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Validating an Engineering Self-Concept Survey

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Abstract

Testing and validating a survey to assess engineering self-concept is discussed in this complete research paper. Engineering self-concept is a multidimensional construct encompassing an individual's perception of their abilities and competencies in engineering. It plays a crucial role in student retention and success in engineering programs. Despite its importance, there is a lack of rigorously validated instruments to measure this construct effectively within engineering. The broader research aims to address this gap by developing and validating a survey instrument to assess engineering self-concept among undergraduate students. This paper focuses on validating the survey as presented in Dirisina & Shehab [1].

The development of the survey instrument was grounded in social cognitive theory and self-concept research, with a specific focus on the domain specificity self-concept. It was hypothesized that a well-constructed survey would capture the multifaceted nature of engineering self-concept, and underlying sub-constructs that aid in predicting an individual's self-concept. The methodology involved a two-stage process. First, survey pre-testing was conducted with subject matter experts to ensure content validity and clarity of items. This iterative process allowed for refinement of the survey questions and structure [1] Second, as described in this paper, the survey was statistically validated using a polychoric correlation analysis. Results obtained from the correlation analysis revealed strong internal consistency and construct validity of the survey items, with a few exceptions, indicating this survey instrument is a reliable and valid tool for measuring engineering self-concept among undergraduate students.

This study contributes to the field of engineering education research by discussing a statistically validated instrument for assessing engineering self-concept, which can be utilized in future research on student retention, academic performance, and career choices in engineering. Furthermore, the validated survey offers educators and administrators a valuable tool for identifying students who may benefit from additional support or interventions to enhance their engineering self-concept and, ultimately, their success in engineering programs.

Introduction and Literature Review

Self-Concept is a psychological construct that originated in the field of educational psychology, and was adopted to fields like engineering education. The researchers that established self-concept defined it as the general perception of an individual regarding their standing in a specific domain [2, 3]. The construct, within its representative domains, was found to be multifaceted while also being hierarchical, based on the exposure and experience of the individual [2, 3]. Along the lines of this characteristic, academic and non-academic facets of self-concept emerged, which was further expanded to engineering self-concept in our prior study [4].

Engineering self-concept, which is a student's perception about their abilities as an engineering student, can have a positive influence on academic performance, which can be further associated with improved retention in engineering [5, 6]. However, there is limited research that consistently captures the construct from educational psychology and adapts it to engineering education, and this research endeavor addresses this gap. This paper is step three of a larger research project, with the two preceding parts documented in prior studies. First, a systematic literature review was performed to gain a deeper understanding of self-concept and identify sub-constructs for the same within engineering education, which led to six sub-constructs being ascertained for engineering self-concept as well as a theoretical framework [4]. The next step involved the partial development of a survey instrument to measure engineering self-concept [1]. Survey statements were established for four (out of six) sub-constructs of engineering self-concept – academic self-description, STEM intrinsic value, belonging, and perceived competence, and are listed in Table 1. To account for the remaining sub-constructs of engineering self-concept theorized by the framework [1], statements to assess engineering identity and resilience were adopted from more sources.

Table 1: Resulting survey statements after two rounds of sorting.

Sub-Construct	Statement
Academic self-description	My academic goals are clear to me
	My study habits are poor
	I often expect to do poorly on exams
	I schedule my study time well
	Courses are usually not challenging for me
STEM intrinsic value	The future benefits of studying engineering are worth the effort
	I expect that studying engineering will be rewarding
	I expect that engineering will be a rewarding career
	A degree in engineering will allow me to get a job where I can use my talents and creativity
	A degree in engineering will allow me to obtain a job that I like
Belonging	I can relate to the people around me in my class
	I feel that I am a member of the engineering community at my institution
	The other students in my classes share my personal interests
	I see myself as a part of the engineering community at my institution
	I have a lot in common with the other students in my classes
Perceived competence	I can excel in an engineering major during the current academic year

	I can succeed in an engineering curriculum
	I can persist in an engineering major during the next year
	I may not do well in my major
	If I try, I will get good grades

Personal, social, and institutional contexts of engineering identity were adopted from various sources [7, 8, 9]. As a part of self-concept, engineering identity is framed as the importance of "being an engineering student" for an individual, and how closely that identity coincides with their personality and goals. To capture a snapshot of a student's engineering identity, a set of curated statements were adapted from 3 different sources: 2 statements from Jensen & Cross [9], 2 statements from Fleming and team [7], and 1 statement adapted from Borrego and team [8]. Moreno-Hernandez and Mondisa [10], defined Resilience as "the ability to recover from hardship". Five items from the Resilience, Grit, and Persistence scale [10] were included within the self-concept survey items to assess a student's resilience.

The inclusion of resilience and engineering identity statements into engineering self-concept provides a comprehensive set of statements to effectively evaluate the proposed facets within the construct. Table 2 lists the survey statements that were intentionally sampled for resilience and engineering identity and the ones that were originally included for belonging, academic self-description, perceived competence, and STEM intrinsic value. The engineering self-concept survey used a 6-point scale (1 – strongly disagree, 2 – disagree, 3 – moderately disagree, 4 – moderately agree, 5 – agree, 6 – strongly agree), to capture student responses.

Table 2: Complete survey instrument used to measure engineering self-concept.

Sub-Construct	Acronym for Reference	Survey Statement
Resilience	r1	I can achieve goals despite obstacles. [10]
	r2	I am able to adapt to change. [10]
	r3	I can deal with whatever comes. [10]
	r4	I think of myself as a strong person. [10]
	r5	I am not easily discouraged by failure. [10]
Engineering identity	eid1	Being good at engineering is an important part of who I am. [9]
	eid2	It matters to me how I do in engineering. [9]
	eid3	Your own sense of who you are (your personal identity) overlaps with your sense of who an engineer is (identity of an engineer). [8]
	eid4	I am fully committed to getting my college degree in engineering. [7]
	eid5	I think that earning a bachelor's degree in engineering is a realistic goal for me. [7]
Belonging	b1	I can relate to the people around me in my class. [11]
	b2	I feel that I am a member of the engineering community at my institution. [12]
	b3	The other students in my classes share my personal interests. [11]
	b4	I see myself as a part of the engineering community at my institution. [12]
	b5	I have a lot in common with the other students in my classes. [11]
Academic self-description	asd1	My academic goals are clear to me. [13]
	asd2	My study habits are poor. [13]

	asd3	I often expect to do poorly on exams. [13]
	asd4	I schedule my study time well. [13]
	asd5	Courses are usually not challenging for me. [13]
Perceived competence	pc1	I can excel in an engineering major during the current academic year. [11]
	pc2	I can succeed in an engineering curriculum. [11]
	pc3	I can persist in an engineering major during the next year. [11]
	pc4	I may not do well in my major. [13]
	pc5	If I try, I will get good grades. [13]
STEM intrinsic value	siv1	The future benefits of studying engineering are worth the effort. [14]
	siv2	I expect that studying engineering will be rewarding. [14]
	siv3	I expect that engineering will be a rewarding career. [14]
	siv4	A degree in engineering will allow me to get a job where I can use my talents and creativity. [11]
	siv5	A degree in engineering will allow me to obtain a job that I like. [11]

Table 2 presents a comprehensive list of survey statements that were obtained through a sorting task performed by subject matter experts [1] and adopting from survey instruments validated in research. The goal for this study is to test the statistical validity of this newly constructed survey instrument. While these statements were derived from previous research, their collective application as a new survey instrument necessitates revalidation. This process serves two crucial purposes: (1) It ensures the reliability and validity of the survey instrument in its current form; (2) It provides contextual validation for employing these statements to measure each identified sub-construct of engineering self-concept.

Methods

Now that a survey for engineering self-concept was established with the help of reputed sources and preliminary testing methods, this section describes the process and tools employed to test the statistical validity of the survey.

Data Collection

The engineering self-concept survey was administered among the first-year undergraduate students enrolled in an engineering orientation class in a predominantly white, midwestern institution. Data were collected during weeks 9, 11 and 12 of the first semester (i.e., in the middle of a 16-week semester). Links to the survey were shared through QR codes with all 841 of the students enrolled in the engineering orientation course. Flyers were also posted in their engineering orientation classroom. The number of students that responded to this survey was 113.

Validating Survey Pre-Testing Results

To assess whether the survey items were measuring/interrogating the intended sub-construct, the researchers analyzed correlations between the grouped survey items. This analysis process is useful to establish construct validity by testing whether all statements are measuring the same construct. If high correlations are observed between certain survey statements, we can make inferences about good internal consistency, suggesting that the items are reliably measuring the same construct. If low correlations are identified between any of the survey items, we can group the stronger items and trim out the weak associations to form a more robust measure of engineering self-concept.

Given that the data are ordinal, polychoric correlation analysis was used to evaluate the association among the five survey items for each subconstruct. Polychoric correlations are used under modest violation of normality to evaluate relations among the variables. This method assumes that the observed ordinal variable represents an underlying latent continuous variable that is normally distributed. It boasts numerous applications in social science research and when measuring self-report data [15, 16].

To examine whether the survey items measured the same construct, a sequence of paired comparisons were performed.

> *H_0: No association exists between the two survey items.*
> *H_1: The two survey items are associated with each other.*

Each pair of survey items under a particular construct were evaluated with this hypothesis. Since the focus of this test was to evaluate associations between the pairs (and not among all pairs), a familywise error rate does not pertain to this scenario. An alpha of 0.05 was used to evaluate the significance of each pair of survey items.

Results

The polychoric correlation tests were performed on the survey items listed in Table 8 and results obtained identified the survey items that strongly correlated with each other. Interpretations of significance and effect size are based on Cohen's [17] seminal work in the field of statistical power analysis. Cohen suggested that correlation coefficients 0.10, 0.30, and 0.50 represent small, medium, and large effect sizes, respectively.

Resilience

The correlation analyses revealed several significant relationships among the survey statements for resilience (Table 3). All correlations, except for r2 & r5 and r3 & r5, revealed statistically significant correlations. The strongest positive correlation was observed between r1 and r4 ($\rho = 0.54$, $p < 0.05$), suggesting a moderate to strong relationship between these two aspects of resilience. Other notable positive correlations included r1 & r2 ($\rho = 0.44$, $p < 0.05$) and r3 & r4 ($\rho = 0.44$, $p < 0.05$), both indicating moderate relationships. Interestingly, r5 showed weak to moderate negative correlations with most other statements, with the strongest negative correlation being with r4 ($\rho = -0.33$, $p < 0.05$). The correlation between r2 and r3 was approaching significance with p=0.0703.

Table 3: Correlation strengths among survey items of resilience.

Resilience Statements		r1	r2	r3	r4	r5
r1	I can achieve goals despite obstacles.	1				
r2	I am able to adapt to change.	0.44*	1			
r3	I can deal with whatever comes.	0.34*	0.19	1		
r4	I think of myself as a strong person.	0.54*	0.24*	0.44*	1	
r5	I am not easily discouraged by failure.	-0.22*	-0.15	0.001	-0.33*	1
						** Indicates significant correlations*

Engineering Identity

The correlation analyses to examine the relationships among the five engineering identity statements revealed several statistically significant correlations, with varying degrees of strength (Table 4). The strongest correlation was observed between eid2 and eid3 ($\rho = 0.68$, $p < 0.05$). Moderate positive correlations were found between eid2 and eid4 ($\rho = 0.37$, $p < 0.05$), eid2 and eid5 ($\rho = 0.33$, $p < 0.05$), and eid3 and eid5 ($\rho = 0.38$, $p < 0.05$),. A weak to moderate correlation was observed between eid3 and eid4 ($\rho = 0.30$, $p < 0.05$), and eid4 and eid5 ($\rho = 0.26$, $p < 0.05$). Notably, eid1 did not show any statistically significant correlations with the other statements, with correlation coefficients ranging from 0.09 to 0.17 ($p > 0.05$).

Table 4: Correlation strengths among survey items of engineering identity.

Engineering Identity Statements		eid1	eid2	eid3	eid4	eid5
eid1	Being good at engineering is an important part of who I am.	1				
eid2	It matters to me how I do in engineering.	0.17	1			
eid3	Your own sense of who you are (your personal identity) overlaps with your sense of who an engineer is (identity of an engineer).	0.09	0.68*	1		
eid4	I am fully committed to getting my college degree in engineering.	0.17	0.37*	0.30*	1	
eid5	I think that earning a bachelor's degree in engineering is a realistic goal for me.	0.12	0.33*	0.38*	0.26*	1
						** Indicates significant correlations*

Belonging

Among the belonging statements, all correlations in the matrix were statistically significant at $p < 0.05$ (Table 5). The strongest correlation was observed between b3 and b5 ($\rho = 0.62$, $p < 0.05$), closely followed by b2 and b4 ($\rho = 0.61$, $p < 0.05$), and b4 and b5 ($\rho = 0.60$, $p < 0.05$), all indicating strong positive relationships. Moderate to strong correlations were found between b3 and b2 (ρ = 0.40, $p < 0.05$), b3 and b4 (ρ = 0.53, $p < 0.05$), and b1 and b5 (ρ = 0.45, $p < 0.05$). The weakest, yet still significant, correlations were observed between b1 and the other variables (ranging from ρ = 0.28 to r = 0.45, $p < 0.05$).

Table 5: Correlation strengths among survey items of belonging.

Belonging Statements		b1	b2	b3	b4	b5
b1	I can relate to the people around me in my class.	1				
b2	I feel that I am a member of the engineering community at my institution.	0.28*	1			
b3	The other students in my classes share my personal interests.	0.31*	0.40*	1		
b4	I see myself as a part of the engineering community at my institution.	0.29*	0.61*	0.53*	1	
b5	I have a lot in common with the other students in my classes.	0.45*	0.38*	0.62*	0.60*	1
** Indicates significant correlations*						

Academic Self-Description

The correlation analyses to examine the relationships among the five survey statements of academic self-description revealed a mix of statistically significant and non-significant correlations, with varying strengths and directions (Table 6). The strongest positive correlation was observed between asd2 and asd4 (ρ = 0.49, $p < 0.05$). Other significant positive correlations included asd1 and asd4 (ρ = 0.37, $p < 0.05$), asd3 and asd4 (ρ = 0.32, $p < 0.05$), and asd2 and asd3 (ρ = 0.30, $p < 0.05$). Interestingly, asd3 showed a weak negative correlation with asd5 (ρ = -0.20, $p < 0.05$). The correlations between asd5 and the other variables were not statistically significant (ranging from ρ = -0.10 to ρ = 0.02, $p > 0.05$). The correlation between asd1 and asd2 (ρ = 0.10, $p > 0.05$) and asd1 and asd3 (ρ = 0.16, $p > 0.05$) were weak and not significant.

Table 6: Correlation strengths among survey items of academic self-description.

Academic self-description statements		asd1**	asd2	asd3	asd4	asd5
asd1**	My academic goals are clear to me.	1				
asd2	My study habits are poor.	0.10	1			
asd3	I often expect to do poorly on exams.	0.16	0.30*	1		
asd4	I schedule my study time well.	0.37*	0.49*	0.32*	1	
asd5	Courses are usually not challenging for me.	-0.10	0.02	-0.20*	-0.06	1
** Indicates significant correlations*						

Perceived Competence

From the correlation tests of the five survey items of perceived competence (Table 7), the strongest positive correlation was observed between pc3 and pc2 ($\rho = 0.66$, $p < 0.05$). Other significant correlations included pc3 and pc1 ($\rho = 0.59$, $p < 0.05$), and pc2 and pc1 ($\rho = 0.44$, $p < 0.05$. The factor pc4 showed significant but moderate correlations with other variables, ranging from $\rho = 0.21$ to $\rho = 0.37$ ($p < 0.05$). The factor pc5 demonstrated significant correlations with all variables except pc3, but only small effect sizes. Interestingly, the correlation between pc3 and pc5 was not statistically significant ($\rho = 0.09$, $p > 0.05$), suggesting these two aspects of perceived competence may be relatively independent.

Table 7: Correlation strengths among survey items of perceived competence.

Perceived competence statements		pc1	pc2	pc3	pc4	pc5
pc1	I can excel in an engineering major during the current academic year.	1				
pc2	I can succeed in an engineering curriculum.	0.44*	1			
pc3	I can persist in an engineering major during the next year.	0.59*	0.66*	1		
pc4	I may not do well in my major.	0.37*	0.21*	0.28*	1	
pc5	If I try, I will get good grades.	0.25*	0.27*	0.09	0.34*	1
** Indicates significant correlations*						

STEM Intrinsic Value

The five survey items of STEM intrinsic value revealed statistically significant positive correlations between all items, with correlation coefficients ranging from moderate to strong (Table 8). The strongest correlations were observed between siv4 and siv3 ($\rho = 0.66$, $p < 0.05$), closely followed by siv4 and siv1 ($\rho = 0.64$, $p < 0.05$), and siv4 and siv5 ($\rho = 0.63$, $p < 0.05$). Strong correlations were also found between siv3 and siv5 ($\rho = 0.60$, $p < 0.05$), and siv3 and siv1 ($\rho = 0.57$, $p < 0.05$). Moderate correlations were observed between siv2 and siv3 ($\rho = 0.53$, $p < 0.05$), siv2 and siv1 ($\rho = 0.46$, $p < 0.05$), and siv2 and siv5 ($\rho = 0.45$, $p < 0.05$). The weakest, yet still moderate, correlation was between siv2 and siv4 ($\rho = 0.40$, $p < 0.05$).

Table 8: Correlation strengths among survey items of STEM intrinsic value

STEM intrinsic value statements		siv1	siv2	siv3	siv4	siv5
siv1	The future benefits of studying engineering are worth the effort.	1				
siv2	I expect that studying engineering will be rewarding.	0.46*	1			
siv3	I expect that engineering will be a rewarding career.	0.57*	0.53*	1		
siv4	A degree in engineering will allow me to get a job where I can use my talents and creativity.	0.64*	0.40*	0.66*	1	
siv5	A degree in engineering will allow me to obtain a job that I like.	0.41*	0.45*	0.60*	0.63*	1
** Indicates significant correlations*						

Discussion

The effect sizes obtained from the polychoric correlation analysis were interpreted as suggested by Cohen [17] specifically for psychological constructs. The analysis of the underlying constructs of engineering self-concept revealed diverse effect sizes.

Resilience demonstrated a positive low to strong effect for items r1, r2, r3, and r4, while r5 indicated a very weak to moderate negative effect size. The moderate to strong positive correlations among r1, r2, r3, and r4 suggest that these statements may be capturing related facets of resilience. The negative correlations and/or insignificant correlations of r5 with other statements, particularly r4, suggest that r5 may be measuring a distinct or even opposing aspect of resilience compared to the other statements.

Engineering identity exhibited moderate to strong effect sizes for eid2, eid3, eid4, and eid5, with eid1 showing very weak effect sizes. The varying strengths of correlations between eid2, eid3, eid4, and eid5 suggest that these items are capturing a multifaceted construct with both interconnected and distinct components. The lack of significant correlations between eid1 and the other statements particularly indicates that eid1 may be measuring a unique construct differing from Engineering Identity.

Belonging consistently displayed moderate to strong effect sizes across all five of its underlying items. The coherence in this construct is evident in the cluster of strong correlations among b1, b2, b3, b4, and b5, which may indicate that a core component of the construct is being measured. Since some correlations were weak to moderate, yet statistically significant, it can be interpreted that they may be capturing a closely related aspect of construct.

Academic self-description presented moderate effect sizes for asd2, asd3, and asd4, whereas asd1 and asd5 showed very weak effect sizes. The significant relationships with moderate effect sizes between asd2, asd3, and asd4 suggest that these items are measuring related but distinct components of the same construct. The lack of significant correlations between asd1 and asd5 and the other variables supports the notion that it may be capturing a unique construct other than academic self-description, and does not exactly align with the other items.

In the case of perceived competence, pc5 had a very weak to moderate effect size, while pc1, pc2, pc3, pc4, and pc5 demonstrated moderate to strong effect sizes. The factor pc5 displayed weaker connections, specifically due to the insignificant connection with pc3. All other items indicated moderate to strong relationships that were statistically significant, suggesting that they are measuring overlapping aspects of a construct.

Notably, STEM intrinsic value exhibited strong effect sizes consistently across all its items (siv1, siv2, siv3, siv4, and siv5). The overall pattern of correlations for STEM intrinsic value items, with all falling in the medium to large effect size range, suggests a coherent structure among these variables. The variations in correlation strengths also indicate that each variable contributes unique information, supporting the multidimensional nature of the construct STEM intrinsic value.

Refining the Survey Instrument

The polychoric correlation tests played a crucial role in validating and refining the instrument designed to assess engineering self-concept among first-year undergraduate students, significantly enhancing its construct validity. This process led to the removal of survey statements r5, eid1, asd1, asd5, and pc5 due to their weak and insignificant correlations with other items within the construct. By retaining only the strong and moderately strong correlated statements (as listed in Table 9), we've strengthened the overall reliability and validity of the instrument.

Table 9: Refined survey instrument for engineering self-concept.

Sub-Construct	Acronym for Reference	Survey Statement
Resilience	r1	I can achieve goals despite obstacles.
	r2	I am able to adapt to change.
	r3	I can deal with whatever comes.
	r4	I think of myself as a strong person.
Engineering identity	eid2	It matters to me how I do in engineering.
	eid3	Your own sense of who you are (your personal identity) overlaps with your sense of who an engineer is (identity of an engineer).
	eid4	I am fully committed to getting my college degree in engineering.
	eid5	I think that earning a bachelor's degree in engineering is a realistic goal for me.
Belonging	b1	I can relate to the people around me in my class.
	b2	I feel that I am a member of the engineering community at my institution.
	b3	The other students in my classes share my personal interests.
	b4	I see myself as a part of the engineering community at my institution.
	b5	I have a lot in common with the other students in my classes.
Academic self-description	asd2	My study habits are poor.
	asd3	I often expect to do poorly on exams.
	asd4	I schedule my study time well.
Perceived competence	pc1	I can excel in an engineering major during the current academic year.
	pc2	I can succeed in an engineering curriculum.
	pc3	I can persist in an engineering major during the next year.
	pc4	I may not do well in my major.

STEM intrinsic value	siv1	The future benefits of studying engineering are worth the effort.
	siv2	I expect that studying engineering will be rewarding.
	siv3	I expect that engineering will be a rewarding career.
	siv4	A degree in engineering will allow me to get a job where I can use my talents and creativity.
	siv5	A degree in engineering will allow me to obtain a job that I like.

The nuanced correlations observed among the survey statements within each sub-construct underscored the necessity of refining the overall instrument. These varying strengths of correlations, both within and between constructs, provide robust support for the multifaceted nature of engineering self-concept. This finding highlights the importance of measuring these distinct yet interrelated aspects separately, offering a more comprehensive and accurate assessment of students' self-perceptions in engineering.

The refinement process has several important implications for first-year engineering education research and practice. It provides researchers with a more precise tool for investigating the complex construct of engineering self-concept among first-year engineering students, potentially leading to more accurate and meaningful results in future studies. Additionally, it offers educators a more reliable means of assessing their students' self-concept, which could inform targeted interventions and support strategies. In conclusion, this refined survey instrument provides a strong foundation for assessing self-concept in the domain of engineering education. Its improved statistical validity and nuanced approach to measuring distinct yet interrelated aspects of engineering self-concept make it a valuable tool for advancing our understanding of how students perceive themselves as they are being exposed to first-year engineering programs and the engineering culture.

Limitations and Future Directions

This study has some limitations to consider. The reliance on smartphones or tablets for QR code scanning and stable internet connections potentially introduced selection bias, possibly excluding students without access to compatible devices or reliable connectivity. This method, while efficient for data collection, may have skewed the sample towards more technologically affluent participants. Additionally, the inability to control for discussions among students while completing the survey could have influenced individual responses, potentially compromising the independence of the data. The digital format of the survey might also have affected response patterns, with the possibility of decreased attention spans or rushed responses compared to traditional paper-based methods. While paper-based surveys could address some of these issues, they present their own challenges, such as ensuring all questions are answered and increased data entry time.

Further limitations include the potential for response bias, where participants might have provided socially desirable answers rather than their true opinions. Despite these limitations, the established survey instrument provides a valuable foundation for validating the conceptual model of engineering self-concept [4]. This refined instrument lays a solid groundwork for future research, including potential longitudinal studies and cross-cultural comparisons, which could further enhance our understanding of engineering self-concept and its development over time.

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