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The Engineering Student Identity Scale: A Structural Validity Evidence Study

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Abstract

Researchers have theorized that having a strongly developed identity as an engineering student contributes to persistence within engineering. Even so, there are no empirically supported measures of *engineering* student identity. The purpose of this study was to provide structural validity evidence for one such measure, the Engineering Student Identity Scale (E-SIS). This paper explores findings and implications of multiple investigations into the structure of the E-SIS. The data collected in this study do not support the current interpretations of the E-SIS as a unified measure of identify with 11 subscales derived from multiple approaches to measuring identity. The results do provide important information regarding revising the E-SIS to align more with fewer subscales and to focus exclusively on items that are directly affected by identity.

I. Introduction

Recent data from the National Science Board (2014) suggests that only half of students who matriculate into undergraduate engineering programs in the United States will earn an engineering degree. Despite immense efforts and funding investments, recruitment and retention issues still persist in engineering. One such effort that has received attention over the past decade is understanding professional identity development in engineering. Before a student can identify with being an engineer though, a student must first identify with being an engineering student; an important distinction that emerged from past research (Pierrakos, Beam, Constantz, & Anderson, 2009). Continuing this research line, we wish to (a) contribute to the understanding of engineering student identity; (b) understand the factors (experiences, situations, and settings) that foster the formation and transformation of identity during the undergraduate experience; and (c) gain insight into improving recruitment and retention of engineering students, particularly underrepresented students. However, in order to empirically explore the role of identity for engineering students, we must first have a psychometrically sound measure of engineering student identity.

Why Care About Identity?

A plethora of previous studies have focused intently on retention issues in engineering; however, this research only describes the issues (French, Immekus, & Oakes, 2005; Geisinger & Raman, 2013; Matthews, 2012; Moller-Wong & Eide, 1997) or suggests potential solutions to them (ASEE, 2012; Kline & Tsang, 2013). Fewer studies have explicitly attempted to discover why students enroll or dropout. We have attempted to address this gap by framing the issues in the context of student identity. Researchers have theorized that having a strongly developed identity as an engineering student contributes to persistence within engineering (Beam, Pierrakos, Constantz, Johri, & Anderson 2009; Cech, Rubineau, Silbey, & Seron, 2011). Even so, engineering student identity has no agreed upon definition. The limited attempts to measure engineering student identity (Dehing, Baartman, & Jochems, 2013; Meyers, Ohland, Pawley, Silliman, & Smith, 2012) do not have sufficient theoretical support, sufficient validity evidence, nor have they provided information that has been successful in informing retention efforts. Nevertheless, although the literature specific to engineering identity is sparse, the field of psychology provides a strong body of diverse identity literature. No previous engineering student identity measures have considered the psychological literature. Thus, to begin exploring identity in engineering students, we borrowed heavily from the established literature in psychology.

How is Identity Defined in This Study?

Using the psychological literature as a guide, researchers (Pierrakos , Curtis & Anderson, 2016; Pierrakos, Casto, Curtis, Pappas & Anderson, 2017) developed the Engineering Student Identity Scale (E-SIS). The E-SIS consists of 38 items representing multiple approaches to measuring identity based on social and identity role theory literature. Sections below briefly review these approaches and Pierrakos, et al. (2016) provide an explanation of each approach.

The concept of identity is heavily rooted in social psychology. Social psychologist, Vivian Vignoles and her coauthors (2006) defined identity as a person's subjective concept of oneself. Operationally, researchers have often further conceptualized group identity through two inter-related theories: identity role theory and social identity theory. These theories are related but examine identity through different lenses (Stets & Burke, 2000; Tajfel & Turner, 1986). Both theories highlight the differences between the members of different groups and the similarities of in-group members as a way of defining group identity. The theories diverge in that identity role theory focuses heavily on the observable behaviors, roles, and expressions of group members whereas social identity theory focuses on the unobservable cognitive processes related to self-categorization into a group. In developing a measure of identity, it is important to recognize that these theories do at points overlap and both must be accounted for when developing an overall idea of the self and thus must be incorporated in any measure designed to assess identity (Stets & Burke, 2000).

Identity role theory. Identity role theory (Stets & Burke, 2000; Stryker & Burke, 2000) is rooted in a sociological framework that defines group identity by the observable characteristics common across those occupying a group-specific role. Identifying with a role consists of incorporating the meanings and beliefs associated with that role into one's self-concept. The theory posits that individual behaviors reflect those role-specified meanings and beliefs. In this vein, identity role theory is concerned with predicting role-related behaviors. While the same person can occupy different roles (i.e. be a member of different groups), those roles that most influence behaviors are considered to have a stronger influence on identity. Thus, because the role-influenced behaviors differ between people, the group identity driving them also differs.

Social identity theory. Social identity theory (Tajfel & Turner, 1986) is a psychological theory that states that the internal process of self-categorization of belonging to a group defines groups identity. The defining characteristics of the group continue to provide the basis of individual social identity, as the characteristics are defined by an internal, cognitive process that is not directly observed. Throughout the psychological literature, researchers have examined several approaches to operationalizing identity. These approaches include unified self-concept, interest, sense of belonging, attitudes, self-enhancement, social-support, and in-group cooperation, distinctiveness, visibility of affiliation, participation, and citizenship (See Pierrakos, 2016 for a description of each of these approaches).

The Engineering Student Identity Scale

The Engineering Student Identity Scale (E-SIS) (Pierrakos et al., 2016; Pierrakos et al., 2017) was created to address the gap in identity literature specific to engineering students. The E-SIS was created through a deductive method (Smith, Fischer, & Fister, 2003). In redefining the construct of engineering-student identity through a psychological lens, the developers began a process of collecting validity evidence as set forth by Benson (1998). Through this process, experts in engineering education and social psychology were recruited to write appropriate items for the measure. An initial large pool of items was revised and reduced to the current set of 38 based on expert consensus (Pierrakos et al., 2016). Through this process, 11 subscales were created, each containing at least 3 items, believed to represent distinctiveness, visibility of affiliation, participation, citizenship, unified self-concept, interest, sense of belonging, attitudes, self-enhancement, social-support, and in-group cooperation. Pilot studies (Pierrakos, Curtis, & Anderson, 2016) indicated that the subscales could reliably differentiate between first-, second-, third-, and fourth-year engineering students; albeit each in a somewhat different way.

Purpose of the Study

In collecting information concerning the formation of engineering student identity, we hope to provide a more holistic and useful framework for academic programs to measure student identity. Moreover, we hope that this information will guide interventions to help students remain in the major and matriculate into engineering jobs. However, in order to use the E-SIS to reliably inform changes, it must first be shown to function in the ways expected by the theories. Although the E-SIS was developed based on a review of established identity theories in psychology, the hypothetical structure has not been empirically tested with engineering students.

To further examine the structure of the E-SIS, several theory-driven confirmatory factor analyses (CFA) will be conducted. The purpose of conducting several CFAs is to determine whether any level of the theories used to develop the scale are supported: an 11-factor model (figure 1.1), a unidimensional model (figure 1.2), or an 11-factor with 1 higher order factor model (figure 1.3). These models also reflect how the E-SIS has to this point been scored, as a single identify factor and 11 subscales, each matching to one of the measurement approaches described above.

Three models are examined in this paper (see Figures 1.1 through 1.3 for a visual of these theoretically based models). Model 1 (Figure 1.1) represents a combination of the 11 separate theoretical approaches and supports the scoring of 11 subscales. Model 2 (Figure 1.2) combines all theoretical approaches into a unidimensional theory of identity and supports the scoring of 1 scale. Model 3 (Figure 1.3) represents a combination of the 11 separate theoretical approaches and additionally combines the 11 theoretical approaches into an overall identity score. Model 3 supports the scoring of 1 overall scale and 11 subscales. In order for the current conceptualization of the E-SIS to be supported, one of these three models should fit the observed data. In other words, our research questions examine: 1) Does the E-SIS represent 11 separate scales?; 2) Does the E-SIS represent one overarching measure of identity?; and 3) Does the E-SIS represent a combination of the 11 separate scales and an overarching measure of identity simultaneously?

Engineering Identity

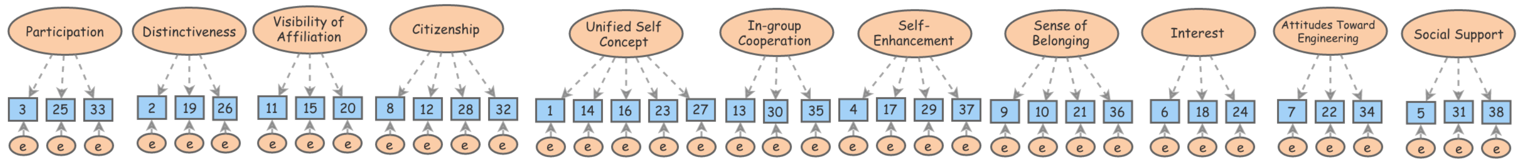

Figure 1.1 Factor structure diagram for model 1.
*note that all factors were allowed to correlate in model 1. Correlation arrows omitted from the diagram for clarity.

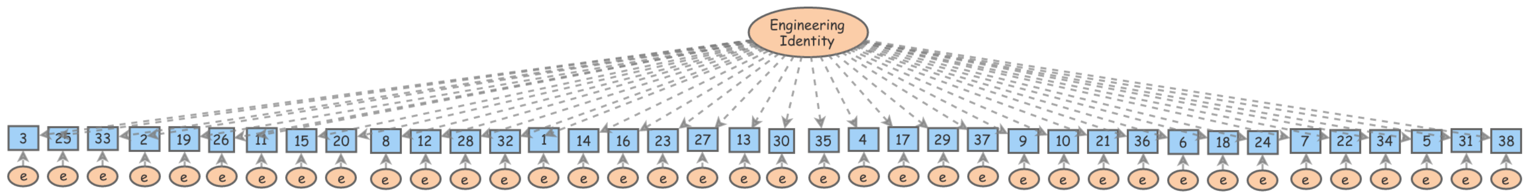

Figure 1.2 Factor structure diagram for model 2.

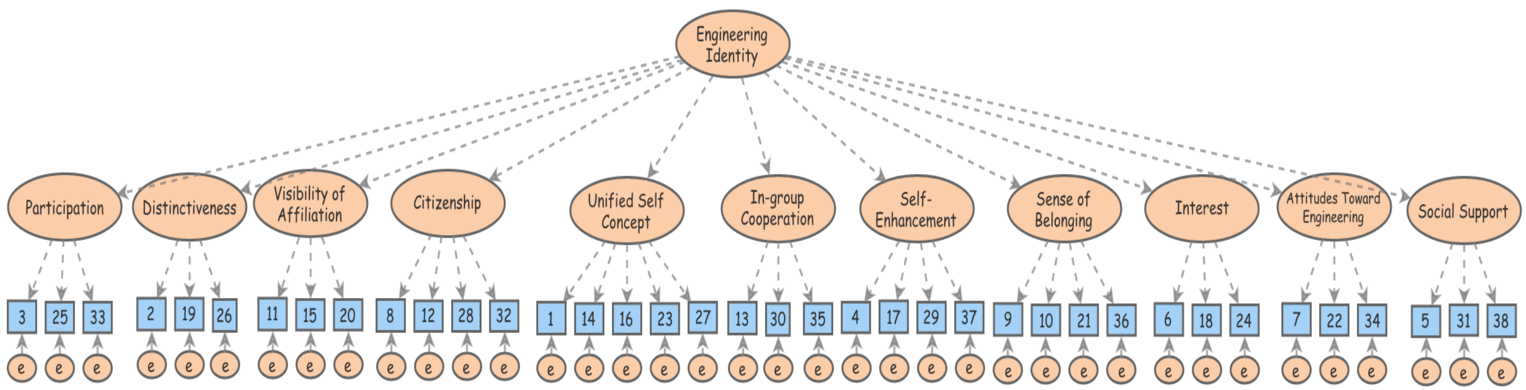

Figure 1.3 Factor structure diagram for model 3.

Method: Participants

Samples of engineering students from 2010 to 2015 responded to the E-SIS and were aggregated into a single dataset for a final sample of 562 participants. All participants were engineering students enrolled at a midsized southeastern university. The engineering program from year to year consists of between 75 to 80% who identify as male, between 15 to 20% who identify as female, and 3% who do not specify. In the current survey collection, for those who reported gender identification, the sample was more heavily female than the program population (28%). However, complete gender data for the *sample* is not available because gender information was not collected during some of the administrations. At the time of data collection, students had completed varying amounts of the engineering curriculum with 124 students in their first year, 94 students in their second year, 163 students in their third year, and 181 students in their final year of the program. All human subject procedures were followed in collecting the program-level data.

Materials and Procedure

The E-SIS, a 38-item instrument designed to gauge a participant's identification with being an engineering student, was the sole measure used in this study. The instrument was created to reflect the theories described in the introduction. The E-SIS was administered via the online survey platform Qualtrics. Participants received an email from the engineering department with a link to the scale and completed the E-SIS on their personal computer. Students who completed the survey were provided a campus dining voucher.

Participants responded to the 38 E-SIS items on a 6-point, Likert-type scale of Strongly Disagree to Strongly Agree. 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.

Data Analysis

The development team for the E-SIS initially suggested scoring the instrument by reporting a single overall score and 11 individual subscale scores. This scoring scheme would map to a higher-order model consisting of 11 factors and a single higher-order factor, engineering identity (Figure 1.3). Higher-order models include a general factor as well as domain specific factors. The relationship among the domain-specific factors is hypothesized to be explained by the general factor (Chen, West, & Sousa, 2006; Patrick, Hicks, Nichol, & Krueger, 2007). In addition to the full theoretical model, given that the 11 operationalized measurement approaches may explain the data more parsimoniously, multiple combinations of models using these theories will be examined (Figure 1.1 through 1.3). Unless otherwise noted, all latent variances were set to 1.

Results

Descriptive statistics for the E-SIS are presented in Table 1. Data were screened for multicollinearity and univariate normality and found to have no significant issues. A non-parametric examination of outliers revealed no issues. The possibility of multivariate outliers was explored by examining the distribution of Mahalanobis distances. No large gaps appeared in the distribution at either end; thus, multivariate outliers are unlikely. Multivariate kurtosis was examined using Mardia's standardized statistic (97.48) and this sample was found to produce value greater than 3 (Bentler & Wu, 2003) indicating possible issues.

In order to inform possible corrections due to multivariate kurtosis later in the analyses, an asymptotic covariance matrix was computed using PRELIS (Jöreskog & Sörbom, 2015). Unfortunately, due to the complexity of the model given the sample size available, the matrix was nonpositive definite and unable to be calculated. However, given that univariate kurtosis was not an issue in any single variable and no definitive guidance for Mardia's coefficient has yet been established by researchers, the multivariate non-normality will be assumed to be minimal and have little effect in the current study. The observed correlation matrix suggests that the patterns of correlations implied by the various models tested in this study (e.g. 11 groups of item correlations more similar to each other than other items for the 11 factor model) are unlikely to hold.

As the data are considered multivariate normal, the models are likely misspecified, and we have a relatively large sample, Maximum Likelihood (ML) estimation was used to analyze the data for all models. Research suggests that ML estimation is more sensitive to model misspecification, does not require the extremely large samples necessary for Weighted Least Squares (WLS) estimation, and does not require a post-hoc adjustment for kurtosis, as used with Maximum Likelihood with a Satorra-Bentler adjustment (ML-SB), due to the assumption of multivariate normal data (Olsson et al., 1999; Olsson et al., 2000). All models were evaluated using LISREL 9.2 (Jöreskog & Sörbom, 2015).

Following the recommendations of Hu and Bentler (1998;1999), global fit was examined for each model using a hypothesis test and at least a two-index presentation strategy. Specifically, the models were assessed using the χ^2, the standardized root mean square residual (SRMR), the Root Mean Square Error of Approximation (RMSEA), and the comparative fit index (CFI). The SRMR, RMSEA, and CFI were chosen based on evidence that they are not as sensitive to sample size as other fit indices, are sensitive to misspecification of both factor loadings and correlations, and function well using ML estimation (Hu & Bentler, 1998). Further, these three indices were paired because SRMR is sensitive to the misspecification of factor correlations while the RMSEA and CFI are sensitive to the misspecification of factor pattern coefficients. Research has suggested the following cutoff values as indicative of model fit: SRMR < .07 to .09, RMSEA < .06 to .08 and CFI >.95 to .96 (Browne & Cudeck, 1993; Hu & Bentler, 1999; Yu & Muthen, 2002). However, the researchers that put forth these recommendations and others (Marsh, Hau, & Wen, 2004) note that these recommendations should be treated as guidelines and not absolute decision points. Thus, these fit indices will be examined in the context of all other information including local misfit as indicated by correlation residuals produced when comparing the model-implied correlations to the observed correlations.

Table 1. Descriptive Statistics for the ESIS Items

Subscale	Item #	Mean	SD	Skew	Kurt
Unified Self Concept	1	4.53	1.09	-0.29	-0.90
Unified Self Concept	14	5.11	0.87	-0.50	-1.04
Unified Self Concept	16	5.19	0.83	-0.61	-0.78
Unified Self Concept	23	4.78	1.06	-0.85	0.76
Unified Self Concept	27	4.65	1.10	-0.53	-0.47
Distinctiveness	19	5.26	0.78	-0.59	-0.84
Distinctiveness	2	4.85	1.07	-0.90	0.60
Distinctiveness	26	4.63	1.20	-0.85	0.44
Participation	33	4.35	1.11	-0.04	-1.07
Participation	3	4.19	1.46	-0.46	-0.74
Participation	25	4.61	1.15	-0.60	-0.09
Self Enhancement	29	5.30	0.81	-0.77	-0.64
Self Enhancement	37	5.27	0.81	-0.70	-0.73
Self Enhancement	17	5.30	0.84	-0.80	-0.71
Self Enhancement	4	4.88	1.12	-0.86	0.18
Social Support	5	4.93	1.21	-1.10	0.58
Social Support	31	4.60	1.25	-0.77	0.04
Social Support	38	4.58	1.53	-0.88	-0.31
In-Group Cooperation	30	4.76	1.28	-0.98	0.39
In-Group Cooperation	35	4.80	1.02	-1.00	1.40
In-Group Cooperation	13	5.11	0.86	-0.48	-1.01
Visibility of Affiliation	11	4.54	1.53	-0.78	-0.53
Visibility of Affiliation	15	4.03	1.44	-0.33	-0.77
Visibility of Affiliation	20	3.93	1.71	-0.31	-1.19
Sense of Belonging	9	5.12	0.99	-0.83	-0.40
Sense of Belonging	21	5.02	1.12	-1.23	1.36
Sense of Belonging	36	4.73	1.14	-0.80	0.15
Sense of Belonging	10	4.87	1.14	-0.90	0.33
Citizenship	12	4.93	1.15	-1.11	0.93
Citizenship	8	5.36	0.78	-0.88	-0.36
Citizenship	32	4.94	0.97	-0.88	0.69
Citizenship	28	5.33	0.80	-0.83	-0.57
Interest	18	5.22	0.80	-0.55	-0.94
Interest	24	5.27	0.80	-0.73	-0.59
Interest	6	5.09	0.83	-0.42	-0.98
Professional Engineering	22	5.37	0.84	-0.99	-0.40
Professional Engineering	34	4.98	1.11	-1.28	1.69
Professional Engineering	7	5.20	0.87	-0.62	-0.96

Full Theoretical Model. For the full higher order theoretical model, the variance of the first-order factors was set using an indicator. Specifically, the metrics of the 11 first-order latent factors were set equal to items 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, and 13 respectively (See Figure 1.3). The overall fit of the theoretical model (Table 2, model 3) was poor. Specifically, the chi square statistic, the RMSEA, and the CFI all indicated model misfit. The SRMR was below the suggested cutoff indicating adequate fit. As noted above, the SRMR is highly sensitive to misspecified factor correlations but is only moderately sensitive to misspecified factor pattern correlations. The RMSEA and CFI, on the other hand, are sensitive to misspecified factor pattern correlations. Therefore, the lack of fit is most likely due to fixing the cross loadings between latent factors and items to zero. An examination of local misfit suggests that 34 of the model implied correlations produce residuals greater than |.15|. Specifically, items 31, 38, 13, 15, 20, and 7 showed correlation residuals greater than |.15| with more than 5 other items. The subscales labeled social support, visibility of affiliation, and advanced (professional) membership contained items that suggested more than 10 correlation residuals greater than |.15| with other items. This is further evidence of model data misfit.

Simple Structure Models. The 11 factor model (Table 2; model 2) did not converge to a solution. Specifically, the proposed solution for the models resulted in a non-positive definite correlation matrix between the latent variables. This issue could be due to model misspecification or to over-factoring of the data. The unidimensional model converged to a solution. For this model (Table 2 model 2) the overall fit was poor. Specifically, the chi square statistic, the RMSEA, and the CFI all indicated model misfit. The SRMR was below the suggested cutoff indicating adequate fit. Again, the lack of fit is most likely due to fixing the cross loadings between latent factors and items to zero. An examination of local misfit suggests that more than 30 of the model implied correlations for each model produce residuals greater than |.15|. This is further evidence of model data misfit. Model implied correlations, residual values, and degrees of freedom calculations for these models are available from the first author upon email request.

Table 2. CFA models, global, and incremental fit indices evaluated for the E-SIS

	χ^2	df	*p*-value	SRMR	RMSEA	CFI
Simple Structure Models						
1 38-item, 11 factors	-	-	-	-	-	-
2 38-item, 1 factor	5062	665	<.001	.07	.11	.73
Higher-order Models						
3 38-item, 11 factors with 1 higher-order factor	3991	654	<.001	.07	.09	.79

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

Discussion

The developers of the Engineering Student Identity Scale relied on a combination of 11 subscales derived from the literature to measure identity. During the development of the scale, the E-SIS has been scored by summing the items on each of the 11 subscales and subsequently summing the subscales to create a total score. The overall score was believed to reflect an overall identity construct while the subscales each represented an operationalized measurement approach. The data collected in this study do not support the interpretation of these summed scores on the E-SIS as specified by relevant theory. In addition, none of the models tested in this study produced adequate model data fit. However, these results provide significant guidance for item revision efforts.

Limitations: Several factors contribute to difficulties in drawing strong conclusions from the current study. First, the participants represented a combined group of engineering students at different stages of their engineering major over a several year period. This may have introduced construct irrelevant variance if the E-SIS items are interpreted differently by students at different times in their major. Unfortunately, we did not have enough students at each stage of the program to test this theory. Future studies should test the invariance of the E-SIS scores across cohorts. Second, many of the models tested in this study required the estimation of hundreds of parameters. Given this, the sample size per parameter, 4 to 1 in the most resource heavy model, may be too low to produce stable estimates. While adequate sample size is dictated by multiple factors, Bentler and Chou (1987) and Bolen (1989) give rough guidelines ranging from 5 to 20 participants per estimated parameter. Future studies should attempt to increase the sample size per parameter ratio by either collecting more data or reducing the complexity of the models in accordance with relevant theory.

Third, upon a review of the item content, it is unclear whether the current conceptualization of the E-SIS will serve best as a set of items caused by engineering student identity or as a set of items that make up engineering student identity. These two situations are different and require different statistical analyses and assumptions. In the former situation, the latent construct of identity drives performance on the items of the E-SIS. This is a latent system that works best when items are correlated with one another in expected ways. This is best analyzed using the SEM methods employed in this study. The latter situation, on the other hand, dictates that the items form a set of composites that can maximally differentiate groups of students with high and low identity; however, the items do not need to be correlated. In fact, the discrimination between groups will be stronger if the items or composites are uncorrelated and thus, differentiate the groups in different ways. This situation would be best analyzed using discriminant function analysis or MANOVA techniques. In an emergent system, SEM techniques, such as CFA, should not be expected to function well. We believe that, given prior research supporting the ability of the E-SIS subscales to discriminate among groups in different ways, that the scale is currently functioning as an emergent system rather than a latent one. Thus, future research should consider the intent of the scale and what information would best serve all relevant stakeholders. This information should be used to refine either the scale or the analytic method as appropriate. Finally, recruitment of participants is often a challenge in such studies. The use of the dining voucher recruitment system may not have attracted a representative group. Future studies should examine the possibility of embedding such measures in program required assessment processes.

Implications for instrument revisions: While the current study does not support the hypothesized factor structure of the E-SIS, these results should be interpreted carefully as they represent only a single analysis using limited data. Even so, the results lend support to revision efforts. A review reveals that while the items were written to address each of the 11 approaches to conceptualizing identity, the items do not necessarily map back to any of the hypothesized more complex conceptualizations of identity theory such as models that differentiate between social and identity-role theories or those that focus on overlapping components of the two theories (i.e. self-categorization, salience and activation; Stets & Burke, 2000). Revisions to the instrument should ensure that the items map to components of a more complex conceptualization of identity.

In addition, a review of the items reveals that some of the items attempt to address behaviors or cognitions that are theoretically directly affected by identity (e.g., *I can see myself* *becoming an engineer when I am done with school*) while others could arguably represent constructs that are precedents to identity (e.g., *I find engineering topics intriguing or exciting*). This distinction supports the creation of two separate instruments; one to measure engineering student identity (E-SIS) and one that includes constructs that are precedents to identify and assesses the developmental progression of students as they move toward developing an identity as an engineering student or engineer. Revisions to the ESIS items should ensure that items address behaviors or cognitions directly *affected* by identity and not merely hypothesized to relate to identity. Such related items should be used as the foundation of the second measure designed to assess how students are progressing in their development *toward* an engineering identity.

The potential for these scales alone or in tandem to assist engineering programs in designing and targeting intervention efforts remains high. Thus, it is important to continue the effort to create scales that can produce reliable scores that lead to valid interpretations. This study, along with future studies and the continued development of theory, provide support for these efforts.

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