Exploring Relationships Between Faculty Values for and Practice in Developing Student Quantitative Reasoning

Researchers have defined quantitative reasoning as abilities or practical skills for people to analyze or interpret real-world statistical information (Rocconi et al., 2013). The American Association of Colleges and Universities (AAC&U) listed quantitative literacy as an essential practical skill (AAC&U, n.d.). Over the past few years, due to the highly competitive job market, college graduates were often required to be equipped with quantitative skills to enter the workforce (Dingman & Madison, 2010; Elrod, 2014; Rocconi et al., 2013). To do that, many colleges and universities have started developing courses related to quantitative reasoning and career skills (Hurney et al., 2011), as studies indicate that colleges and universities play an important role in preparing students with career skills, including communication, critical thinking, and problem-solving (Nelson, 2021; Rocconi et al., 2013).

In the report *How College Contributes to Workforce Success: Employer Views on What Matters Most*, Finley (2021) found that employers find these practical skills crucial for students' career success in the workforce. However, few studies have explored faculty perceptions of the importance of quantitative reasoning and how faculty help develop students' quantitative reasoning and career-related skills. To support the development of students' quantitative reasoning and transferable skills for their career success, it is crucial to explore faculty perceptions of the importance of quantitative reasoning activities as it may influence the way they structure their courses or how they encourage students to be involved in career-related activities. Therefore, this study explores how faculty perceptions of the importance of quantitative reasoning relate to their encouragement of students they teach or advise to participate in work-related activities and how they structure their courses to help develop students' transferable skills.

Formally, the purpose of this study is to explore the relationship between faculty values for quantitative reasoning, how much faculty structure their courses to help develop students' real-world

skills, and to what extent faculty encourage students to participate in career- or transferrable skills-related activities. Three research questions guide this study:

1. How do faculty perceptions of the importance of quantitative reasoning relate to the ways they structure their courses to help develop students' career-related skills?
2. How do faculty perceptions of the importance of quantitative reasoning relate to how they encourage students they teach or advise to participate in transferrable skill- or career-related activities?
3. How do the relationships in the previous two questions differ across disciplinary areas?

Framing Perspectives and Literature

Two critical perspectives guided our thinking for this project: the importance of quality teaching to quality learning and the importance of quantitative reasoning in workforce success. For the former, several studies have shown a positive relationship between faculty quality teaching and students' quality education (Kezar, 2014; Umbach and Wawrzynski, 2005). For example, Umbach and Wawrzynski (2005) found that students were more likely to have higher levels of engagement and better learning outcomes when faculty members were highly engaged in teaching. In addition, some scholars and researchers also indicated that faculty perceptions and effective teaching practices significantly affect student engagement and learning outcomes at colleges and universities (Kezar, 2014; Umbach and Wawrzynski, 2005). This inspired our exploration of the relationships between faculty values and faculty practice.

One way to further understand teaching and learning and the pedagogical practices of faculty is to understand their decision making when planning their courses as it is during this process that faculty make decisions about the content and how to engage students in the content of their courses (Lowther et. al., 1990). Our understanding of the choices that faculty make when planning and creating their courses is decades old and relies on qualitative interviews and focus groups (e.g., Andreson et. al., 1985;

Powell & Shanker, 1982; Stark et. al., 1988; Young & Irving, 2005). Despite these limitations, the findings of this small body of literature are rather consistent. Primarily, faculty rely on the norms and their personal beliefs about their discipline to guide their goals and curricular choices (Andreson et. al., 1985; Stark, 2000; Warcholak, 2014). Their beliefs about the way students learn (Stark, 2000; Stark et. al., 1988) and the purpose of higher education (Stark, 1991) were also strong influences on the educational goals and choices of faculty.

Although external factors (market forces, institutional mission, sociocultural contexts, etc.) are certainly influential on faculty practice (Lattuca & Stark, 2009), researchers consistently found that faculty beliefs about their discipline and how students learn are the strongest influences on faculty instructional choices (Stark, 2000; Stark et. al., 1988). Even when faculty disagree on the purposes of higher education or the way students learn, their perceived values of their discipline were most important when designing courses (Stark, 2000). This was especially true when faculty developed introductory or general education courses (Lowther et. al., 1990; Stark, 2000). Without a body of literature suggesting this is no longer true, we chose to include faculty members' course goals for student development and perceptions of the importance of quantitative reasoning as essential components in this study. The overwhelming influence of a faculty members' discipline on their pedagogical choices may be a source of conflict for external calls to incorporate quantitative reasoning and transferable workplace skills across disciplines.

Quantitative Reasoning Skills

People today live in an age where quantitative information is everywhere in their daily lives, and they have to equip themselves with skills to analyze information to support their decision-making processeses (Elrod, 2014). Moreover, many higher education stakeholders have increasingly discussed the importance of quantitative skills for workforce success. For example, the American Association of Colleges and Universities listed quantitative literacy as one of their essential learning outcomes (AAC&U,

n.d.). In addition, the Lumina Foundation's Degree Qualifications Profile also stressed the importance of quantitative reasoning skills as one of the critical intellectual skills for students to develop in college (Elrod, 2014). As a result, quantitative reasoning-related activities have proliferated in the education setting within colleges and universities. Unlike traditional perspectives that quantitative skills are only for students majoring in fields like Mathematics, Science, and Physics, the development of quantitative reasoning skills is no longer limited to people in the STEM fields. In fact, educators and students in the non-STEM fields have shown a growing interest in obtaining such skills at work and school. Unfortunately, researchers have found that the quantitative skills they gain are difficulty to apply in real-world settings and are not often useful in their future careers (Ganter & Barker, 2004).

Increasingly, employers have been seeking new hires equipped with knowledge and skills gained from colleges and universities, including the ability to work with data and statistical skills and use career-related technology (Flaherty, 2021; Finley, 2021). Students from various disciplinary areas such as business, education, public health, and social science are now encouraged to develop or demonstrate quantitative reasoning skills, such as solving real-world problems, thinking quantitatively, and analyzing quantitative information before entering the job market (Elrod, 2014). Given the importance of quantitative reasoning skills in workforce success, some faculty and administrators at colleges and universities have perceived the importance of quantitative reasoning and incorporated quantitative reasoning experience into their courses (Elrod, 2014). For example, Carleton College launched the Quantitative Inquiry, Reasoning, and Knowledge initiative to help develop students' sense of quantitative reasoning (Lutsky, 2008; Steele & Kilic-Bahi, 2008). Bowdoin College also developed programs that target student development in quantitative reasoning skills (Elrod, 2014).

Although some educators at colleges and universities have perceived the importance of quantitative reasoning skills and designed courses to develop students' skills, most courses were only offered in general education courses (Elrod, 2014). Quantitative reasoning teaching practices have yet to

be expanded commonly across different disciplinary areas as students in STEM fields are more likely to engage in quantitative reasoning-related activities than their non-STEM peers (Rocconi et al., 2013). As faculty at colleges and universities play an important role in developing students' quantitative reasoning skills, exploring faculty perceptions and their teaching practice concerning quantitative reasoning is important. Therefore, this study examines the relationships between faculty perceptions and faculty practice with respect to quantitative reasoning. Additionally, as these skills are considered essential across all fields and future careers, the study explores how these concepts relate to each other within different disciplinary areas.

Methods

The data for the study come from the 2021 administration of the Faculty Survey of Student Engagement (FSSE). FSSE is a large-scale survey that focuses on faculty and instructional staff members' perspectives and expectations regarding student engagement, instructional practices, and their motivations for teaching at four-year degree-granting colleges and universities (Faculty Survey of Student Engagement, n.d.). In addition to the FSSE core survey, various additional item sets that focus on topics important to higher education are appended to the core survey. In this study, we used data from an item set that focused on developing students' transferable-, career-, and workforce-related skills and abilities to better explore how faculty perceive the importance of activities that contribute to student career plans and goals and develop work-related skills. After listwise deletion of responses from institutions that did not participate in the topical module, there were 4,003 faculty respondents from 31 four-year institutions. The final sample size is 2,703 faculty respondents after deleting all missing data. Table 1 displays respondent characteristics.

Table 1. Faculty Characteristics

	Count	%
Disciplinary area		
Arts and Humanities	860	24.6
Biological Science, Agriculture, & Natural Resources	262	7.5
Business	321	9.5

Communications, Media, & Public Relations	233	6.7
Education	323	9.2
Engineering	180	5.1
Health Professions	274	7.8
Physical Science, Mathematics, & Computer Sciences	295	8.4
Social Sciences	418	12.0
Social Service Professions	87	2.5
Other disciplines	244	7.0
Academic rank		
Professor	768	24.5
Associate Professor	618	19.7
Assistant Professor	549	17.5
Instructor or Lecturer	784	25
Others	419	13.4
Gender Identity		
Man	1373	44.1
Woman	1558	50.0
Another gender identity	22	0.7
I prefer not to respond	160	5.1
Race/Ethnicity		
American Indian or Alaska Native	10	0.3
Asian	194	6.2
Black or African American	286	9.2
Hispanic or Latino	104	3.3
Middle Eastern or North African	97	3.1
Native Hawaiian or other Pacific Islander	3	0.1
White	2035	65.4
Another race or ethnicity	27	0.9
Multiracial	123	4.0
I prefer not to respond	234	7.5

Measures

We first ran exploratory factor analysis (EFA) to determine three scales, including quantitative reasoning, work-related course goals, and professional transferable skill using principal components analysis extraction method. The EFA results showed a component for quantitative reasoning scale with three items, a component for work-related course goals with four items, and a component for professional transferrable skills with five items based on the eigenvalues, the scree plots, and the total variance explained. The analyses were performed in SPSS 28.

Specifically, the quantitative reasoning latent construct is faculty perceptions of the importance of quantitative reasoning. This was an exogenous variable that consists of three items that ask faculty how important they think the use of quantitative reasoning is for students in their courses. The course goals latent construct, how much faculty design the goals and outcomes of their courses to help develop students' career-related skills, is an endogenous variable that consists of three items that ask faculty to what extent they structured their selected course section so that students can learn and develop certain skills. The professional transferable skills latent construct, how much faculty actively contribute to developing students' career plans, work-related skills, and transferable skills for the workplace, is an endogenous variable and consists of five items that ask faculty to what extent they have encouraged students they teach or advise to participate in career-related activities. Table 2 to 4 display full descriptions and descriptive statistics for all scales and items and correlations between the scales.

Table 2.
Quantitative Reasoning, Course Goals, and Transferable Skills Items

Scale	Item	N	Mean	S.D.
	In your selected course section, how important is it to you that the typical student do the following? *Response options: 4 Very important, 3 Important, 2 Somewhat important, 1 Not important*			
Quantitative Reasoning	Reach conclusions based on their own analysis of numerical information (numbers, graphs, statistics, etc.)	3067	2.9	1.1
	Use numerical information to examine a real-world problem or issue (unemployment, climate change, public health, etc.)	3062	2.6	1.1
	Evaluate what others have concluded from numerical information	3061	2.6	1.1
	To what extent do you structure your selected course section so that students learn and develop in the following areas? *Response options: 4 Very much, 3 Quite a bit, 2 Some, 1 Very little*			
Work-related Course Goals	Acquiring job- or work-related knowledge and skills	3002	2.8	1.0
	Working effectively with others	3003	2.9	1.0
	Developing or clarifying a personal code of values and ethics	3000	2.6	1.1
	Understanding people of other backgrounds (economic, racial/ethnic, political, religious, nationality, etc.)	2989	2.7	1.1
	During the current school year, whether course-related or not, to what extent have you encouraged students you teach or advise to do the following? *Response options: 4 Very much, 3 Quite a bit, 2 Some, 1 Very little, 0 Not at all*			

Professional Transferrable Skills	Network with alumni or professionals to make potential career connections	2973	1.8	1.3
	Communicate your knowledge, skills, and experiences to potential employers	2965	2.0	1.3
	Use career-specific technology (devices, programs, or tools used by those in the field)	2961	2.2	1.3
	Research a career interest, a potential employer, or the job market	2962	2.1	1.3
	Learn about a career or industry from practicing professionals	2957	2.1	1.3

Table 3. Descriptive Statistics for Three Scales

Scale	N	Mean	Range	ICC	Alpha (α)
Quantitative Reasoning	3076	2.7	1-4	.03	.867
Work-related Course Goals	3013	2.8	1-4	.03	.744
Professional Transferrable Skills	2984	2.1	0-4	.03	.884

Table 4. Correlations between Scales

Scale	Quantitative Reasoning	Work-related Course Goals	Professional Transferrable Skills
Quantitative Reasoning	1		
Work-related Course Goals	.22	1	
Professional Transferrable Skills	.28	.51	1

Analysis

After determining the three latent constructs, we conducted structural equation modeling (SEM) with maximum likelihood estimation. First, we ran confirmatory factor analyses (CFA) to examine the relationship between observed and latent variables and the correlations among latent variables. Next, we ran SEM to explore the relationships between latent variables. Finally, we used ANOVAs, Tukey Post-hoc comparison, and multi-group analyses to test mean differences and compare the regression paths by disciplinary area. To meet the minimum sample size for multi-group analysis, we combined faculty respondents in Engineering with those in Physical Science, Mathematics, & Computer Sciences and put faculty in Social Service Professions into the Other Disciplines category. We utilized R to perform all the analyses. We chose to fix the first factor loading of each latent variable to 1 to put the matrix on an observed variable and used several approximate fit indices to evaluate the model goodness of fit,

including chi-square (χ^2), the comparative fit index (CFI) and the Tucker Lewis Index (TLI), and the root mean square error of approximation (RMSEA). We determined the goodness of fit of the models using the criteria recommended by Hu and Bentler (1999), including chi-square (χ^2), CFI > .95, TLI > .95, and RMSEA < .05.

Limitations

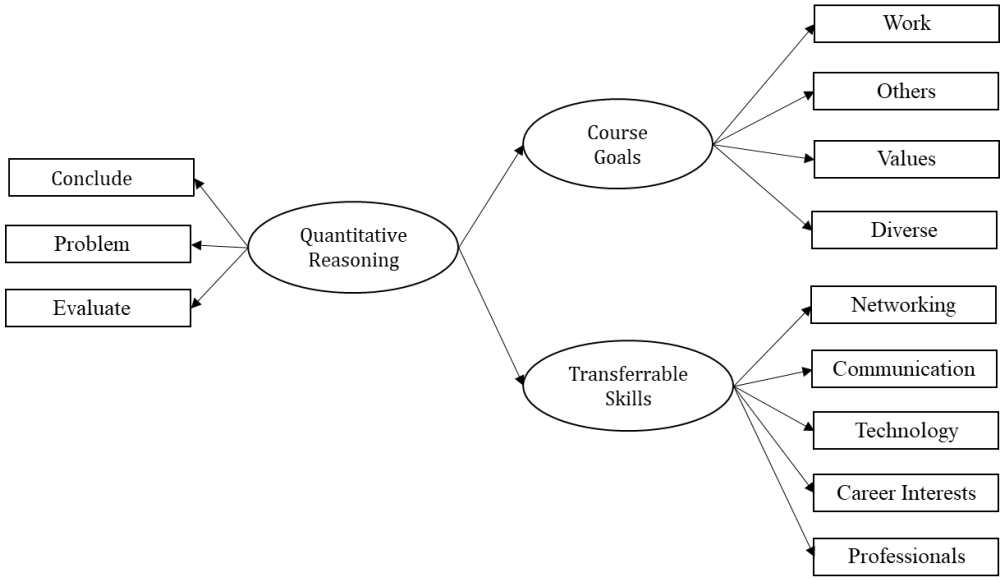
Institutions elect to participate in FSSE, and our study focuses on a subset of institutions that chose to append an extra item set about faculty practice related to developing transferable skills. It is possible that institutions interested in collecting this type of information are somehow fundamentally different (in terms of goals, programming, etc.) than a randomly selected group of institutions. Our results should be generalized with caution. Additionally, although faculty practice has been shown to be directly related to student performance, we do not have student data to corroborate or celebrate the success of student development of quantitative reasoning skills. Finally, although our sample sizes did allow for us to conduct the analyses we present here, the count of faculty in this study is relatively small and so results should not be considered to be true for all faculty at all institutions.

Results

Measurement Model

Our CFA results showed poor chi-square $\chi^2(51) = 1306.94$, p-value < .001, acceptable CFI (.923) and TLI (.900), and poor RMSEA (.095). Since the results suggested a model misspecification, we ran modification indices to re-specify the model. We correlated the error terms of items from the course work (fcgwork ~ fcgdiverse, fcgvalues ~ fcgdiverse, fcgwork ~ fcgvalue, and fcgothers ~ fcgvalues) and the error terms items from the transferrable skill scale (fTRN01w21 ~~ fTRN01x21 and fTRN01r21 ~~ fTRN01x21). After implementing the suggested changes, the final measurement model had an improved goodness of fit, with improved chi-square ($\chi^2(45) = 358.848$, $p < .001$), decent CFI (0.981) and TLI (0.972), and RMSEA = 0.05 [90% CI = .046, .056]. Figure 1 presents the final structural model.

Figure 1. Structural Equation Model



Regression Model

The results showed that all freely estimated factor loadings were positive and statistically significant, suggesting that the observed variables sufficiently explain the latent variables (Table 5). In the regression analysis between the latent variables, both course goals (β = .30, SE = .02, $p < .001$) and transferable skills (β = .39, SE = .03, $p < .001$) were significantly and positively predicted by importance of quantitative reasoning, suggesting that faculty members were more likely to structure their courses for students to develop certain career-related skills and encourage students to participate in career-related activities if they thought it was important for students to engage in quantitative reasoning activities (Table 5). For the initial model fit statistics, the initial model appeared to be a significant ($\chi^2 = 522.505$, $p < .001$), suggesting model misspecification; a decent CFI (.920); a poor TLI (.893); and a poor approximation for the RMSEA (.106). These results suggest that the model is not consistent with the data due to poor chi-square statistics, TLI, and RMSEA fit statistics.

Table 5.
Parameter Estimates of Structural Model

Variables	Estimate	SE	p-value	Variance
Quantitative Reasoning				
Conclude	1			.55
Problem	1.26	.03	< .001	.18
Evaluate	1.13	.03	< .001	.29
Course Goals				
Work	1			.46
Others	.80	.04	< .001	.61
Values	.89	.04	< .001	.62
Diverse	.71	.04	< .001	.89
Transferrable Skills				
Networking	1			.66
Communication	1.07	.02	< .001	.47
Technology	.86	.02	< .001	.98
Career Interests	.99	.02	< .001	.70
Professionals	1.07	.03	< .001	.59
Regressions				
Quantitative Reasoning				.64
Course Goals	.30	.02	< .001	.55
Transferable Skills	.39	.03	< .001	.95

ANOVA and Multi-Group Models

In the final set of analyses, we examined if faculty members report different levels of perceptions of the importance of quantitative reasoning, course planning, and transferrable skills and if the relationships between the latent constructs differ across disciplinary areas. Table 6 shows the mean difference among faculty across disciplines. The ANOVA results showed that faculty in Art and Humanities were less likely to perceive the importance of students' use of quantitative reasoning than faculty in other disciplines. Regarding course goals, faculty in Education were more likely to structure their courses to help students learn and develop work-related knowledge and skills than faculty in all other disciplines. Faculty in Biological Science, Agriculture, & Natural Resources and Engineering, Physical Science, Mathematics, & Computer Sciences were less likely to structure their courses to help students develop certain skills than faculty in Health Professions and Social Sciences. Concerning transferrable skills, faculty in Art & Humanities were less likely to encourage students to participate in career-related activities than faculty in Business, Communications, Media, & Public Relations, Education,

and Health Professions. Faculty in Communications, Media, & Public Relations and Education were more likely to encourage their students to participate in career-related activities than faculty in Engineering, Physical Science, Mathematics, & Computer Sciences, and Social Service Professions.

Table 6.
ANOVA Results for Three Latent Constructs across Disciplinary Areas

	Quantitative Reasoning		**Course Goals**		**Transferrable Skills**	
F (Significance)	69.47	***	35.55	***	9.77	***
Disciplinary Area	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Arts and Humanities	2.1	.96	2.8	0.72	1.9	1.11
Biological Science, Agriculture, & Natural Resources	3.1	.80	2.4	0.79	1.9	1.08
Business	3.0	.81	2.7	0.79	2.1	1.08
Communications, Media, & Public Relations	2.9	.93	2.8	0.78	2.3	1.04
Education	3.1	.84	3.2	0.69	2.3	0.98
Engineering, Physical Science, Mathematics, & Computer Sciences	3.0	.84	2.5	0.84	1.9	1.11
Health Professions	2.9	.87	2.9	0.77	2.2	1.08
Social Sciences	2.9	.89	2.7	0.75	2.0	1.02
Other disciplines	2.7	.94	3.1	0.74	2.3	1.08

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

After knowing the mean differences, we continued to look at the structural differences between the three latent constructs using multi-group analyses. Our baseline configural model showed a model misspecification (χ^2 (468) = 1589.09, $p < .001$)), CFI = .935, TLI = .917, and RMSEA = .082 [90% CI = .077, .086]. The final model demonstrated well fit to the data after implementing suggested changes from modification indices, (χ^2 (414) = 720.865, $p < .001$)), CFI = .982, TLI = .974, and RMSEA = .045 [90% CI = .040, .051]. The regression results showed a positive relationship between quantitative reasoning and course goals latent variables across disciplinary areas. We also found a positive relationship between quantitative reasoning and transferrable skills across disciplines except for faculty in Communications, Media, & Public Relations.

Table 7.
Multi-group analyses across disciplinary areas

Disciplinary Area	Course Goals	Transferrable Skills

Latent Variable (Quantitative Reasoning)	Estimate		SE	Estimate		SE
Arts and Humanities	.27	***	.03	.34	***	.05
Biological Science, Agriculture, & Natural Resources	.29	***	.07	.36	***	.10
Business	.29	***	.05	.32	***	.08
Communications, Media, & Public Relations	.25	***	.07	.11		.08
Education	.08	*	.04	.18	*	.07
Engineering, Physical Science, Mathematics, & Computer Sciences	.21	***	.04	.37	***	.07
Health Professions	.19	**	.06	.33	***	.08
Social Sciences	.17	***	.04	.39	***	.06
Other disciplines	.21	***	.05	.42	***	.07

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

Discussion and Implications

We found that faculty perceptions of the importance of quantitative reasoning significantly predicted how faculty structure their courses to help develop students' numerical skills and how they encourage students to participate in transferrable skills-related activities. Our findings confirm and extend previous studies that faculty perceptions have a critical effect on student engagement and learning outcomes (Kezar & Maxey, 2014; Umbach & Wawrzynski, 2005). If faculty members perceived quantitative reasoning as an essential skill for students' career development, they were more likely to structure their course goals and encourage and advise their students to develop the ability to work with data and statistics. Our findings also align with notions that faculty disciplinary norms drive their curricular decision making (Stark, 2000; Stark et. al., 1988).

The finding that faculty values for quantitative reasoning related to faculty planning their courses to include important transferable and workplace skills was consistent across disciplines. So, even if faculty in a field like Arts and Humanities, that is not known for its mathematical components, felt it was important for students to participate in activities that develop quantitative literacy, they were more intentional about including such activities in their courses. Perhaps not surprisingly, however, faculty in Arts and Humanities found the least value in students developing quantitative reasoning skills. It's possible that faculty in this field do not understand the value of such skills to students regardless of their future career choices or that faculty in this field do not see how quantitative reasoning connects in

any way to their discipline. Faculty development programs and workshops or interdisciplinary partnerships could help these faculty find the value in quantitative reasoning and find ways to incorporate it into their courses.

Another finding relevant to faculty development is that faculty in biological and physical science fields were less likely to structure their courses for students to learn and develop workplace skills. This aligns with findings that faculty in such fields are less focused on pedagogical techniques than they are the transmission of disciplinary knowledge. This may correspond to findings that students may learn mathematical skills, but they have difficulty applying them to real-world situations of find them practically useful outside of their coursework (Ganter & Barker, 2004). Ensuring that students are not just able to learn mathematical or statistical concepts but also use them in practical situations is an important area for faculty in these fields to focus on.

The overall findings of this study could prompt administrators to better understand their faculty's perceptions and values as they are so closely related to student engagement and learning. Moreover, our findings point to one way that colleges and universities can do better to prepare students with liberal education skills for workforce success—focus on the values and practices of their faculty. If higher education institutions truly want to instill quantitative literacy across the curriculum and have graduates with well-developed workplace skills, conversations about faculty and disciplinary values should be had at all levels of hiring, merit review, and tenure and promotion. This will help to ensure that faculty understand the value of these skills to their institution and students. Future research should additionally consider conducting multigroup analyses to see if there are differences in the constructs studied between faculty rank, gender identity, race and ethnicity, and institutional characteristics.

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