Model-building in Engineering Education

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My research is focused on developing interdisciplinary theoretical frameworks and methodological designs capable of modeling the social and psychological drivers of behavior, decision-making, and information processing across multiple domains (e.g., health, education, the workplace).

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Model Building in Engineering Education

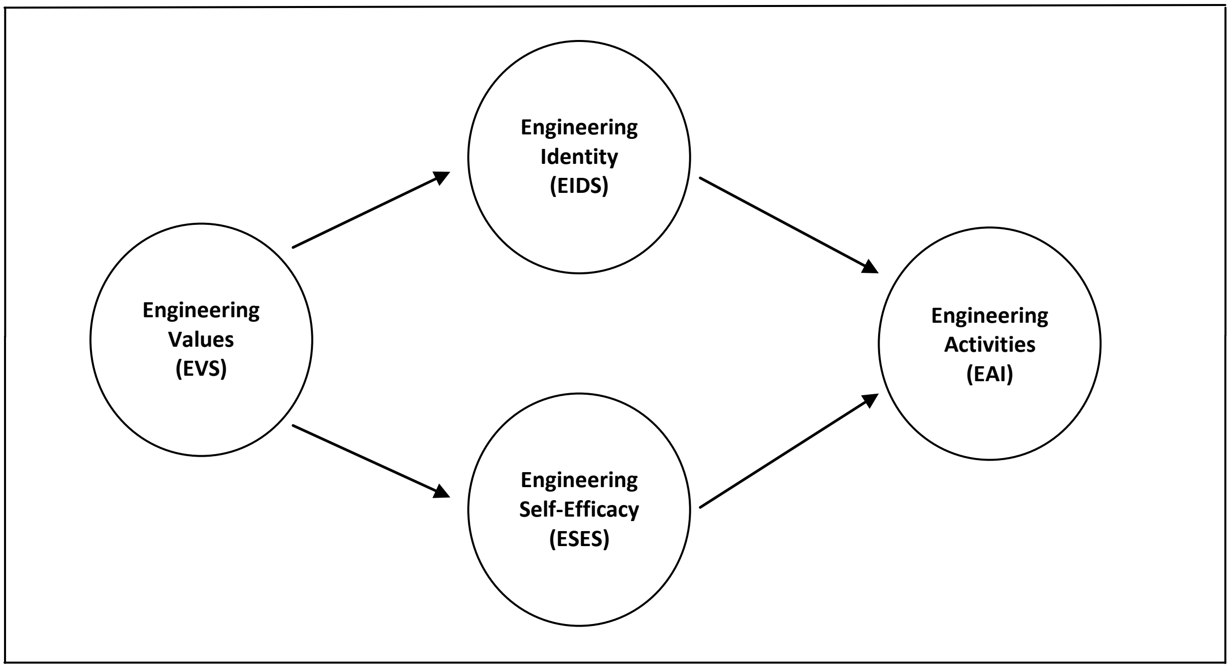
This paper reports on research that is part of a lager project taking place at a mid-sized public HBCU funded through the National Science Foundation's Revolutionizing Engineering and computer science Departments (RED) program. The purpose of the RED program is to encourage and support innovation projects that develop new, revolutionary approaches and change strategies that enable the transformation of undergraduate engineering education [1]. A vital component of this particular RED project involves the development and validation of survey-based measures of Engineering Values, Self-Efficacy, and Identity: and a model that combines the constructs into a causal sequence aimed at explaining the motivators of student learning. Past research [2], reported on the results of the first stage in this broader research objective. This paper reports on the second stage in the development and assessment of an Engineering Values Scale (EVS), an Engineering Self-Efficacy Scale (ESES), an Engineering Identity Scale (EIDS), and an exploratory model aimed at explaining student engagement in extracurricular engineering-related activities.

Background

The overall RED project that this study is a part of involves an investigation of whether aligning courses with the *innovators' order* [3], through curricular changes that incorporate needs finding and engineering design education across all four undergraduate years will empower students to become innovators by enhancing their (a) valuation of engineering skills and knowledge (b) identification as engineers, and (c) feelings of self-efficacy within engineering. The overarching hypothesis is that students who gain practice at identifying important needs and designing solutions the need will more greatly value the skills and knowledge of the discipline, increasingly see themselves as capable within the field (self-efficacy), and internalize a strong engineering identity. These social psychological motivators of learning will in turn drive students to be engaged in their course work, seek out opportunities to engage in extracurricular engineering-related activities, and persist to graduation.

Initial results from the first stage of the project reported on the development of survey-based measures of engineering values, self-efficacy, and identity [2]. The scales were found to be both valid and reliable. Furthermore, using an information-based approach to Structural Equation Modeling (SEM), an exploratory model of the motivators to student engagement in extracurricular engineering-related activities (e.g., study groups, organizational membership, summer enhancement programs), was developed. The exploratory model indicated that self-efficacy beliefs and engineering identity were the most proximal motivators of engaging in engineering related activities, and valuation of engineering skills and knowledge was a more distal motivator operating through self-efficacy and identity (Figure 1). The current study uses newly gathered student data to pursue two objectives. The first objective is to use this new sample data to assess the cross-sample reliability and validity of the Engineering Values Scale (EVS), Engineering Self-Efficacy Scale, and Engineering IDentity Scale (EIDS). The second objective is to apply the same information-based approaches to modeling and inference to further assess the plausibility of a range of causal models possibly confirming the model identified in Stage 1 (Fig. 1), or refining it to reflect new information gained. Thus, the first objective is to further confirm the validity and reliability of the scales, and the second objective is aimed at refinement of the causal model.

Figure 1. Exploratory Model of Motivation to Engage in Extracurricular Engineering-related Activities Hypothesized Model 1: Engineering Identity and Engineering Self-Efficacy Intervening



Note: Standardized principal component scores were used to represent each construct in the SEM. EVS=Engineering Values Scale, ESES=Engineering Self-Efficacy Scale, EIDS=Engineering Identity Scale, EAI=Engineering Activities Index.

Engineering Student Self-Efficacy, Identity, and Values

Self-efficacy

Disparities within engineering education between low-income, minority, and female students have been noted for some time. Certain variables (e.g., ability) have been touted to explain this unfortunate reality; however, cognitive influences such as self-efficacy have also been examined [7]. Self-efficacy, a key component of social cognitive theory [8], is a motivator to learning and can be defined as a person's belief that he or she has the ability, strength, and determination to engage with the environment and succeed [9]. Bandura [10] argued that as individuals experience greater self-efficacy, the more likely they are to persist and to succeed. Subsequent educational research appears to support Bandura's position, indicating that academic self-efficacy is a strong predictor for academic success among undergraduate engineering students [6].

A number of researchers have operationalized self-efficacy within the domain of engineering to cover both general facets of self-efficacy, as well as task or skill-specific facets of the construct [11,12,13,14]. Of interest to this study are students' general perceptions of their self-efficacy to become professional engineers, possessing the ability to identify societal and industry needs, and corresponding design solutions. We posit that by consistently providing undergraduate engineering students with opportunities to identify real societal needs and design potential solutions, their feelings of self-efficacy will increase; and so in turn, their classroom academic performance will be enhanced.

Engineering Values

Values can be thought of as guiding principles in one's life, and the relative importance of a given set of values guides one's actions [see 15]. This axiom is certainly true within an academic context [16]. Undergraduate students who value the skills and knowledge within the field of engineering education and the engineering profession as a whole are more likely to enter engineering programs, persist, and succeed [17]. Cech [4], further suggested that engineering students who appreciate the relationship between their education and their future contributions to society through technological innovation tend to pursue academic and scientific work which has some attached social value. By contrast, engineering students who do not make this connection are more likely to view their engineering education as stale, boring, and task-driven, with any related social implications as tangential to their work, at best. Of particular relevance to this study is the finding that low-income and underrepresented minority students tend to drop out of

STEM careers when those careers are not highly connected with their communities and broader societal issues [18,19].

Martin [20] provided commentary upon the importance of finding personal meaning in one's work and how such meaning can give way to "intelligibility and value." Individuals who can link what they value with what they do bring a heightened sense of commitment and motivation to their efforts, likely resulting in greater productivity and pride in product. Though Martin speaks specifically to personal valuing of engineering as a profession, engineering students may also possess such deeply-held commitments to the profession of engineering. We posit that by consistently providing undergraduate engineering students with opportunities to identify real societal needs and design potential solutions, their valuation of engineering will increase; and so in turn, their classroom academic performance will be enhanced.

Engineering Identity

Identities are meanings attached to the self-concept that position individuals within networks of relationships and organizational and social structures [21]. They are built-up from social interaction and influence behavior and behavioral change through the process of self-verification [22]. Students who identify as engineering students and soon-to-be professional engineers are more likely to matriculate their course of study, culminating in successful graduation [23]. Developmentally-speaking, identity formation is a dynamic and vibrant process, evolving out of interactions between individuals and significant others, preferences and predilections, and contextual influences [24]. Consequently, engineering programs have the potential to inculcate engineering identity [25]. Identifying as an engineering student or future professional engineer has programmatic implications as well. Jungert [26] studied students' evolving engineering identities and discovered that students often fused pride in their programmatic experiences with pride in their emerging professional expertise. We posit that by consistently providing undergraduate engineering students with opportunities to identify real societal needs and design potential solutions, students will be exposed to the types of social interactions and feedback from significant others that build strong engineering identities. This in turn will enhance their classroom academic performance as students seek continued self-verification as an engineer [21].

Theory & Hypotheses

According to the Ecological Theory of Human Development [29], human development involves complex interrelationships among four concepts: process-person-context-time. Bronfenbrenner and Morris [30] theorized that development evolves out of *processes* (e.g., interactions) occurring in *context*. The overall RED project that this study is a part of is an investigation of the interactions between students and instructors, as well as between students and “objects and symbols” (e.g., course curriculum), within students’ *microsystems* (e.g., classroom, laboratory, pro), as they matriculate through the program [29]. These *processes* have the potential to powerfully influence student development [30]. The curricular changes that incorporate needs finding and design across all four years of the curriculum are a direct effort to intervene in these processes and interactions between students, faculty, and the objects and symbols within their immediate learning environments.

Within Ecological Theory engineering values, self-efficacy, and identity operate within the realm of the *Person* consisting of *force, resource,* and *demand* characteristics. *Person force* characteristics are developmentally-instigative or –disruptive behaviors which can forward or hinder development. Within engineering education, developmentally-instigative behaviors might be engaging in extracurricular engineering-related activities such as attending facilitated study groups, engineering conferences, and internships. We assume that engineering values, self-efficacy and identity motivate engagement in these types of developmentally-instigative behaviors. That is, as students' valuation of engineering, engineering self-efficacy, and engineering identities become stronger so in turn do students engagement in the developmentally-instigative activities. Importantly however, whereas self-efficacy beliefs and identities are typically shown to be relatively proximal influences (and outcomes) on behavior, values are more distal, operating instead as guiding principles of behavior and general outcomes of past behavior [15,20, 2].

Several basic hypotheses will be used to confirm the validity of the scales used to measure engineering values, self-efficacy, and identity and further assess the plausibility of the theoretical framework that grounds the exploratory model of the motivators of engagement in extracurricular engineering-related activities.

(H1) Students who more highly value engineering as a set of skills and abilities, as a career choice, and way to improve peoples' lives (i.e., engineering values) will engage in more extra-curricular engineering-related activities.

(H2) Students who have more positive beliefs about their ability to accomplish the things needed to succeed as an engineering student and professional engineer (i.e., engineering self-efficacy) will engage in more extra-curricular engineering-related activities.

(H3) Students who more strongly identify as engineers (i.e., engineering identity), will engage in more extracurricular engineering-related activities.

(H4) Students' beliefs about their abilities to succeed as and engineering student (self-efficacy), and their identification as an engineer (engineering identity), will act as intervening influences between engineering values engaging in extracurricular engineering-related activities (Figure 1).

Methods

A web-based questionnaire was administered to students in six introductory engineering courses in the Fall of 2018 at a mid-sized public Historically Black University in the U.S. During a regular class session, instructors of each course disseminated a link to their students via the course learning platform. Students were asked to click on the link, redirecting them to the survey which took approximately 15 minutes to complete. A total of 286 questionnaires were completed and returned useable. The questionnaire contained scales developed by [2], to measure Engineering Values, Self-efficacy, and Identity. The Engineering Values Scale (EVS), contains 8 items arranged on a 7 point Likert scale. The items assess both general and specific aspects of the field of engineering with higher scores reflecting greater valuation. The Engineering Self-Efficacy Scale (ESES), contains 6 items arranged on a 7 point Likert scale. The items assess a general form of self-efficacy as well as self-efficacy directly related to engineering design with higher scores representing greater self-efficacy. The Engineering Identity Scale (EIDS), contains 9 items arranged on a 5 point Likert scale. The five of the items assess engineering identity salience and four of the items assess engineering identity prominence. An 8 item index of extracurricular engineering-related activities was created and responses were transformed to z-scores to ensure normality.

Item-analyses, alpha reliability testing, and Principal Components Analysis (PCA) were used to confirm the unidimensionality and internal consistency of the scale measures of each construct (i.e., engineering values, self-efficacy, and identity). Bivariate correlations between the first Principle Component (PC), scores for each the constructs and the extracurricular

Engineering-related Activities Index (ZEAI), were then calculated to test hypotheses 1-3. Hypothesis 4 was tested by conducting an information-based multi-model comparison [31], using a series of Structural Equation Models (SEMs), to assess the most plausible causal ordering of the constructs in relation to engagement in extracurricular engineering-related activities.

Results

Table 1 contains information describing the sample. In total 286 completed surveys were collected. The sample was comprised of primarily Black (76.9%), Male (60%), Freshman (76.2%), engineering majors.

Table 1. Descriptive Statistics

Variable	Percentage of Sample
Race/Ethnicity	
Black	76.9%
White	5.9%
Other	17.2%
Household Income	
< 20,000	11.9%
20,000< > 39,999	18.4%
40,000<>59,999	18.4%
60,000<>79,999	19.7%
80,000<>99,999	9.0%
>100,000	22.5%
Sex	
Female	28.5%
Male	68.9%
Other	2.6%
Employment Status	
Working Full Time	2.0%
Working Part Time	24.7%
Unemployed (Looking for work)	37.7%
Unemployed (Not looking for work)	37.3%

Mothers Highest Level of Education	
High School	15.6%
Some College	14.8%
Associates Degree	9.5%
Bachelors Degree	32.8%
Masters Degree	23.4%
Doctoral Degree	4.1%
Year in School	
Freshman	76.2%
Sophomore	14.1%
Junior	6.7%
Senior	1.1%
Graduate/Other	1.9%
Academic Program	
Civil, Architectural and Environmental Engineering	22.9%
Chemical, Biological, and Bio Engineering	25.8%
Electrical and Computer Engineering	18.1%
Mechanical Engineering	24.7%
Computational Science and Engineering	2.2%
Industrial and Systems Engineering	4.4%
Computer Science	1.9%

Note: N=286

Scale development.

Next we turn to an analysis of the psychometric properties of each of the scales. We examined inter-item correlations and calculated a Cronbach's *alpha* in order to assess the internal consistency of each scale, and we conducted Principal Components Analysis (PCA), to assess their unidimensionality and derive component scores to be used in later analyses [32]. Beginning with the reliability analysis of the EVS, Cronbach's *alpha* for the EVS was strong (α=.911). Unrotated Principal Component (PC) loadings for the EVS are presented in Table 3. All items loaded strongly on a single PC which explained a total of 63.4% of the variance across all of the items. Combined, these results provide solid evidence that the EVS has a high degree on internal consistence and is measuring a single, unidimensional construct. Strong results were also found for the ESES, which produced a Cronbach's *alpha* of (α=.808). Although two PCs were extracted with eigenvalues greater than 1, all ESES items loaded strongly on the first PC which explained a total of 52.3% of the variance across all of the items. A second PC with an eigenvalue just above 1 was also extracted. This second PC explained 17.8% of the total variance across all scale items. As with the EVS, these results provide solid evidence that the ESES is an internally consistent and has strong unidimensional properties. Cronbach's *alpha* for the EIDS was very high also (α=.828). Although two PCs were extracted, all EIDS items loaded strongly on the first component ranging from a low of r=.482 to a high of r=.756. The first PC explained a total of 43.1% of the variance across the items. As with the other scales in this analysis, we can conclude that the 1st PC of the EIDS constitutes what [33] refers to as a "size factor" (p. 38): or a situation when all items in a scale load strongly and in the same direction on the 1st PC. Combined this results suggest that the EIDS contains an acceptable level of unidimensionality, and the items are highly internally consistent.

As a methodology, when PCA extracts multiple components it does so such that each successive component is Orthogonal (unrelated) to the others and conceptually represent contrasts. Consequently, the expected pattern of loadings for the 2nd PC on the ESES and the EIDS will be a mix of positive and negative signs. As can be seen in Table 2, this expectation is confirmed. Indeed the 2nd PC on the EIDS (which explains 22.7% of the total variance within the scale items), appears to represent a contrast between the items assessing the prominence of an engineering identity (positive loadings), and the items assessing the salience of an engineering identity (negative loadings). Similarly, the interpretation of the two PCs extracted on the ESES scale fall along predictable lines, with the second component representing a contrast between efficacy in relation to design and needs finding (positive loadings), and the items assessing self-efficacy in relation to "being a professional engineer" (negative loadings).

Table 2. Psychometric Properties for the Engineering Values Scale, Engineering Self-Efficacy Scale, and Engineering Identity Scale.

SCALE	Component Loading	
Engineering Values Scale (α = .911)	1	2
I am confident that…		
1) Strong math abilities will enhance my career.	.739	-
2) Strong abilities to identify industry and social needs will enhance my career	.707	-
3) A degree in engineering will allow me to obtain a well paying job.	.838	-
4) A degree in engineering will give me the kind of lifestyle I want.	.837	-
5) Strong programming skills will enhance my career.	.584	-
6) A degree in engineering will allow me to get a job where I can use my talents and creativity.	.880	-
7) A degree in engineering will allow me to obtain a job that I like.	.885	-
8) A degree in engineering will allow me to improve peoples' lives.	.849	-
Variance Explained	63%	
Engineering Self Efficacy Scale (α =.808)		
I am confident that…		
1) I understand the design process.	.658	.582
2) I have the capabilities to accomplish design.	.740	.324
3) I have the capabilities to identify industry and social needs.	.677	.303
4) I have the knowledge required to be a professional engineer.	.760	-.494
5) I have the skills to be a professional engineer.	.775	-.532
6) I can succeed as a professional engineer.	.722	-.055
Variance Explained	52%	18%
Engineering Identity Scale (**α** =.828)		
How likely are you to discuss your desire to be an engineer with…		
1) A co-worker.	.724	-.246
2) A friend.	.756	-.455
3) A friend of a friend.	.674	-.264
4) A family member.	.712	-.418
5) A person you are romantically attracted to.	.685	-.448
6) Being a professional engineer is an important part of my self-image.	.572	.566
7) Being. a professional engineer is an important reflection of who I am.	.482	.691
8) I have come to think of myself as an engineer.	.651	.509
9) I have a strong sense of belonging to the community of engineers.	.605	.523
Variance Explained	43%	23%

Note. Unrotated Principal Component Solution. *N*=286.

Bi-variate Correlation Tests

We tested hypotheses 1-3 by assessing the bi-variate correlations between the first PC scores for each of the scales and the index of self-reported engagement in extracurricular engineering-related activities (Table 3). Surprisingly, engineering values were not correlated with engagement in engineering activities. These results do not support H1 and suggest that engagement in extracurricular engineering-related activities is not directly related to students' valuation of engineering. This result may however be somewhat misleading for two reasons. First, there is relatively little variability within both the data on student engagement in engineering-related activities ($\bar{X}$ = .58, *sd* =.85), and the Engineering Values Scale ($\bar{X}$ = 48.8, *sd* =.7.28). Said another way, most students highly value engineering and most students do not engage in many extracurricular engineering-related activities. A second explanation may relate to the more distal influence theorized to exist between values and behavior (H4). Indeed, if engineering self-efficacy and identity act as intervening influences between values and behavior as hypothesized, direct bi-variate correlations between values and behavior would likely be weak or possibly even non-existent. Hypothesis two is weakly supported as the bi-variate correlation between the ZEAI and ESES is (r=.16, p<.05). Similarly, hypothesis three is also weakly supported as the bi-variate correlation between the ZEAI and EIDS is (r=.10, p<.15). These relatively weak correlations may also be in part explained by the relatively little variability within the data on student engagement in engineering-related activities.

Table 3. Bivariate Correlations between the Engineering Activities Index (EAI), and the Engineering Values, Engineering Self-Efficacy, and Engineering Identity.

Scale	ZEAI	EVS	ESES	EIDS
ZEAI	1			
EVS	.001	1		
ESES	$.16^{**}$	$.32^{***}$	1	
EIDS	$.11^{*}$	$.30^{***}$	$.47^{***}$	1

Note: Raw scores on the EAI were transformed to standardized (z-scores). EVS=Engineering Values Scale, ESES=Engineering Self-Efficacy Scale, EIDS=Engineering Identity Scale; *N*=286.

Multi-model Comparative Analysis

Although Null Hypothesis Significance Tests (NHST), such as those reported above can be useful for assessing relationships between constructs, they have important limitations when applied to model building. Namely, NHST and the classical approach to statistical inference assume that "…there is a single correct (or even true), or at least, best model, and that model suffices as the sole model for making inferences from the data." [34, p. 261]. What's more, researchers typically rely on a single test of the probability of obtaining a given set of data under the condition of the null-hypothesis. Alternatively, information-based approaches postulate multiple models (based on theory and past research), and comparatively assess them via an information criterion statistic (e.g., AIC, BIC), to determine the model that best approximates a given set of data. To test H4 we conducted an information-based multi-model comparison [31], using a series of Structural Equation Models (SEMs), to assess the most plausible causal ordering of the constructs in the model. Within an SEM context, AIC and BIC constitute relative fit indices providing directly comparable parsimony adjusted estimates of the *distance* between the structural model and the data in the correlation/covariance matrix. Lower values of AIC and BIC indicate better and more parsimonious fit.

Figure 1 depicts the Hypothesized Model 1 which was developed in prior research [see 2]. In this model, engineering self-efficacy and identity act as intervening influences between engineering values and engagement in engineering activities. We also posited 14 alternative models that re-arrange the causal ordering of engineering values, self-efficacy, and identity. The models vary based on which constructs are exogenous (a variable that is not dependent on another variable in the model), which are endogenous (a variable that is dependent on another variable in the model). For the purpose of analyses, we arranged the models being tested into one of four different classes: (1) models with one exogenous variable and two levels of endogenous variables (Figure 2), (2) models with one exogenous variable, two levels of endogenous variables that are related (Figure 3), (3) models with two exogenous variables and two levels of a single endogenous variable (Figure 4), and (4) models with one exogenous variable and three levels of endogenous variables (Figure 5).

Figure 2. Model Classification (1) models with one exogenous variable and two levels of endogenous variables.

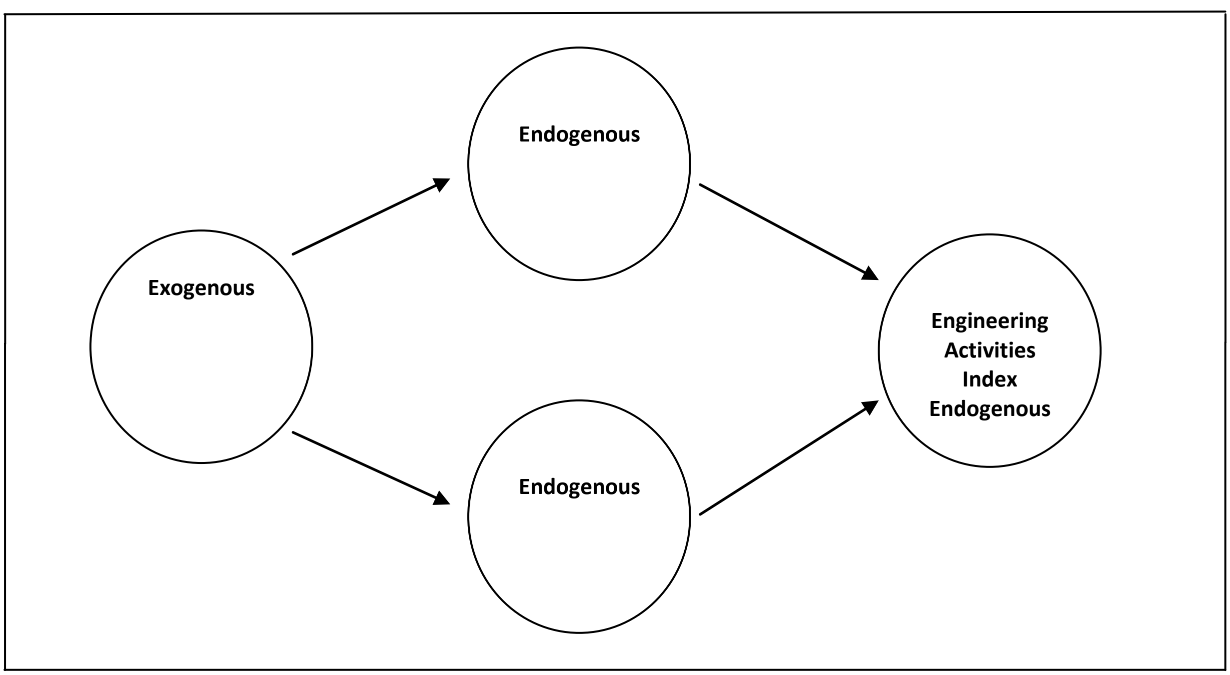


Figure 3. Model Classification (2) models with one exogenous variable, two levels of endogenous variables that are related

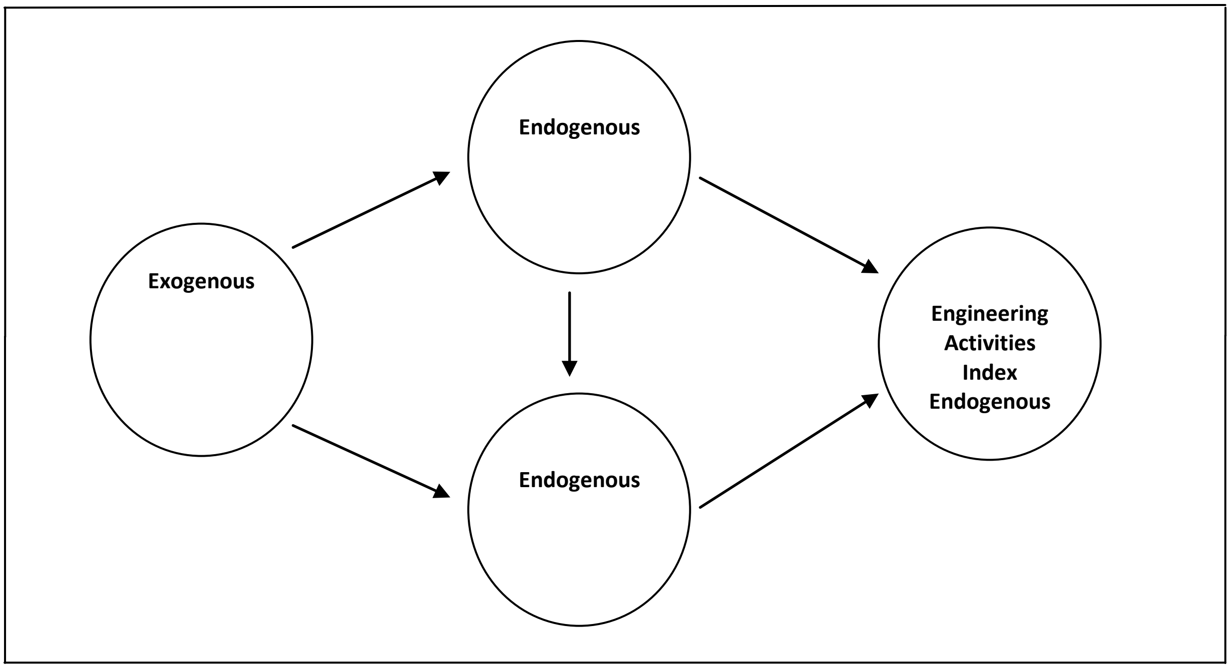


Figure 4. Model Classification (3) models with two exogenous variables, and two levels of a single endogenous variable.

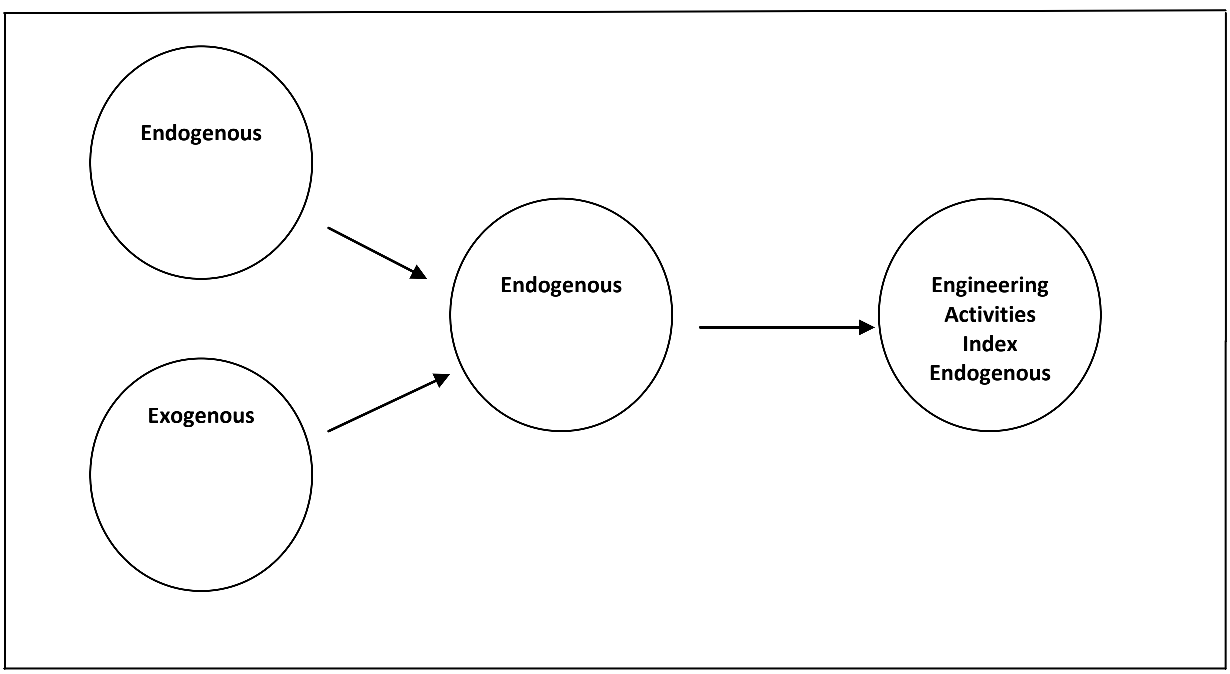


Figure 5. Model Classification (4) models with one exogenous variable and three levels of a single endogenous variable.

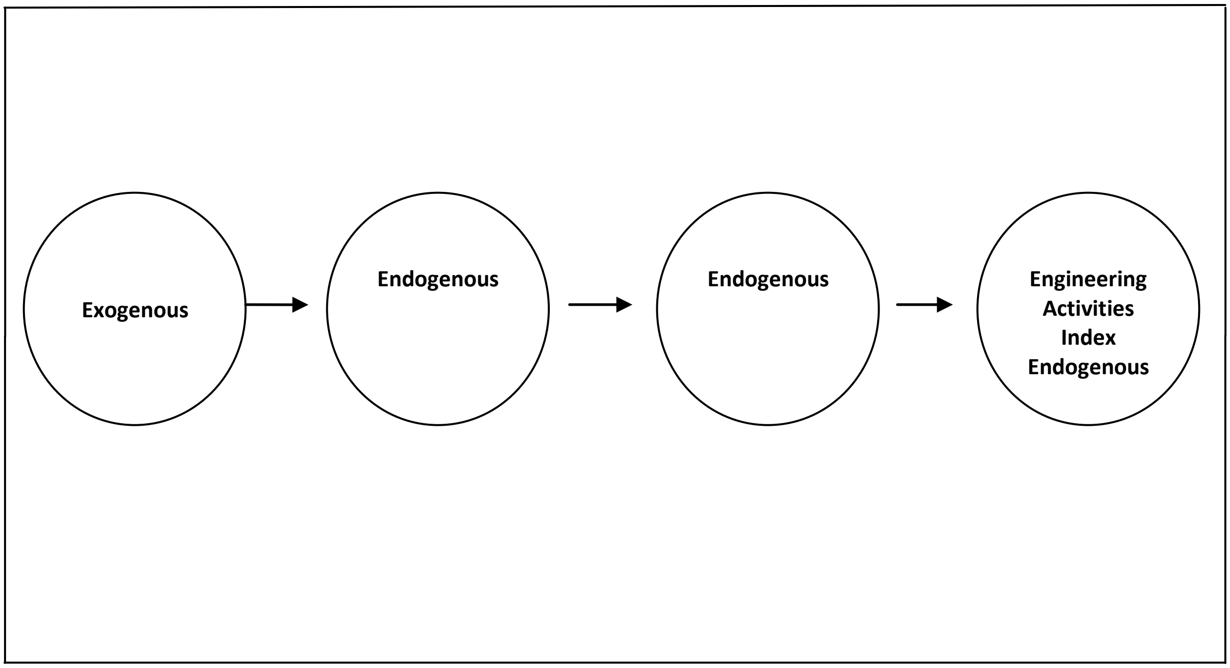


Table 4 lists the AIC and BIC scores for the hypothesized model and the 14 alternative models by model classification type. For those in model class (1), alternative model 2 appears to best approximate the data (*AIC*=23.92; *BIC*=49.52). For those in model class (2), alternative model 5 appears to best approximate the data (*AIC*=16.82; *BIC*=46.07). For those models in class (3), alternative model 8 appears to best approximate the data (*AIC*=11.46; *BIC*=29.74), and this is in fact the best approximating model across all classes. Finally for those models in class (4), alternative model 11 best approximates the data (*AIC*=22.56; *BIC*=44.50). Although these results do not support hypothesis four, it is important to note that the best approximating model (alternative model 8), does model engineering values as distal motivators of engagement in engineering-related activities operating through engineering self-efficacy as a more proximal and intervening motivator. This new analysis however places engineering identity as a second proximal motivator.

Table 4. Multi-Model Comparison

Model Classification	Model #	Exogenous Variable(s)	Intervening (Endogenous) Variable(s)	Dependent Variable	AIC	BIC
1 Exogenous 2 Levels of Endogenous (1)	Hypothesized Model 1	EVS	EIDS,ESES	ZEAI	61.98	87.57
	Alternative Model 2	**EIDS**	**EVS, ESES**	**ZEAI**	**23.92**	**49.52**
	Alternative Model 3	ESES	EVS, EIDS	ZEAI	29.79	55.38
1 Exogenous 2 Levels of Related Endogenous (2)	Alternative Model 4	EVS	ESES, EIDS	ZEAI	16.93	46.18
	Alternative Model 5	**EIDS**	**EVS, ESES**	**ZEAI**	**16.82**	**46.07**
	Alternative Model 6	ESES	EVS, EIDS	ZEAI	19.88	49.13
2 Exogenous 2 Levels of Endogenous (3)	Alternative Model7	EIDS,ESES	EVS	ZEAI	17.15	35.43
	Alternative Model 8	**EIDS, EVS**	**ESES**	**ZEAI**	**11.46**	**29.74**
	Alternative Model 9	ESES, EVS	EIDS	ZEAI	14.27	32.55
1 Exogenous 3 Levels of Endogenous (4)	Alternative Model 10	EIDS	EVS->ESES	ZEAI	60.5	82.44
	Alternative Model11	**EVS**	**EIDS->ESES**	**ZEAI**	**22.56**	**44.50**
	Alternative Model 12	EVS	ESES->EIDS	ZEAI	28.17	50.11
	Alternative Model 13	EIDS	ESES->EVS	ZEAI	31.05	52.985
	Alternative Model 14	ESES	EIDS->EVS	ZEAI	28.25	50.18
	Alternative Model 15	ESES	EVS->EIDS	ZEAI	63.31	85.25

Note: N=286, EVS=Engineering Values Scale, ESES=Engineering Self-Efficacy Scale EIDS=Engineering Identity Scale, ZEAI=Engineering Activities Index.

Discussion

Improving engineering education requires systematic assessment and evaluation of the impacts that educational initiatives have on students. Toward this end, this paper reports on the second stage in the development of survey-based scale measures of engineering values, self-efficacy and identity. The results provide strong cross-sample evidence of the reliability and validity of each of the measures. The results of the multi-model comparative analysis did not fully support the hypothesis (H4), regarding how these constructs may combine to drive engagement in extracurricular engineering-related activities. However, we do find partial support for it. Namely, past research [2], found that engineering values operates as a distal motivator of engagement in engineering-related activities, and the results presented here do not contradict this finding. Instead they offer a revised model that includes both engineering values and identity as distal drivers of engagement with and intervening impact of student self-efficacy.

Important next steps in this project will be to gather qualitative data from students and faculty regarding the content of the EVS, ESES, and EIDS. Next a (validation) sample of undergraduate engineering majors should be used to assess the scales using more deductive approaches such as Confirmatory Factor Analysis. Because the multivariate causal model has been revised, a third information-based multi-model comparison should be conducted with a new sample of students in introductory engineering courses from this same university. This will allow a conclusion to be drawn regarding the best approximating model for data gathered on this particular population: undergraduate engineering majors at a mid-sized public Historically Black University. Following this, we will draw a validation sample and assess the best approximating model with Latent Variable Structural Equation Modeling (a deductive factor analytic methodology) using absolute measures of Model Fit (e.g., χ^2, *RMSEA)*, and the assessment of path coefficients. These measures and model (along with traditional summary data such as enrollment, retention, and GPA), will then be used to assess the effectiveness of curricular and programmatic changes that are the core of the overall RED project.

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