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Towards a Survey Instrument for Use In Proactive Advising

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This paper focuses on developing a survey instrument to support proactive advising strategies based on data analysis. Proactive advising strategies aim to identify at-risk students early, as these students often delay seeking support, and engage them effectively in the support process[1]. An advising curriculum can be created to provide structure for the support process[2]. Outcomes include improvements in student self-efficacy and ultimately in student persistence to remain in the major[3]. The Mediation Model of Research Experiences (MMRE) empirically established engineering self-efficacy, teamwork self-efficacy, and identity as an engineer as mediating, person-centered motivational psychological, processes that transmit the effect of programmatic support activities into an increased commitment to an engineering career[4]–[8]. For the current work, we speculate that students with low measures of engineering self-efficacy, teamwork self-efficacy, or engineering identity are good candidates for proactive advising intervention. Additional measures of non-cognitive and affective attributes may also provide guidance in the planning and implementation of the intervention[9]–[14].

An initial development of a proactive advising survey instrument is reported. Survey items were drawn from two validated sources: the MMRE survey instrument[5] and the SUCCESS instrument[15], [16]. A concise short-form instrument is desired for the current application to maximize the likelihood students will complete the entire survey. Since both the MMRE and SUCCESS instruments are relatively long, a subset of questions from these instruments is initially included. Seven questions were selected for each of the four constructs: self-efficacy, teamwork self-efficacy, engineering identity, and commitment to an engineering career. Recognizing that the validity and reliability of the resulting instrument will not be the same as the source surveys[17], this paper assesses the suitability of the short-form survey for the purposes of proactive advisement planning.

Measurement Constructs and Survey Development:

The survey instrument has 28 total items distributed evenly across the four constructs as follows:

Engineering Self-Efficacy: Engineering self-efficacy is a student's belief in their ability to succeed in a specific area. Seven survey items are included to assess confidence in engineering coursework and confidence as an engineer, three derived from the SUCCESS instrument and four from the MMRE instrument.

Teamwork Self-Efficacy: Teamwork self-efficacy is an assessment of a student's confidence in their ability to work in a team and perceived leadership ability. Seven items are drawn directly from the MMRE's "Confidence in Leading and Working on an Engineering Team" construct.

Identity as an Engineer: Identity as an engineer (or engineering identity) includes being recognized as or viewing oneself as a certain 'kind of person' in the context of engineering. Seven total items are included to assess aspects of identity such as recognition, interest, and community belongingness, six were taken from the SUCCESS instrument and one from the MMRE instrument.

Commitment to an Engineering Career: Commitment to an engineering career is related to a student's dedication to pursuing a career as an engineer. Seven items are taken unmodified from MMRE's "Commitment to Engineering" construct.

Survey Administration and Sample Population

The survey was administered, with IRB approval, during the Spring 2023 semester. Survey participants came from the mechanical and aerospace engineering department of a large land-grant university. Initial data cleaning involved excluding respondents who didn't complete entire survey sections, while retaining those who provided coded missing values or responded with "Not Sure." The cleaning process maintained standard Likert scale weighting for downstream analyses. The resulting sample size was 317 undergraduate students with approximately 66.2% male and 33.8% female. In terms of race and ethnicity the population was 60.5% white, 18.1% Latina/o, 13.1% Asian, 3% Black, 0.9% mixed-race, and 4.4% other or did not respond. With regard to number of years in college the population was 21% 2^{nd} year, 29.2% 3^{rd} year, 32.8% 4^{th} year, 17% 5 or more years.

Internal Consistency

Internal consistency is the reliability of the survey items for measuring their respective construct and this was evaluated using Cronbach's alpha analysis (using SPSS software). The internal consistency was found to be excellent for commitment to an engineering career (α = 0.916), good for engineering identity (α = 0.849) and teamwork self-efficacy (α = 0.811) and acceptable for engineering self-efficacy (α = 0.772).[18]

Factor Analysis

Factor analysis is a statistical technique that can be used to identify underlying factors that explain the correlations among a set of observed variables. In the context of survey research, factor analysis can be used to optimize survey questions by identifying the underlying constructs that are being measured and evaluating the reliability and validity of the items.

Both Exploratory (EFA) and Confirmatory (CFA) Factor Analysis were performed. The EFA was used to explore how well survey instruments drawn from two separate sources would align and to determine if the underlying construct definitions from the two instruments agree. The EFA was performed using SPSS with Principal Axis Factoring (PAF). A Kaiser-Meyer-Olkin (KMO) statistic of 0.892 indicating factor analysis is appropriate[19]. Oblimin rotation with Kaiser normalization indicated a four-factor solution with distinct, but correlated, subscales suggested by the pattern and magnitude of factor loadings. Survey items defining the Engineering Identity construct tended to separate into two subscales: 1) Self-Recognition and Student Community (subscale α = 0.83, typical question "I enjoy being in engineering.") and 2) External-Recognition (subscale α = 0.81, typical question "My peers see me as 'an engineer'"). Engineering identity sub-scale 1 tended to load with items from Commitment to an Engineering Career, consistent with a high level of correlation between those items. Engineering Identity Sub-Scale 2 consistently loaded as a separate construct. Engineering Self-Efficacy also tended to segregate into two sub-scales: 1) Achievement Expectancy (α = 0.68, typical question "I expect to do well in my engineering classes") and 2) Confidence as an Engineer (α = 0.75, typical question "I can use technical skills to solve engineering problems"). As may be expected, the presence of subscales for Engineering Identity and Engineering Self-Efficacy subscales arise from the different wording and emphasis in the two source survey instruments suggesting that the two source instruments have slightly different interpretations of the latent constructs.

Following the EFA, a single-level CFA was performed, using the lavaan package in R with the MLR estimator. Initially a correlated, four-factor model (model 1) was considered, with the four survey constructs being assigned to the four latent variables. The goodness of fit results for model 1 are CFI = 0.836, TLI = 0.819, RMSEA = 0.080, and χ^2=1085 (p<0.001). Allowing for correlated errors between selected items improved model 1 fit slightly. A second model (model 2) using six-factors (subscales defined above are separated as separate factors) was tried based on the results of the EFA. Correlations of errors on selected items was also incorporated in model 2. Goodness of fit results for model 2 are CFI = 0.909, TLI = 0.897, RMSEA = 0.060, and χ^2=743 (p<0.001). Root mean square error of approximation (RMSEA) values below 0.08 are considered acceptable with values below 0.05 desired[20]. Model 2 provides improvements, but still fall slightly below typical thresholds of CFI = 0.95 and TLI = 0.90 for acceptable model fit[18]. The covariance matrices for the two model are shown in Table 1 and 2 for model 1 and 2, respectively. The Analysis of Variance (ANOVA) between model 1 and model 2 was used to compare the relative fit with results, shown in Table 3, indicating that model 2 provides a significantly improved fit (Pr < 0.001). These results indicate that combining survey items from the two sources adds complexity to the interpretation of results and that the underlying constructs of Engineering Identity and Self-Efficacy are defined slightly differently in the two sources.

Table 1 CFA Model 1 Covariance Matrix

	Teamwork	Identity	Commitment
Self-Efficacy	0.38	0.56	0.33
Teamwork		0.23	0.11
Identity			0.82

Table 2 CFA Model 2 Covariance Matrix

	Self-Efficacy 2	Teamwork	Identity 1	Identity 2	Commitment
Self-Efficacy 1	0.70	0.33	0.52	0.49	0.32
Self-Efficacy 2		037	0.46	0.64	0.30
Teamwork			0.19	0.34	0.11
Identity 1				0.68	0.84
Identity 2					0.50

Table 3 ANOVA between Model 1 and Model 2

	Df	AIC	BIC	χ^2	χ^2 diff	Df diff	Pr(>χ^2)
Model 2	48	7601.3	7761.7	93.486			
Model 1	344	19497.3	19841.1	1085.034	796.84	296	<0.001

Structural Equation Modeling

A two-level Structural Equation Model (SEM) using MPLUS was performed to see if the shortened survey instrument could properly represent the MMRE theoretical framework. SEM derives from factor analysis and path analysis. By integrating these two approaches, SEM provides a generalized framework where unobservable latent variables are estimated from observed indicator variables.[21] The experimentally verified MMRE model is represented in Figure 1 and allows for both direct and indirect effects of Engineering Self-Efficacy, Engineering Identity, and Teamwork Self-Efficacy on Commitment to an engineering career[7]. This model has been independently verified in an application to a career-forward chemistry lab course for engineering students[22]. Results for the current work are represented in Table 4 for Model 1 which includes the 28 survey items ((CFI = 0.807, TLI = 0.802, RMSEA = 0.085, χ^2 = 5372 (p<0.001)). Model 3 (CFI = 0.968, TLI = 0.962, RMSEA = 0.056, χ^2 = 1996 (p<0.001)) was obtained by retaining the 3 survey items with highest factor analysis loading within each construct resulting in a survey with 12 survey items. The motivation for including model 3 was to give an indication of how an extremely compact instrument (3 items per construct) represents the relationships between constructs. Results from Payne and Crippen[22] and Chemers, et al.[7] are used for comparison. We note that Payne and Crippen[22] disaggregated their results as URM and non-URM (but not by gender). For this work we disaggregated by URM and non-URM as well and report the non-URM results in this paper. Chemers, et al. [7] report results for the entire population without disaggregation. Model 1 and Model 3 give similar results characterized by Engineering Identity having a strong direct effect on Commitment to an Engineering Career as did the comparison references[7], [22]. Both comparison references show a direct effect of Engineering Self-Efficacy on Commitment which was not observed in either Model 1 or 3. However a strong indirect path of Self-Efficacy affecting Identity and Identity affecting Commitment is observed and was also present in the comparison references. Note that the current survey engineering self-efficacy items used 3 items from the SUCCESS instrument and 4 items from the MMRE instrument. As observe in the EFA results above, the 3 SUCCESS items tended to load with the commitment to an engineering career. The difference in wording on the SUCCESS items may be adversely affecting the SEM effect from self-efficacy to commitment. Payne and Crippen[22] is the only study showing a statistically significant direct affect from teamwork self-efficacy to commitment. The primary contribution of teamwork self-efficacy is indirect through the construct of engineering self-efficacy. The results indicate that the current survey instrument did not capture all of the trends observed in the reference comparisons. We note that in the previous works, the measurements were situated within activities designed to spotlight student competence and that emphasized participation in teamwork activities. The current survey was administered to the general mechanical and aerospace engineering student population without being tied to any preparatory activity. Model 1 and Model 3 both performed similarly in terms of the SEM results.

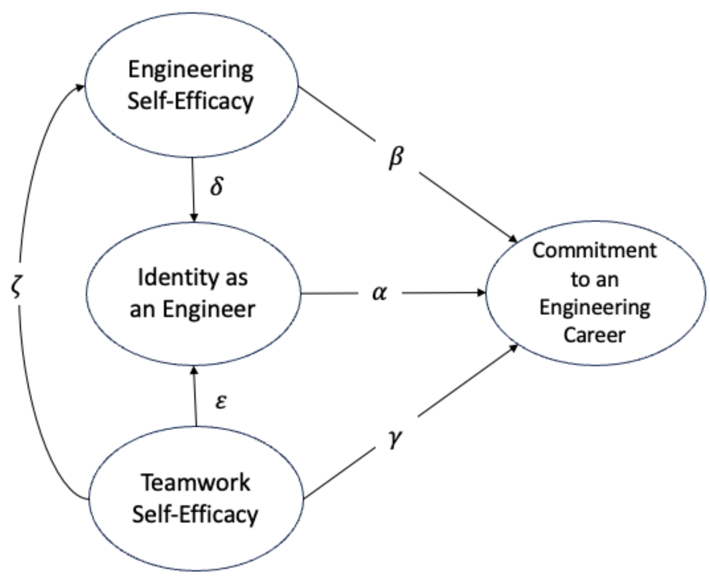

Figure 1. Mediation Model of Research Experiences (MMRE) structural equation model.

Table 4 SEM Model Comparisons

	α	β	γ	δ	ε	ζ
Model 1	0.778 [a]	NS	NS	1.129 [a]	NS	0.302 [a]
Model 3	0.713 [a]	NS	NS	0.963 [a]	NS	0.181 [c]
Payne and Crippen	0.394 [a]	0.517 [a]	-0.097 [c]	0.494 [a]	NS	0.404 [a]
Chemer, et al.	0.51 [b]	0.10 [b]	NS	0.24 [b]	NS	0.11 [b]

Model 1 = Complete instrument (28 Items), Model 3 = Reduced instrument (12 Items)
[a]p<0.001, [b]p<0.01, [c]p<0.05, NS = Not Significant

Conclusion

A shortened version of a survey instrument, based on the Mediation Model of Research Experiences (MMRE) theoretical framework was developed and evaluated for use in a data driven, proactive advising process. Items for the shortened instrument were drawn from two sources, with slight differences in wording between questions on the two instruments for the same underlying constructs. Results from this work indicate that the source instruments are measuring somewhat different definitions of the engineering identity and engineering self-efficacy constructs. Linear confirmatory factor analysis results indicate that a more complicated model with two sub-constructs was desirable to model the current results. Comparisons of structural equation models with results from the extant literature confirm the strong relationship between identity as an engineer and commitment to an engineering career. The relationship between engineering self-efficacy and commitment to an engineering career was not well represented by the current instrument and suggest that using survey items drawn from the MMRE instrument (relative to the SUCCESS instrument) is preferable in terms of representing the MMRE framework.

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