The Engineering Student Identity Scale

A Cross Disciplinary Exploration of Factor Structure

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***Abstract*— To correctly engage in the instrument development process takes time. According to Benson's model of construct validation (1) there are at least three lengthy stages (substantive, structural, external) to construct validation when developing a new measure. This study examines how instrument structure impacts the validation process and what it can tell us about instrument revision. In this study we will take a closer look at the development of the Engineering Student Identity Scale (ESIS). After engaging in the in-depth substantive stage of instrument development, the instrument developers began the process of examining whether the anticipated factor structure of the measure fit the observed data. Results from a series of CFA analyses indicated that none of the hypothesized models fit the observed data. While instrument revision at any stage of development is important and likely to lead to a better measure, it is important to gather as much information as possible from each stage to guide revisions. In an effort to better understand how the items on the ESIS instrument function together, a cross-disciplinary team of psychology and engineering experts conducted a series of CFAs and an EFA to examine the factor structure present in the observed data. Initial results support a six-factor structure. Implications for the next round of instrument development are discussed.** **Keywords—engineering identity, retention, recruitment**

I. Introduction

Despite immense efforts and funding investments to diversify the undergraduate engineering student body, recruitment and retention issues still persist in engineering (2). One area that has received attention during the past decade is professional identity development in engineering education. Before a student can identify with being an engineer though, a student must also identify with being an engineering student. This is an important distinction that emerged from our past research (3)(4). Through our larger body of research work, we want to contribute to our understanding of the engineering student identity. This involves understanding the factors (experiences, situations, and settings) that foster the formation and transformation of this identity during the undergraduate experience in order to gain insight into improving recruitment and retention of engineering students, particularly underrepresented students. However, in order to empirically explore the role of identity, we must first have a psychometrically sound measure of engineering student identity. Our previous work has focused on the development of such an instrument (3)(4).

II. The Engineering Student Identity Survey (E-SIS)

Using the lens of identity theory, we developed the Engineering Student Identity Scale (ESIS). We conducted an extensive literature review, examining the domain of identity development and exploring the relationships among identity and theoretically related constructs (i.e Benson's substantive stage). ESIS Items were developed using approaches grounded in the psychological identity literature (e.g. sense of belonging, visibility of affiliation, and distinctiveness). This resulted in the creation of 38 items designed to assess 11 separate subscales, each mapping back to one of the psychological approaches to assessing identity. Sample items associated with each of the identity themes are presented in Table 1. On each of the 38 items, participants were asked to rate "the extent to which you agree" with each item on a 6-point Likert scale, with 1 being "Completely Disagree" and 6 being "Completely Agree." The overall ESIS score ranges from 1 to 6 with higher scores indicating a more developed overall engineering identity. The item scores for each subscale were averaged to create subscale scores. Thus, ranges for each of the subscales also ranged from 1 to 6. Estimates of reliability for each of the subscales were adequate (Cronbach's α = .69 - .90).

Implementing the second stage of Benson's framework (i.e. structure) for establishing construct validity evidence, we conducted an initial examination of item functioning. For this intital evidence, the items were administered to over 500 engineering students from 2010 to 2016. If items were measuring the subscales they were created to measure, one would expect a given item to be more correlated with items on the same subscale than to items created to measure other subscales. Initial item analysis indicated that while some items performed as expected, the performance of other items were less clear. To further examine the structure of the ESIS, several theory-driven confirmatory factor analyses (CFA) were conducted. However, none of the expected models were supported (5). While it is likely these models did not fit the data because the created items did not adequately represent the identity approaches selected during the substantive stage, an inadequate sample size may have been the reason some of the models did not converge.

In the current study, additional data was added to the earlier dataset in hopes that some of the more data heavy models would converge if the CFAs were repeated. In addition, a further examination of the items and their origins revealed roots in both psychological and sociological theory. In order to

The authors would like to acknowledge the support of the National Science Foundation. Please see acknowledgements.

978-1-5090-5920-1/17/$31.00 ©2017 IEEE

further explore the relationships across both the items and cross-disciplinary theories we conducted an Exploratory Factor Analyses (EFA). The results of both the CFA and EFA analyses are considered in their contribution to scale revision efforts and implications for identity theory in STEM are also discussed.

Table 1: Sample items by identity theme

Subscale	Sample Item
Unified Self-Concept	I feel like I am fundamentally the same person when engaged in engineering and non-engineering activities.
Distinctiveness	Being a member of the engineering community is something that distinguishes me from others
Participation	I actively seek out participation in engineering-related activities
Self-Enhancement	Being an engineering student makes me feel important
Social Support	I have peers in engineering with whom I can share my joys and sorrows
In-group Cooperation	I feel comfortable around other engineering students
Visibility of Affiliation	I can often be seen off campus with other engineering students
Sense of Belonging	I feel a strong sense of belonging to engineering
Citizenship Behaviors	I feel a great deal of loyalty toward engineering
Interest	I find engineering topics intriguing or exciting
Attitudes toward Becoming an Engineer	I can see myself becoming an engineer when I am done with school

III. METHODS

A. Participants

Samples of engineering students from 2010 to 2017 responded to the E-SIS and were aggregated into a single dataset for a final sample of 668 participants. This data set included over 100 additional student responses collected in 2017. All participants were engineering students enrolled at a midsized southeastern university. Complete gender data for the sample is not available because gender information was not collected during some of the administrations. However, for those who reported gender identification, the sample was more heavily female (28%) than the program population. At the time of data collection, 153 students were in their first year, 135 were students in their second year, 183 were students in their third year, and 205 were students in their final year of the program. All human subject procedures were followed in collecting the program-level data.

B. Materials and Procedure

The E-SIS is a 38-item instrument designed to gauge a participant's identification with being an engineering student. The instrument was created to include 11 approaches to measuring identity. This pool of items contains sets of three items designed to represent participation, distinctiveness, visibility of affiliation, in-group cooperation, interest, attitudes, and social support; sets of four items designed to represent citizenship, self-enhancement, and sense of belonging; and a set of five items designed to represent unified self-concept (see (3) for a more complete discussion of these approaches). Participants responded to the 38 E-SIS items on a 6-point, Likert-type scale of Strongly Disagree to Strongly Agree. The E-SIS was administered via the online survey platform Qualtrics. The engineering department sent students an email with a link to the scale for completion on their personal computer. Student's only incentive for completing the E-SIS was a dining voucher for use on campus.

IV. RESULTS

A. Confirmatory Factor Analyses

A series of Confirmatory Factor Analyses were conducted to test three theorized structures for the items on the ESIS (5). Initial results suggested that none of the theorized structures were supported by the empirical data. For a full description of the assumption testing, chosen procedures, and results for data prior to 2017, see (5). After the addition of the 2017 data, the results for the one-factor model suggest worse fit to the data. This is evidenced by a larger chi-square value and a lower CFI index compared to previously estimated values. After the addition of the 2017 data, the higher order model no longer converges to a solution. This indicates severe model data misfit. The 11-factor model did not converge to a solution with either dataset. The results of the new CFA analyses continue to suggest that the theorized models do not fit the observed data well. Thus, exploratory factor analysis procedures were employed.

B. Exploratory Factor Analyses

An Exploratory Factor Analysis (EFA) using principal axis factoring was conducted on the 38 items with oblique (promax) rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .97, and all KMO values for the individual items were greater than .9, which is well above the convention for an acceptable limit of .5. Bartlett's test of sphericity $\chi 2$ (703) = 13196.84, $p < .001$, indicated that relations between items were sufficiently large for EFA. An initial analysis was conducted to obtain eigenvalues for each component in the data. Eight factors had eigenvalues greater than Kaiser's criterion of 1 and in combination explained 61% of the variance. The scree plot was slightly ambiguous and showed inflections that would justify retaining 3, 6, or 8 factors. Given the large sample size, and the convergence of the scree plot and Kaiser's criterion on 8 factors, we explored the 8-factor solution in the final analysis. However, factors 7 and 8 were found to contain only one unique item and thus a 6-factor solution is presented. Table 2 shows the factor loadings after rotation along with descriptive information, and communality value.

Table 1: CFA models, global, and incremental fit indices evaluated for the E-SIS

Simple Structure Models							
		χ^2	df	p-value	SRMR	RMSEA	CFI
1	38-item, 11 factors	-	-	-	-	-	-
2	38-item, 1 factor	6009	665	<.0001	.07	.11	.71
Higher-order Models							
		χ^2	df	p-value	SRMR	RMSEA	CFI
3	38-item, 11 factors with 1 higher-order factor	-	-	-	-	-	-

*Notes: '-'indicates that the model did not produce admissible results.
Degrees of Freedom calculations for all models available upon request from the first author.

Table 2: Sample items by identity theme

Item	factor1	factor2	factor3	factor4	factor5	factor6	Communality	Mean	SD
Prof 7	0.98						0.74	5.28	1.04
Sob 10	0.90						0.73	5.00	1.11
Prof 34	0.84						0.76	5.08	1.04
Prof 22	0.80						0.71	4.99	1.07
Sob 9	0.72						0.64	5.07	1.09
Cit 8	0.62						0.73	4.91	1.16
Int 18	0.61						0.62	5.21	0.92
Cit 12	0.55						0.57	5.34	0.85
Int 6	0.50						0.53	5.19	0.92
Voa 11		1.00					0.80	4.51	1.55
Ss 38		0.96					0.72	4.57	1.55
Voa 20		0.96					0.74	3.91	1.71
Igc 13		0.73					0.71	4.76	1.29
Ss 5		0.67					0.63	4.90	1.25
Ss 31		0.60					0.57	4.59	1.25
Usc 27		0.51					0.64	4.61	1.13
Igc 35		0.46				0.42	0.66	4.99	1.06
Sob 21		0.45					0.64	4.72	1.12
Se 17			0.88				0.68	5.19	0.99
Se 4			0.69				0.51	5.21	0.95
Se 37			0.64				0.67	4.85	1.13
Dist 19			0.57				0.59	4.84	1.08
Voa 15			0.45		0.41		0.48	4.01	1.44
Usc 14				0.78			0.68	5.00	1.10
Usc 16				0.65			0.63	5.08	1.02
Usc 1				0.55			0.26	4.43	1.23
Part 33					0.64		0.68	4.59	1.16
Part 25					0.63		0.46	4.24	1.45
Part 3					0.51		0.50	4.28	1.21
Cit 32						0.56	0.58	5.28	0.92
Se 29						0.42	0.66	5.22	0.98
Igc 30						0.41	0.51	4.79	1.04
Sob 36							0.72	4.85	1.12
Dist 2							0.51	5.22	0.84
Dist 26							0.30	4.63	1.19
Cit 28							0.53	4.91	0.98
Usc 23							0.65	4.78	1.06
Int 24							0.39	5.03	0.98
% Variance	45%	7%	3%	2%	2%	1%			

*Note: All loadings less than .40 are suppressed for interpretability

V. Discussion

Repeating the CFAs with a larger sample size did not assist the models in converging. In fact, the opposite occurred. Models that converged during the initial study (5) failed to converge, reinforcing our previous conclusions that the hypothesized models do not adequately fit the data. The only model to converge in the present study was the one-factor model; however, the fit indices indicate worse fit than in the previous study. This reinforces the need for additional item revisions.

The researchers conducted the EFA in an attempt to gather additional information regarding how the items were functioning together. While the results show a possible 6-factor solution, the majority of the variance was accounted for by the first (45%) and second factors (7%). There is no clear interpretation of the factors for either the 6 or 2-factor solution; however, many of the items in factor one may align with the identity development theory of self-categorization and many of the items on factor two may align with the salience that is theorized to come after self-categorization (6)(7). It may also be informative that all of the items that load on factor 1 have either "I" or "me" in the stem. This may suggest a wording effect. In terms of the instrument development process, we cannot move into the external stage of Benson's model until the structural stage yields support for the construct validity of the emerging instrument. Thus, we intend to use information gathered from the CFA and EFA processes to revise the ESIS.

Given the results of this study combined with those from the previous study (5), some researchers might become disheartened with the scale development process. However, this would be a mistake. The process of test development is inherently a process of trial and revision. Our first attempt did not pan out as we would have hoped. This is not surprising; the first attempts in test development hardly ever do. The results of these studies provide a wealth of evidence supporting not only that the scale is not working as expected, but also providing valuable information regarding how the scale might be improved. For example, we can see ample evidence that the wording of some items likely influenced student responses. In our revision efforts, we can now use that information to eliminate item-wording differences that are irrelevant to the information that we want to collect. Armed with this information we go back to the substantive stage, re-engage our experts, and produce revised items using the information we have gathered from our series of studies. We are excited and confident in our knowledge that the next version of the ESIS will be better than the first. We are also comfortable in the knowledge that our second effort may not be our final effort, but, that we will again gain information vital to the long-term scale development process.

Acknowledgment

The authors would like to acknowledge the support of the National Science Foundation Awards #EEC-0824337 and #EEC-0846468. The views expressed in this paper are those of the authors and do not necessarily represent those of the NSF. We would also like to thank the engineering students that participated in this study and the following research team members – Kathleen Casto and Anna Zilberberg – who were instrumental with the development of the survey and data analysis.

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