Development of the Persistence of Engineers in the Academy Survey (PEAS)

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Abstract

This paper reports the development procedure for the Persistence of Engineers in the Academy Survey (PEAS). Faculty are identified as the pivotal resource around which the outcomes of postsecondary 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 the PEAS, this paper details a procedure for the development of a scale to probe the factors that may affect a faculty member's persistence in relation to gender/sexual orientation, race/ethnicity, and SES identities framed in intersectionality. Therefore, the PEAS includes a scale to measure constructs related to persistence and demographic items to capture the respondents' various social identities. To create a valid measure of the underlying constructs, several steps were taken during the scale development, including face/content validity analyses, exploratory factor analyses for validity evidence, and internal consistence reliability evidence. Through two pilot studies from 394 STEM faculty from three institutions, the factor structure of the PEAS scale was identified to have 10 factors indicated by 60 items with good internal consistency reliability evidence. To finalize the items and factor structure of the instrument, confirmatory factor analyses are planned, targeting engineering faculty in nation. The finalized PEAS are expected to contribute to the development of a more diverse workforce in the engineering academy.

I. Introduction

This paper reports the development procedure for the Persistence of Engineers in the Academy Survey (PEAS). This survey was developed as part of a multi-year, mixed-methods research project funded by the NSF to explore the experiences of women tenure-track faculty in engineering. Faculty are identified as the pivotal resource around which the outcomes of postsecondary education revolve; therefore, it is essential to understand who they are; what they do; and whether, how, and why they are changing [1] [2]. Although they represent an increasing share of engineering faculty, women continue to be underrepresented in many engineering disciplines [3] [4] and as tenured faculty [5] [6]. On average, women tenured/tenure faculty represented approximately 16.9% of the academic workforce in engineering in 2017 [6]. Research is needed to identify organizational barriers that impede the participation and advancement of women faculty [7]. As one critical component of the PEAS, this paper details a procedure for the development of a scale to explore the perspectives of engineering faculty in the United States (US) about ways that gender, race/ethnicity, and socioeconomic status (SES) affect their persistence in the academy. Intersectionality [8] is used as a framework to guide the survey design and data analysis.

Inequality touches most aspects of human social life and is at the heart of social science research [9]. Intersectional research can enable scientists to examine heterogeneity within multiple social identity categories and how power and equality are tied to membership in those categories. Else Quest and Hyde [10] observed that exclusive focus on marginalized groups may contribute to their marginalization. On the other hand, inter-categorical approaches to compare groups can

highlight the impact of power and privilege inequality between different categories. While there is a need for intersectional research, many scientists caution we may fall into an intersectionality trap by failing to consider variations of experience within a population [11] [12].

A. Theoretical Framework

The PEAS probes the factors that may affect an individual's persistence as a faculty member in relation to gender/sexual orientation, race/ethnicity, and SES identities. The survey includes a scale to measure constructs related to persistence and demographic items to capture the respondents' various social identities. We used intersectionality first as a theory to guide the identification of constructs and creation of items for the constructs and then as a methodological approach to analyze data based on respondents' multiple demographic identities.

Persistence is defined as the personal tendency to endure through hardships to achieve goals or continue a course of action [13] [14]. We differentiate persistence as a personal measure or quality and retention as an organizational measure or quality [15]. The PEAS is designed to explore the personal experiences of faculty as they continue in careers in the academy. Persistence is addressed in the literature with an early examination of its meaning by Ryans [16] who also describes attempts to quantitatively assess persistence by Spearman (1863-1945), the British psychologist who developed statistical measures including factor analysis.

We also differentiate the action of persisting, or, in other words, the fact that a person is continuing as an engineering discipline faculty member, with the conditions that may contribute to one's experience as they persist in a faculty role. The factors that underlie persistence and impact a person's experience can be examined through the analysis of a population at a specific point in time. These are the factors we seek to investigate with the PEAS, not the personality traits of an individual that may contribute to their ability to persist or the organizational outcome that results from faculty persistence. On the other hand, we suggest the action of persisting as an engineering faculty member would be better investigated through a longitudinal study. Together, our cross-sectional study findings could be used with a future longitudinal study to explore if specific factors might correlate with an individual continuing (or persisting) as a faculty member.

Intersectionality is a term credited to Crenshaw [8], who used it to describe the simultaneous consideration of race and gender because analysis of race or gender alone fails to capture the experiences of women of color. Since its introduction, intersectionality has become something of a buzzword across academic disciplines, particularly in the social sciences [17]. Academic definitions tend to emphasize gender, race/ethnicity, and SES, among others, but there is no consensus definition for intersectionality. As there is no commonly accepted meaning, we rely on the three common assumptions identified by Else-Quest and Hyde [10] [18] in their working definition of intersectionality: (1) A recognition that all people are characterized simultaneously by multiple social categories, including, gender, race/ethnicity, SES, and sexual orientation; these multiple categories are interconnected or intertwined, and the experience of each social category is linked to the other categories; (2) A dimension of inequality or power is embedded within each of these socially constructed categories, and a recognition of inequality or power is essential to an intersectional analysis; and (3) These categories are characteristics of the

individual as well as the social context inhabited by that individual and the significance of these characteristics may be fluid and dynamic.

There is also a lack of agreement about intersectionality as a concept [18]. Some authors find intersectionality is a theory, others argue it is an analytic approach, and still others view intersectionality as a combination of both [9] [19] [20]. We view intersectionality as both a theoretical and methodological approach to understanding the meaning and consequences of an individual's multiple social category characteristics in relation to inequality and power. This intersectional approach enables us to consider respondents' multiple and interconnected identities as we strive to avoid the measure of any single demographic category as a discrete and complete identity [21]. Our work builds upon that of recent authors [10] [18] [22], who envision the potential of incorporating intersectionality into quantitative research. In particular, Else-Quest and Hyde [10] observed, "…assessing measurement invariance is ripe for an intersectional approach (p.327).

B. Purpose of the Study

The main purpose of developing the PEAS is to identify factors that may affect engineering faculty' persistence. This paper examines two questions regarding the scale development appeared in the PEAS to assess engineering faculty's psychological aspects on work climate for persistence. Therefore, study aims to evaluate the PEAS scale constructs and items through psychometric evaluation, providing reliability and construct validity evidence. Following research questions guided this study. As we aimed to survey engineering faculty using the valid and reliable PEAS, we targeted science, technology, engineering, and mathematics (STEM) faculty in general during the scale development procedure of this study.

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

II. Method

A. Survey Development

We undertook several steps during the scale development process to create a valid measure of the underlying constructs as guided by Clark and Watson [23]. First, we reviewed the literature to see how others have approached the problem of persistence in women engineering faculty and find the specific area is understudied. Although there have been many studies of persistence in female STEM students (e.g., [24]) and female engineering students in particular (e.g., [25]), there have been far fewer efforts to investigate persistence of female engineering faculty. Our study is informed by research of higher education faculty exploring the experiences of women in the academy (e.g., [26] [27]) and the literature on women in engineering careers (e.g., [28]).

Second, we identified ten constructs from the literature, including both psychological factors (e.g., motivation) and institutional factors (e.g., organizational climate and policies), that impact persistence of engineering faculty. Through the literature review, we identified eight factors

related to motivation and work climate that may affect faculty persistence. Based on the intersectionality framework, two additional factors (e.g., Finance During Higher Education, and Financial Responsibility) were considered to probe the effects of SES on the persistence of faculty. Table 1 presents the ten constructs, how each is defined in context of our study, and supporting literature.

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	[28] [29]
Departmental Climate for Diversity	An individual's perception of how well the department or unit attracts and recruits faculty in regard to different social identities, specifically gender, race/ethnicity, and class	[30] [31]
Departmental Climate for Inclusion	An individual's perception of how well the department or unit considers and supports faculty members from underrepresented groups in regard to different social identities, specifically gender, race/ethnicity, and class	[32]
Opportunities for Advancement/ Promotion	An individual's perceptions of the environment for advancement and/or promotion.	[33] [34]
Sense of Belonging	An individual's perceptions of the connection to and level of comfort in the workplace at the departmental level	[35] [36]
Scholarly Recognition	An individual's perceptions of colleagues' formal and informal acknowledgement of professional contributions, expertise, and performance.	[26] [30]
Mentoring	An individual's perceptions of the availability and quality of career development and psychological support from experienced colleagues	[30] [37]
Work/Life Balance	An individual's perceptions of the relationship between work and non-work obligations and demands.	[34] [38]
Finance During Higher Education	An individual's perceptions of his or her financial situation during higher education as an undergraduate and/or graduate student.	[39] [40]
Financial Responsibility	An individual's perceptions of his or her current financial situation and ability to fulfill obligations.	[40] [41]

Third, we identified demographic items from the literature noting that gender and SES are major components of our intersectional approach. Gender and sexual orientation questions are based on the APA Resolution on Data About Sexual Orientation and Gender Identity [42]. Demographic SES is probed at two points in time. First, during K-12 with a yes or no question asking if the respondent received free or reduced (F/R) lunch. We believe our questions are a more accurate indicator of SES than parent education level even though this is a binary measure of economic

status [43]. Gorard [44, pp. 1005] found the F/R lunch status in the US is "largely an indicator of child poverty threshold, rather than of social and cultural resources" which are often tied to a parent's education level. Taylor [45] found one advantage of free/reduced lunch as a measure of SES is that its definition and eligibility criteria have remained stable over time. We then probed SES during college with another yes or no question asking about receipt of need-based financial aid, as SES of individuals is a variable that changes over time through one's life.

Next, we again reviewed the literature for existing scales that measure any of the ten constructs. August and Waltham [46] examined faculty work-life through Hagedorn [15]'s Conceptual Framework of Faculty Job Satisfaction by probing departmental climate, workload, professional productivity, mentoring, tenure practices, and departmental influence. Gardner [34] investigated women faculty satisfaction and departure with items that included departmental fit, resources, informal network, respect from colleagues, recognition, work-life balance, and tenure and promotion processes. Yost et al. [37] examined recruitment of women in STEM and considered departmental fit, collegiality, mentoring, work-life balance, workload, and funding. Welch and Jha [47] investigated determinants of satisfaction among faculty with subconstructs that included: satisfaction with rewards, recognition, and reputation within the department; perceived influence over hiring, tenure, promotion, resource support, and service assignment within the department. Pedersen and Minnotte [27] studied the gendered network of university service work among STEM faculty and focused on workplace climate, specifically job satisfaction, scholarly isolation, workplace interpersonal conflict, and job stress.

Fourth, we generated a pool of items based on existing scale items, modifications of existing ones, and adding new items. The pool of items were judged by a panel of professors, post doctorates, and graduate students in engineering education to confirm face and content validity, which resulted in 63 items using six-point Likert-type responses (1 = strongly disagree to 6 = strongly agree) for the first pilot study. Based on the findings from the first pilot study, we revised and added new items for the second pilot study, which resulted in 65 items for the same ten constructs. Based on the comments from the participants and findings from the first pilot study, some demographic and background questions were revised and added for clarification on the PEAS for the second pilot study.

B. Participants

We conducted our first pilot study with STEM faculty at a Midwestern public research university in fall 2018. Potential participants were identified and contact information was obtained through public listings available on university websites. Data were collected online using a self-reported questionnaire administered through the PEAS [48]. While 1,276 STEM faculty were invited, 237 responded, but 215 completed the survey (16.8% response rate). Based on the EFA results, the second pilot study was conducted with STEM faculty at a second Midwestern public research university and a small private research university in the South in winter 2018. While around 1,800 STEM faculty were invited, 204 faculty members responded, but 179 completed the scale section of the survey (9.9% response rate). The mean age of the first pilot participants was 50.0 (n = 213, SD = 12.05) and the mean age of the second participants was 50.7 (n = 176, SD = 12.6). Table 2 shows the demographic characteristics of the participants from the PEAS capturing variables of gender, race/ethnicity, and class framed in intersectionality.

Table 2. Demographic Characteristics of STEM Faculty Participants

Category	Subcategory	First Pilot		Second Pilot	
		n	%	*n*	%
Sex	Female	80	37.2	81	45.3
	Male	135	62.8	98	54.7
Gender	Female	80	37.2	80	44.7
	Male	131	60.9	94	52.5
	Not to answer	4	1.9	2	1.1
Ethnicity	Hispanic	13	6.0	6	3.4
Race	Non-Hispanic	202	94.0	170	95.0
	American Indian or Alaska Native	0	0.0	2	1.1
	Asian	25	11.6	19	10.6
	Black	5	2.3	8	4.5
	White	167	77.7	140	78.2
	Multiracial	5	2.3	1	0.6
Nationality	Citizen by born in USA	149	69.3	127	70.9
	Citizen by naturalization	46	21.4	21	11.7
	Citizen by born in non-USA	2	0.9	2	1.1
	Permanent resident	14	6.5	22	12.3
	International (2W, 1A, 1H)	4	1.9	4	2.2
Class	High School F/R lunch	10	4.7	10	5.6
	Financial Support during College	156	72.6	109	60.9
	Need-based Financial Aid for College	58	27.0	40	22.3
	Work outside to finance College Education	117	54.4	94	52.5
	Debt Free Higher Education (No)	88	40.9	81	45.3
Undergraduate	Outside of USA	57	26.5	45	25.1
Education	USA	158	73.5	134	74.9
Highest	Doctoral	206	95.8	175	97.8
Degree	Master's	8	3.7	1	0.6
	MD/PhD	1	0.5	3	1.7
Track	Tenure	180	83.7	132	73.7
	Non-tenure	35	16.3	47	26.3
Major	Science	122	56.7	139	77.7
	Engineering	77	35.8	32	17.9
	Mathematics	13	6.0	8	4.5
	Technology	1	0.5	0	0.0
Total		215	100.0	179	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 and internal consistency reliability analyses for reliability. 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 7.11 [49] was utilized as an estimator to obtain parameter estimates for factor analyses with categorical data.

First, an exploratory factor analysis (EFA) was conducted using 214 STEM faculty data from the first pilot study 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 revised items and added new items for the ill-structured constructs. Third, another EFA using 179 STEM faculty data from the second pilot study was conducted again to identify underlying factor structure and irrelevant items that did not fit into any factors that exist in the revised scale. Finally, 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 [50], to investigate how items are inter-related within each factor, sub-factor, and the overall instrument.

III. Results

A. Exploratory Factor Analysis Modeling

First Pilot Study. Polychoric correlation coefficients among the 63 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 [51]. This yielded ten factors considered for inclusion in a putative factor structure for the scale. According to Stevens' [52] 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. This cutoff functioned to suppress any irrelevant items that did not fit well into the designated factor. In addition, if an item loaded onto more than one factor, then the item was excluded. This resulted in insufficient number of items less than three items loaded onto the two factors (Opportunities for Advancement/Promotion and Sense of Belonging). This resulted in 45 items, out of the original 63, that had significant factor loadings onto one of eight factors, indicating each item's unique contribution to one of the factors.

Second Pilot Study. Based on the findings and comments from STEM faculty participants from the first pilot study, some scale items were revised and new items were added to reinforce the two constructs (Opportunities for Advancement/Promotion and Sense of Belonging) and other constructs. Particularly, we revised items for mentoring, considering two underlying sub-constructs of mentoring on career development and psychological support in the literature ([30] [37]). These revision and addition resulted in a total of 65 items for ten constructs. A similar pattern of the polychoric correlation coefficients was found for the data collected from 179 STEM faculty at different two universities. Again, EFA revealed that 60 items loaded on the ten

factors were considered for inclusion in a putative factor structure for the scale. Table 3 examples an item loaded for each construct on the PEASE Scale.

Table 3. Example Items for Ten Constructs in the PEAS Scale

#	Construct	Item
1	Intrinsic Motivation	I keep 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 and/or 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 with whom I can exchange confidences.
8	Work-Life Balance	My work responsibilities do not interfere with my personal responsibilities.
9	Finance during Higher Education	Finances did not delay my transitions across educational levels.
10	Financial Responsibility	I keep my job to fulfill my financial responsibilities.

B. Internal Consistency Reliability Evidence

Data from the 179 STEM faculty from the second pilot study were utilized for the reliability analysis. The overall reliability of the PEAS scale with 60 items was Cronbach's $\alpha = 0.959$. Each construct housed in the PEAS scale appeared to have good internal consistency as shown in Table 4. Cronbach's α values of the 10 constructs ranged from 0.780 to 0.985. 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 4 shows the number of items tested for EFA modeling in the first and second pilot studies along with the internal consistency reliably evidence.

Table 4. Number of Items and Internal consistency reliability evidence of the PEAS

Construct	First Pilot		Second Pilot		
	N_i	N_f	N_i	N_f	Cronbach's α
Intrinsic Motivation	5	5	5	5	0.897
Departmental Climate for Diversity	5	4	4	4	0.929
Departmental Climate for Inclusion	10	9	9	9	0.936
Opportunities for Advancement/Promotion	5	0	5	4	0.898
Sense of Belonging	8	0	10	8	0.919
Scholarly Recognition	9	9	8	8	0.957
Mentoring	6	6	11	11	0.985
Work/Life Balance	5	5	5	5	0.886
Finance During Higher Education	5	3	4	3	0.780
Financial Responsibility	5	4	4	3	0.865
Total	63	45	65	60	0.959

Note. N_i = number of the total items in the construct; N_f = number of the total items validated for the construct after EFA

IV. Discussion

This study aimed to develop the PEAS as a valid measure of higher education engineering faculty persistence. First, we identified ten constructs from the literature to represent both psychological (motivation) and institutional factors (work climate). Next, we identified demographic items from the literature and included items to probe gender, race/ethnicity, and SES based on the intersectionality framework. Our items were evaluated for content and face validity and we tested 63 items in the first pilot study. The EFA with the data from 214 STEM faculty resulted in 45 items, out of the original 63, having significant fit with eight of the designated constructs (intrinsic motivation, departmental climate for diversity, departmental climate for inclusion, scholarly recognition, mentoring, work/life balance, finance during higher education, and financial responsibility). Items for two constructs (opportunities for advancement/promotion and sense of belonging) either cross loaded with more than one factor or loaded below the designated cutoff factor. Based on these results and respondents' comments, some scale items were revised and new items were added for mentoring in addition to opportunities for advancement and sense of belonging. A second pilot study consisting of a total of 65 existing, revised, or new items for the ten constructs collected data from 179 STEM faculty. The EFA identified the factor structure of the 60 items loaded on one of ten factors. In summary, through two pilot studies with 394 STEM faculty from three institutions, the factor structure of the PEAS scale was identified to have ten factors indicated by 60 items with good internal consistency reliability evidence.

A. Limitations of the Study and Suggestion for Future Research

There are several limitations in this study. First, even though we identified the constructs as factors that may relate to STEM faculty persistence, they are not certain yet until we find their associations with STEM faculty persistence. Our comprehensive literature review supports a broad range of factors as potential predictors of faculty persistence. However, we had to select a limited number of factors for the PEAS questions and scale items because there is no way to

include all of them. Therefore, the factors probed in the PEAS are not the definitive or only factors underlying an individual's persistence as a faculty member.

Second, a sampling bias might exist. University based faculty members are recognized as a unique cohort in online survey research. Surveys are a popular research tool, and the survey response rate of higher education faculty is associated with the civic virtue of responsible involvement as a university community member. However, low response rates in surveys of university faculty do occur. Menachemi [54] found several reasons for non-participation among university faculty. First, questions that address sensitive topics may increase the non-response rate even when survey participation is anonymous. The PEAS probes topics that may be considered sensitive or private. Next, certain subpopulations may be too busy to respond. We received emails from some potential respondents stating they were too busy to participate in our study. In addition, some potential respondents may not trust the researchers or feel that any good will come from their participation. We also received emails from potential respondents who observed university climate studies were too common and not helpful.

However, low response rates in a university division such as a department may also indicate faculty disengagement from institutional service. Mathews [55] investigated faculty survey non-respondents. One key theme that emerged was that many faculty groups, including faculty of color, foreign-born faculty, and long-term associate professors, are the least likely to participate in surveys of workplace attitudes. The PEAS seeks to investigate the experiences of engineering faculty including many of the subgroups identified by Mathews. This unintended selection process within our target population may result in survivor bias where certain subgroups lack visibility within the survey results.

Third, even though the target population for the PEAS is higher education engineering faculty in the US, the sample for this study consists of STEM faculty at three universities. Therefore, the results are limited in generalizability, and we should not make inferences beyond the sample characteristics of this study.

To finalize the items and factor structure of the instrument, confirmatory factor analyses will be applied to a new data set collected during spring 2019 from a national study, targeting engineering faculty in nation. Additional evaluations of validity, such as convergent, discriminant, concurrent, and predictive, are planned for future study.

Meaningful comparisons of subjective constructs between groups requires that scale items and latent traits of individuals should remain independent of group membership, such as a demographic identity [56] [57]. Measurement invariance, (MI), also known as measurement equivalence, is a condition where a test or scale is found to measure the same construct in the same way across different groups [58]. MI is important because it is viewed as a prerequisite to comparing group differences and similarities [59]-[61]. We echo Davidov et al. [59] in emphasizing that MI does not imply there are no differences between groups on a measured construct. Rather, individuals from different groups who have the same position should provide similar responses, and this allows differences based on individual traits rather than a group identity to emerge. We recommend a future study on measurement invariance of the PEAS across subgroups.

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 discipline faculty member.

B. Significance of the Study

We anticipate the finalized scale will be generalizable across populations across different institutions in the United States. The 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. Therefore, this study is significant because it provides insight that institutions could use to support faculty in engineering.

According to the National Science Foundation, the marginal participation and advancement of women in STEM is often a result of external factors unrelated to an individual's ability or performance [7]. Two of the external factors identified are the organizational constraints of academic institutions and the culture and climate of academic organizations. This study begins to provide an understanding of how organizational constraints, culture, and climate are viewed and experienced by individuals differently based on the entwined social positions of gender, race/ethnicity, and SES. It is hoped that the findings of this study can inform both the hiring process to attract more candidates and the promotion and tenure process to improve the retention rate and advancement of individuals from underrepresented populations in engineering faculty positions.

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