Validation of the Climate Scale in the Persistence of Engineers in the Academy Survey (PEAS)

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Abstract

This research paper describes the validation procedure for the Persistence of Engineers in the Academy Survey (PEAS). Faculty are identified as the pivotal resource around which the outcomes of higher education revolve; therefore, it is essential to understand who they are, what they do, and whether, how, and why they are changing. As one critical component of PEAS, this paper describes the procedure for the validation of a scale to probe factors that may affect an individual's persistence as a faculty member in relation to intersecting social identities including gender identity, race/ethnicity, disability status, and social class. PEAS was designed to reveal insight into the departmental level processes and the different climates produced by those processes for faculty members. Data collected by PEAS can begin to shed light on the factors influencing important outcomes, such as job satisfaction and employee retention. The finalized PEAS, as a tool for administrators to gauge departmental level climate related to employee persistence, is expected to contribute to the development of a more diverse workforce in academic engineering.

I. Introduction

This paper describes the validation procedure for the Persistence of Engineers in the Academy Survey (PEAS). PEAS was created as part of a multiyear, multiphase, mixed-methods research project funded by the NSF to explore the experiences of women and women of color tenure-track engineering faculty. The initial development procedure for the survey was previously reported [1]. This survey probes factors that may contribute to an individual's experiences as they continue, or persist, as a faculty member in association with their intersecting social identities. PEAS consists of scale items and demographic questions. The scale items measure ten constructs identified from the literature, such as organizational climate and motivation factors, that underpin an individual's personal experiences as they persist in an academic engineering career (See Table 1). The demographic items capture the respondent's various intersecting socially constructed identities, including gender identity, race/ethnicity, disability status, and social class.

Table 1. Definition of the Ten Constructs in the Scale for the PEAS

Construct	Definition	References
Intrinsic Motivation	An individual's perceptions of the motivation to work due to innate satisfaction and pleasure	[2] [3]
Departmental Climate for Diversity	An individual's perception of how well the department or unit attracts and recruits faculty from diverse backgrounds	[4] [5]
Departmental Climate for Inclusion	An individual's perception of how well the department or unit considers and supports faculty members from diverse backgrounds	[6]
Opportunities for	An individual's perceptions of the environment for	[7] [8]

Advancement/ Promotion	advancement and/or promotion	
Sense of Belonging	An individual's perceptions of the connection to and level of comfort in the workplace at the departmental level	[9] [10]
Scholarly Recognition	An individual's perceptions of colleagues' formal and informal acknowledgement of professional contributions, expertise, and performance	[11] [4]
Mentoring	An individual’s perceptions of the availability and quality of career development and psychological support from experienced colleagues	[4] [12]
Work/Life Balance	An individual's perceptions of the relationship between work and non-work obligations and demands	[13] [14]
Finances During Higher Education	An individual's perceptions of his or her financial situation during higher education as an undergraduate and/or graduate student	[15] [16]
Financial Responsibilities	An individual's perceptions of his or her current financial situation and ability to fulfill obligations	[16] [17]

The scale items used in PEAS were developed specifically for this project. We examined scales from existing surveys that probe academic workplace climates and rejected them based on principals of best practice [18] [19]. We found existing scales tended to lack sufficient validity evidence or had design problems. For example, the RIT Faculty Career Life Survey assesses constructs of interest to us, including recognition, mentoring, work-life balance, and tenure and promotion. However, validity evidence was limited to a test of the final instrument on paper by four individuals with experience in assessment and evaluation for clarity of questions, formatting, and completion time [20].

Other NSF-ADVANCE supported climate surveys, such as University of Delaware’s 2018 ADVANCE Faculty Climate Survey and University of Michigan’s 2017 combined ADVANCE-Diversity, Equity and Inclusion Survey presented design problems. The questionnaires ask respondents to speculate about the ideas and experiences of other individuals. Item examples include: (1) Underrepresented minority faculty are less likely than White faculty to get career advice from colleagues, (2) the environment promotes adequate collegial opportunities for women, (3) faculty in my department are supportive of faculty with disabilities; and (4) rate along a 7-point Likert scale from 1-poor to 7-excellent the climate within your department for: women, faculty of color, LBGTQ faculty, faculty with disabilities, and for overall diversity. While the responses to these items may be interesting, they are unlikely to provide information about the lived experiences of the populations of interest. However, these item examples would be well-suited to explore how one population understands the experiences of another. Our intent is to probe individual perceptions about their reality as a faculty member of an engineering department, and the recommended approach is to ask respondents about their own firsthand experiences [21][22].

A. Purpose of the Study

The main purpose of this study is to provide validity and reliability evidence of the PEAS. This paper examines three questions regarding the scale validation appeared in the PEAS to assess engineering faculty's psychological aspects on workplace climate for persistence. Therefore, study aims to evaluate the PEAS scale constructs and items through psychometric evaluation, providing reliability and validity evidence. Following research questions guided this study.

1. To what extent does construct validity of the PEAS scale hold for engineering faculty?
2. What level of internal consistency reliability exists for engineering faculty's data from the PEAS scale?
3. To what extent does criterion validity of the PEAS scale hold for engineering faculty?

B. Conceptual framework

Intersectionality. Intersectionality is a term first credited to Crenshaw [23], who used it to describe the simultaneous reality of race and gender because examination of race or gender alone fails to capture the experiences of Black women in the U.S. Since its inception, intersectionality has become a buzzword in the social sciences [24], but there is no universally accepted academic definition for the term. Our understanding of intersectionality is based on the working definition from Else-Quest and Hyde [25][26]: every person is characterized simultaneously by multiple social identity categories, these categories are intertwined and linked to each other, there is an element of power or inequality embedded within each category, and these categories characterize not only a person's social identity[s] but also the person's ever-changing social context. Our study is informed by the concept of intersectionality in two ways: first, as a theory to guide the identification of constructs and the creation of scale items to probe those constructs and, second, as a methodological approach to analyze data based on the survey respondents' multiple demographic identities.

Diversity in the Engineering Professoriate. A literature review indicated that most studies of faculty diversity aggregate engineering with science, technology and mathematics disciplines to examine STEM as a whole. While STEM as an aggregation of fields has become a point of focus because of the disciplines' long-standing lack of faculty diversity [27], there are a few studies that examine differences between disciplines. Gumpertz et al. [28] analyzed institutional records at four large land grant universities for hiring of assistant or associate professors. Data were disaggregated by gender/discipline and race/discipline. The team found that women in engineering were more likely than men to leave the institution and depart without tenure. They found no such differences between genders in science, technology, and mathematics. The authors noted that minority faculty representation was so low at the institutions involved in this study that it limited the ability to understand their retention/promotion experiences.

Durodoye et al. [29] examined institutional records at four large land grant universities for differences in faculty career outcomes by gender and race. The team looked for promotion and tenure patterns for women and underrepresented minority faculty and differences between academic disciplines. This study included both STEM and non-STEM disciplines. When all of the disciplines were analyzed as one group, data indicated women were at a significantly higher risk of leaving without tenure. When data were analyzed by discipline, this disparity disappeared, except for engineering where women left at a higher rate than men and without tenure. Minority faculty also left engineering without tenure at a higher rate than non-minority colleagues at three of the four universities. The authors conclude that the study's findings indicate there is a need to understand the processes and behaviors that conflict with diversity and inclusion goals as "many small puzzles, as opposed to one large one" [29].

Engineering continues to struggle with the puzzle of low diversity in the professoriate. In ASEE's annual Engineering By The Numbers, Roy [30] reported on diversity in the engineering faculty at institutions in the U.S. Tenure/tenured track women average 17.4%, with the greatest number of women in environmental engineering (28.9%) and the least in aerospace (11.8%). We note the category of 'women' includes all racial and ethnic identities. Analysis of racial/ethnic minority faculty of all genders revealed: 2.4% African American with 1,890 institutions as two of the top three universities of employment, 18.3% Asian, and 3.8% Hispanic including the 148 faculty members at the University of Puerto Rico. The report does not provide breakout data for women of color faculty. Another study found less than 150 Black women engineering faculty across all departments with approximately 1/3 of the women employed at one of the 1,890 institution [31].

Organizational Climate at the Departmental Level. We designed PEAS to probe several constructs associated with departmental level climate. We focus on the climate in the academy at the departmental level for several reasons. First, Ehrhart et al. [32] differentiate organizational climate from organizational culture. An organization's climate is defined as the perceptions and meaning individuals attach to the experiences they have at work, whereas culture is understood as the basic assumptions about the world and the values that guide life in organizations. Organizational climate can be assessed through psychometric survey because the instrument's purpose is to probe what a respondent perceives about their experiences. Second, organizational climate research should be focused on a specific unit [33]. In a large organization, such as a university, it is recommended to make the department the unit of analysis because employee performance is assessed at that level [21]. Recent studies have indicated that the departmental level work environment is an important factor in job satisfaction and employee retention, especially for women and minority faculty [11] [34] [35][36].

In addition to a specific focus, organizational climate research should be framed on a strategically relevant outcome and/or process [32][37]. Ehrhart et al. [32] observed that the focus on strategic outcomes and processes has significantly improved not only the validity of climate research but also the understanding of the contexts in which these climates occur. Burke [38] found that the processes and outcomes focus can indicate specific practices and behaviors that may serve as interventions in organizations to enhance performance in those areas. PEAS has a strong focus on the departmental level climate for persistence. Our climate constructs include: departmental climate for diversity, departmental climate for inclusion, sense of belonging, scholarly recognition, mentoring, work-life balance, and opportunities for advancement/ promotion. The focus on climate for persistence can reveal insight into the departmental processes and the various climates produced by those processes for faculty members and shed light on important outcomes such as job satisfaction and employee retention [32].

Social Class and the Professoriate. Due to our intersectional approach, social class is a component of both the demographic questions and constructs probed by scale items. There is little research on the experiences of academics from working class and disadvantaged social class backgrounds [39]. Grimes and Morris [40] found that sociology faculty from working-class backgrounds never truly felt they belonged in the academy. Shott [41] identified the U.S. academy's tendency to ignore social class issues as a problem that results in a failure to recognize the "countless unearned advantages accruing to those with higher-earning and well-educated parents." In a more recent study, Lee [42] found the academy fosters upper-middle class norms and this heightens class-based stigma. There is a call to include social class origins in higher education academic staff diversity concerns. It would increase the overall understanding of the impact of social class in determining life and learning outcomes [43]. As Waterfield [40] suggested in context of social class, "exploring intersecting marginalized identities would enrich understandings of subtle forms of social exclusion in higher education". In addition to demographic questions, we also probe social class in the following constructs: finances during higher education and financial responsibilities.

II. Method

A. Survey Revision

The scale development process followed the steps as guided by Clark and Watson [44], including first identifying constructs through a literature review, creating scale items for the constructs, and refining the scale items through face/content validity analyses. Next, we conducted an initial test of scale items through a pilot study targeting STEM faculty at one public university. Initial pilot study data were analyzed through exploratory factor analysis (EFA) and, based on those results, we revised some items to improve wording clarity and added some new items. Then we tested the existing, revised, and newly added items by conducting an additional EFA using new data from a second pilot study targeting STEM faculty at one private and one public university. Survey completion time was approximately 30 minutes and the scales were presented in the same order to all respondents.

Through the two pilot studies using EFAs, the factor structure of the PEAS scale was identified to have 10 factors indicated by 60 items with good internal consistency reliability evidence (See the details for [1]). Based on the feedback from survey respondents, another round of scale item revision was conducted to refine items for engineering faculty. This resulted in 59 items for the same 10 constructs. Table 2 examples an item developed for each construct on the PEAS Scale.

Table 2. Example Items for Ten Constructs in the PEAS Scale

#	Construct	Item
1	Intrinsic Motivation	I stay in my job because the work is interesting.
2	Departmental Climate for Diversity	My department is committed to hiring diverse faculty.
3	Departmental Climate for Inclusion	My department has a zero-tolerance policy for workplace bullying.
4	Opportunities for Advancement/Promotion	The criteria for tenure/promotion are transparent.
5	Sense of Belonging	I am engaged with colleagues in my workplace.
6	Scholarly Recognition	Colleagues in my department value my expertise.
7	Mentoring	I have a mentor at work who I can count on.
8	Work-Life Balance	I have time for both my work and personal life.
9	Finances during Higher Education	I took care of the costs of completing my higher education.
10	Financial Responsibilities	I stay in my job to fulfill my financial responsibilities.

B. Participants

Potential participants were identified and contact information of engineering faculty in the USA was obtained through public listings available on university websites. A Python script enabled us to collect emails of the engineering faculty from university websites. In fall 2019, data were collected online using a self-reported questionnaire administered through the PEAS [45]. While approximately 28,400 engineering faculty were invited by email, 1,555 responded and 985 completed responses on the scale section of the PEAS, which became participants of this study. The mean age of the first pilot participants was 51.5 (n = 899, SD = 12.1). Table 3 shows the demographic characteristics of the participants from the PEAS capturing variables of gender, race/ethnicity, and class framed in intersectionality.

Table 3. Demographic Characteristics of Engineering Faculty Participants

Category	Subcategory	*n*	%
Sex	Female	279	28.3
	Male	657	66.7
Gender	Female	271	27.5
	Male	637	64.7
	Other/Not to answer	28	2.8
Ethnicity	Hispanic	48	4.9
Race	Non-Hispanic	886	89.9
	American Indian or Alaska Native	2	0.2
	Asian	86	8.7
	Black	18	1.8
	White	753	76.4
	Multiracial	20	2.0
Disability Status	Yes	141	14.3
	No	786	79.8

Social Class	High School F/R lunch	59	6.0
	Financial Support during College	609	61.8
	Need-based Financial Aid for College	224	22.7
	Work outside to finance College Education	609	61.8
	Debt Free Higher Education [No]	337	34.2
Highest Degree	Master's	28	2.8
	PhD	937	95.1
Track	Tenure	892	90.6
	Non-tenure	71	7.2
Major	At least one degree in engineering	835	84.8
	No engineering major	133	13.5
Total		985	100.0

Note. Due to unspecified responses, the numbers are inconsistent with the total numbers of the participants.

C. Data Analysis

To answer each research question, we considered the following data analyses methods: factor analyses for construct validity, internal consistency reliability analyses for reliability, and correlation matrix between variables of interests for criterion validity. The six-point Likert scale used in the scale is naturally categorical and the distribution of responses for each item was skewed and did not follow a normal distribution. Therefore, robust weighted least squares (WLSMV) employed in Mplus 8 [46] was utilized as an estimator to obtain parameter estimates for factor analyses with categorical data.

First, an exploratory factor analysis (EFA) was conducted by randomly splitting the data in half (n = 493) to identify underlying factor structure and irrelevant items that did not fit into any factors that exist in the scale. For the EFA, eigenvalues, and factor loadings after oblique rotation of GEOMIN, which is the default rotation of the M*plus,* were calculated to judge the number of factors and items for each factor. Second, after identifying the factor structure and irrelevant items for the scale, we conducted confirmatory factor analyses (CFAs) using the other half of the data (n = 492) to confirm and refine the factor structure identified through the EFA. Third, as we identified a factor structure and items for the PEAS scale, we calculated the reliability coefficient of internal consistency, Cronbach's α, using SPSS Statistics 25 [47][48] to investigate how items are inter-related within each factor, sub-factor, and the overall instrument. Finally, for criterion validity evidence, we calculated a correlation matrix between the scores averaged from the items loaded for the identified factors and variables of interests, such as sex, minority/majority status, disability status, social class, etc. the state standardized mathematics achievement test scores.

III. Results

A. Exploratory Factor Analysis Modeling

Polychoric correlation coefficients among the 59 items, which are ordered categorical variables, revealed that the coefficients were positively or negatively correlated, meaning that putative factors identified through an EFA are not independent. In addition, multicollinearity (strong correlations over .85) did not exist between items, implying that those items do not measure the same aspect of the constructs. We extracted the number of factors underlying the data based on the point of inflection of the curve in the scree plot [49]. This yielded ten factors considered for inclusion in a putative factor structure for the scale. According to Stevens' [50] guideline about the relationship between the sample size and cutoff factor loading, we considered items with a factor loading greater than 0.40 significant for the designated factor [51]. This resulted in 59 items, that had significant factor loadings onto one of 10 factors, indicating each item's unique contribution to one of the factors.

B. Confirmatory Factor Analysis Modeling

A CFA was conducted to confirm the factor structure for the 59 item PEAS scale using another half of the data ($n = 492$). We evaluated the CFA model through three steps: (a) checking the consistency of multiple goodness-of-fit indexes and judging the fit of the model to the data; (b) examining localized areas of poor fit; and (c) inspecting parameter estimates, such as factor loadings, factor variances, and residual variances to ensure reliability on each item to the latent factor. All 59 items had loadings that met the minimum criteria of 0.40 [52], and all factor loadings were significant and all fit indexes were in a good-fit range: $\chi 2(1{,}607) = 3335.9$, $p < .001$, root-mean-square error of approximation (*RMSEA*) = 0.047 with 90% confidence interval of 0.045 and 0.049, comparative fit index(*CFI*) = 0.984, Tucker-Lewis index(*TLI*) = 0.983, and standard root mean squre residual (*SRMR*) = 0.040. Factor correlation coefficients among the four factors ranged from -0.200 to 0.865 as shown in Table 4.

Table 4. Standardized Factor Correlation Coefficients among the Ten Factors

#	Factor	2	3	4	5	6	7	8	9	10
1	Intrinsic Motivation	0.334*	0.421*	0.409*	0.516*	0.424*	0.275*	0.452*	0.185*	-0.200*
2	Departmental Climate for Diversity		0.795*	0.583*	0.592*	0.607*	0.372*	0.263*	0.196*	0.009
3	Departmental Climate for Inclusion			0.706*	0.741*	0.759*	0.472*	0.329*	0.203*	-0.044
4	Opportunities for Advancement/Promotion				0.574*	0.633*	0.406*	0.330*	0.256*	-0.041
5	Sense of Belonging					0.865*	0.500*	0.345*	0.232*	-0.108*
6	Scholarly Recognition						0.463*	0.292*	0.269*	-0.101*
7	Mentoring							0.163*	0.198*	-0.037
8	Work/Life Balance								0.258*	-0.060
9	Finance During Higher Education									-0.043
10	Financial Responsibility									1.000

Note. $^*p < .05$

C. Internal Consistency Reliability Evidence

Data used for CFA were utilized for the reliability analysis. The overall reliability coefficients of the PEAS scale with 59 items were Cronbach's α =0.966. Each construct housed in the PEAS scale appeared to have good internal consistency as shown in Table 5. Cronbach's α values of the 10 constructs ranged from 0.638 to 0.978. All items of the PEAS scale were worthy of inclusion because the removal of any items would not increase the score reliability for any construct and the PEAS scale as a whole [53].

Table 5. Number of Items and Internal Consistency Reliability Evidence of the PEAS (n = 492)

#	Construct	n_i	Cronbach's α
1	Intrinsic Motivation	5	0.892
2	Departmental Climate for Diversity	4	0.919
3	Departmental Climate for Inclusion	9	0.945
4	Opportunities for Advancement/Promotion	4	0.910
5	Sense of Belonging	8	0.945
6	Scholarly Recognition	8	0.962
7	Mentoring	11	0.978
8	Work/Life Balance	4	0.902
9	Finances During Higher Education	3	0.638
10	Financial Responsibilities	3	0.885
	Total	59	0.966

Note. n_i = number of the total items in the construct

D. Criterion Validity Evidence

To assess criterion validity, we calculated the correlation coefficients among each of the 10 PEAS scale constructs and variables of interests (See Table 6). The correlation coefficients of ten factors showed varied significance with demographic variables.

Table 6. Correlation Matrix between Variables of Interests

Factor	4	5	6	7	8	9	10	11	12	13
1 Sex (0 = male, 1 = female)	-0.057	-0.248*	-0.253*	-0.180*	-0.193*	-0.219*	-0.005	-0.130*	-0.061	-0.008
2 Minority status (0 = White; 1 = Others)	-0.001	-0.032	-0.049	0.004	-0.04	-0.02	0.05	0.017	-.108*	0.048
3 Disability status (0 = No, 1 = Yes)	-0.103*	-0.077*	-0.084*	-0.091*	-0.140*	-0.128*	-0.075*	-0.164*	-0.001	0.067*
4 Intrinsic Motivation	1.000	0.275*	0.374*	0.371*	0.454*	0.396*	0.287*	0.436*	0.155*	-0.152*
5 Departmental Climate for Diversity		1.000	0.732*	0.522*	0.564*	0.571*	0.306*	0.248*	0.124*	-0.036
6 Departmental Climate for Inclusion			1.000	0.647*	0.703*	0.710*	0.401*	0.346*	0.179*	-0.042
7 Opportunities for Advancement/Promotion				1.000	0.542*	0.590*	0.349*	0.339*	0.205*	-0.041
8 Sense of Belonging					1.000	0.834*	0.488*	0.351*	0.179*	-0.084*
9 Scholarly Recognition						1.000	0.433*	0.314*	0.199*	-0.071*
10 Mentoring							1.000	0.212*	0.147*	-0.076*
11 Work/Life Balance								1.000	0.227*	-0.098*
12 Finance During Higher Education									1.000	-0.008
13 Financial Responsibility										1.000

Note. $*p < .05$

IV. Discussion

The purpose of this study was to obtain initial validity evidence for the scale on the Persistence of Engineering in the Academy Survey (PEAS) in order to provide an instrument to measure the factors related to an engineering faculty member's persistence, or continuation, in an academic engineering career. First, we conducted a literature review and identified ten possible factors that influence an individual's experience as a faculty member. The factors include: intrinsic motivation, departmental climate for diversity, departmental climate for inclusion, opportunities for advancement/promotion, sense of belonging, scholarly recognition, mentoring, work-life balance, finances during higher education, and financial responsibilities. Then we generated items to fit with the ten constructs and assessed item fit through a content and validity process. Next, we conducted EFA, using data from two pilot studies of STEM faculty at three universities, and it resulted in 10 factors significantly indicated by 60 items. We removed, revised, and added items based on the EFA data. Then, we used data from 985 respondents collected from engineering faculty nationwide to conduct EFA and CFA. The CFA data from this study yielded Cronbach's alphas ranging from 0.638 to 0.978 with an overall reliability coefficient of 0.966. This reliability evidence indicates that the PEAS scale as used for engineering faculty persistence has good internal consistency evidence.

The correlation matrix of the ten constructs with demographic variables revealed that female engineering faculty presented relatively lower scores on Departmental Climate for Diversity, Departmental Climate for Inclusion, Opportunities for Advancement/Promotion, Sense of Belonging, Scholarly Recognition, and Work/Life Balance. These findings align with previous studies indicating women experience the academic workplace differently, and less positively, than their male colleagues. White engineering faculty tended to have better finances during their higher education than their counterparts. Engineering faculty with a disability showed lower scores on most of the constructs except Finances During Higher Education. We can infer individuals experience the departmental workplace differently based on socially constructed identities such as gender, race/ethnicity, disability status, and social class. We note that ongoing instrument validation is essential. Validity does not reside in the instrument itself, but characterizes the inferences derived from the data collected by the instrument [54].

A. Limitations of the Study and Suggestion for Future Research

One limitation of this study is a potential sampling bias. We compared our respondent demographics with the national demographics of engineering faculty [15]. Females represent 28.3% of our sample, but the nationally make up 17.4% of engineering faculty. Hispanics are also overrepresented in our faculty sample, 4.9% versus 3.7% nationally. On the other hand, Asians were significantly underrepresented in our sample with 8.7%, compared to the national average of 28.3%. Our sample of Black/African American faculty, 1.8%, is a little bit short of the national average of 2.4%.

Additional evaluations of validity, such as convergent, discriminant, concurrent, and predictive, are planned for future study. We also suggest a future investigation of the organizational outcome of persistence through a longitudinal study to find if any of our specific factors correlate with the likelihood of an individual continuing as an engineering faculty member.

B. Significance of the Study

This study begins to provide an understanding of how organizational climate is viewed and experienced differently by individuals based on intersecting identities such as gender identity, race/ethnicity, disability status, and social class. The focus on climate for persistence can reveal insight into the departmental processes and the various climates produced by those processes for faculty members and shed light on important outcomes such as job satisfaction and employee retention [32].

We anticipate the finalized scale will be generalizable across populations across different institutions in the United States. PEAS would be suitable to measure persistence of faculty in any academic department and not limited to only engineering disciplines. As a generalizable instrument, this scale would contribute to the development of a more diverse workforce in the academy. Our survey would enable administrators to identify climate factors in need of improvement including those that may disproportionately impact faculty members from underrepresented groups.

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