publicize geoscience career opportunities to students in introductory and major courses. Adding an assignment to explore geoscience careers is one way to further engage students in learning about career options (e.g., Nagy-Shadman, 2018).
- Talk to colleagues inside and outside of their departments to share ideas and strategies to foster inclusive and equitable geoscience courses and programs.

Participation in workshops and other professional development positively influences changes in teaching practice (e.g., Manduca et al., 2017) and should be used to share best practices related to creating inclusive geoscience courses that support diverse student populations. We recommend that such professional development be incorporated into existing programs, and also that new programs be developed and supported. These professional development programs should reach graduate students; new and experienced faculty; and faculty at two-year colleges (e.g., Macdonald et al., 2019), four-year colleges, and universities that offer graduate degrees. In addition to professional development opportunities for individual faculty and graduate students, we also suggest focusing on the department as a unit (e.g., NAGT Traveling Workshops Program) to enact changes in teaching practices. These varied professional development opportunities should include teaching practices related to the four categories focused on in this article—geoscientist representations, curricular choices, learning strategies, and career pathways—and also other practices that are integral to removing barriers and broadening participation (e.g., Wolfe and Riggs, 2017; Callahan et al., 2017).

The disproportionate demographics in the geosciences have been persistent. With the choices faculty make in how to teach and what to teach, they and their courses may be either early roadblocks or entry ramps to geoscience careers. As geoscience faculty, we must make changes in our instructional practices to remove barriers, and to attract and support a diverse population of geoscientists.

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