Classifying Survey Items related to Engineering Self-Concept for Application in First-Year Engineering

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Introduction

This research paper is a step towards building a survey instrument to measure engineering self-concept. A prior systematic review [1] identified multiple sub-constructs of engineering self-concept: perceived competence, engineering intrinsic value, belonging, academic self-description, resilience, and engineering identity. This study focuses on identifying survey statements that accurately assess these sub-constructs. The survey statements identified in the systematic review of literature were found to have confounding and ambiguous language/messaging as they described the sub-constructs of engineering self-concept. The language was either unsuited for the context of engineering undergraduates or unclear in referring to the pertaining construct.

A new set of survey statements that represented the constructs in focus were then sampled from other sources in engineering education. To make sure the selected statements were consistently perceived to be interrogating the pertaining constructs, the researchers performed a multi-step validation study. First, 43 survey statements were filtered from some prominent surveys in the field of engineering education. Then 10-subject matter experts (SMEs) performed a card-sorting procedure, where each of the 43 statements was sorted according to the 5 constructs. The SMEs were faculty members who are active in engineering education. Each faculty either holds a doctorate in engineering education or has significant experience teaching and working with first year students. This task was intended to accomplish grouping of the survey statements to the sub-constructs through expert knowledge.

Preliminary analysis revealed confusion between the constructs of perceived competence and self-efficacy given that the survey statements for these constructs appeared to be randomly attributed to each construct. Thus, an abbreviated card sorting task was again conducted. During this step the SMEs were presented with a subset of 11 survey statements from the original collection and asked to group them into either perceived competence or self-efficacy. This paper discusses the card sorting activities and their implications towards building a survey instrument to assess engineering self-concept.

Literature Review

A systematic review [1] distinguished between self-concept and self-efficacy and discussed the resultant operating definitions for the two constructs. This review found evidence that the two constructs in focus were often used interchangeably and were considered as the same measure in practice. This created inconsistencies in understanding of the two constructs. The goal of the review was to understand how self-concept and self-efficacy were different and to establish the underlying constructs of engineering self-concept. The researchers sought to build a survey to assess engineering self-concept through this process. The review revealed 6 different sub-constructs for engineering self-concept – academic self-description, perceived competence, engineering intrinsic value, belonging, engineering identity, and resilience.

One of the sub-constructs identified above, perceived competence is closely related in theory to self-concept, which is further found in literature to be confounded with self-efficacy. So, to account for and eliminate entanglement of survey statements between perceived competence and

self-efficacy, we also include self-efficacy in the sorting task. The current paper identifies definitions for each of these terms and then delves into identifying survey statements that would be appropriate for assessing them (excluding engineering identity and resilience) in first year engineering students.

Self-Efficacy refers to the outcome expectations in an upcoming task and the confidence to produce desired behaviors and expected outcomes [2], [3]. It is very task and scenario specific. However, conflicting research is found regarding this argument, that the framing of self-efficacy to be general or task-specific needs to be explicit [4]. So, to maintain consistency in the meaning and the term, we use self-efficacy as "engineering task-related self-efficacy".
Academic Self-Description is the way an individual perceives and describes themselves in academic contexts [5]. Survey statements to measure this construct should specifically probe to lead the individual to picture a description of themselves with respect to the statement, and rate themselves in that respect.
Perceived Competence deals with broad perceptions of self and has the closest relation to self-concept out of all the outlined underlying constructs. It is the context/field specific perceptions of an individual regarding their abilities, standing in that field [1].
Engineering Intrinsic Value is the innate interest, joy, and value attained by an individual while participating in an activity, specifically in engineering [6].
Belonging is considered as the degree to which an individual feels that they fit and belong in the program, and the program is a good fit to their future goals.

The review [1] identified multiple sources where the above sub-constructs were used as part of a larger survey to measure self-concept within engineering students. However, it was challenging to retrieve survey items to build an overall survey specifically for engineering self-concept. This was due to confounded usage of survey items. For instance, the two survey statements "I am interested in the way science and engineering help people", and "I am interested in reading websites, magazines or books about scientific issues" were used as measures for STEM Identity [7]. But the linguistic composition is not consistent with the operational understanding of an individual's identity.

The researchers decided to conduct a new search to find alternative survey statements that could be used to build an instrument to assess the sub-constructs defined for engineering self-concept. Multiple survey instruments identified in the literature review were examined to identify particular statements that aligned with the 6 constructs defined by [1] as important for engineering self-concept. To this end, a new pool of statements was sampled from these widely applied surveys in engineering education.

Reference [8] explored differences in engineering identity between lower and upper-division undergraduate students in engineering. Engineering identity in their paper was based on a model that encompasses performance/competence, interest, recognition (by others and self) and efficacy as the key components of identity. Out of the survey statements used in [8], one statement was sampled with to represent and assess self-efficacy, three for perceived competence, and one for engineering intrinsic value.

A study by Cokely and Patel [9] measured the psychometric properties from the scores of the Academic Self-Concept Scale (ASCS), a 40-item scale that measures the "perceptions and feelings students have about their academic abilities" developed by [10]. From this scale, eight survey statements were sampled to measure academic self-description, four to measure perceived competence, one to measure engineering intrinsic value, and two to measure self-efficacy.

The Longitudinal Assessment of Engineering Self-Efficacy (LAESE) [11], [12] was designed to identify changes in self-efficacy of engineering undergraduates, by focusing on efficacy and coping strategy in challenging situations, expected outcomes from pursuing engineering, expectations of workload in engineering undergraduate classes, process of choosing an engineering major, extent of career exploration, and influence from role models. From this survey instrument, four statements were sampled to measure perceived competence, three for engineering intrinsic value, four for belonging, and one survey statement for self-efficacy.

The Pittsburg Freshman Engineering Attitudes Survey (PFEAS) was designed to assess and track the abilities and attitudes of engineering freshmen [13]. It measures several aspects of students' attitudes including their expectations of the engineering profession. For the purposes of this sorting procedure, 8 survey statements were sampled to assess engineering intrinsic value.

In an evaluation of students' attitudes towards engineering, design, and technology with an introduction to makerspace [14], the researchers analyzed the sense of belonging among students by utilizing an adaptation of a previously validated scale [15]. For the sorting procedure, three survey statements were sampled to represent and assess belonging.

Methods and Results

A total of 43 survey statements were sampled from 5 different sources (described in the previous section) by mapping each statement to the intended construct. Table 1 provides a detailed account of the statements that were extracted from each survey instrument.

Table 1: Survey statements sampled with intended sub-construct.

Intended sub-construct	Statement	Source
Academic Self-Description	I feel like a failure sometimes.	[9]
	I may not do well in my major.	
	I often expect to do poorly on exams.	
	My study habits are poor.	
	I'd like to be a better student.	
	I schedule my study time well.	
	I am a capable student.	
	I feel that I am better than the average college student.	
Perceived Competence	It is hard to keep up with classwork,	[9]
	If I try, I will get good grades,	
	My academic goals are clear to me.	
	Courses are usually not challenging for me.	
	I am confident that I can understand physics/chemistry/math outside of class.	[8]
	I can overcome setbacks in physics/chemistry/math.	

	I can understand concepts I have studied in physics/chemistry/math.	
	I can succeed in an engineering curriculum.	[11], [12]
	I can excel in an engineering major during the current academic year.	
	I can complete any engineering degree at this institution.	
	I can persist in an engineering major during the next year.	
Engineering Intrinsic Value	I expect that engineering will be a rewarding career.	[13]
	I expect that studying engineering will be rewarding.	
	The advantages of studying engineering outweigh the disadvantages.	
	The future benefits of studying engineering are worth the efforts.	
	I don't care for this career.	
	Engineering is an occupation that is respected by other people.	
	I am studying engineering because it will provide me with a lot of money; and I cannot do this in other professions.	
	I am studying engineering because I enjoy figuring out how things work.	
	A degree in engineering will allow me to get a job where I can use my talents and creativity.	[11], [12]
	A degree in engineering will allow me to obtain a well-paying job.	
	A degree in engineering will allow me to obtain a job that I like.	
	I enjoy learning the concepts I have studied in my engineering classes.	[8]
	Being an engineering student is rewarding.	[9]
Belonging	I can relate to the people around me in my class.	[11], [12]
	I have a lot in common with the other students in my class.	
	The other students in my classes share my personal interests.	
	Someone like me can succeed in an engineering career.	
	I see myself as a part of the engineering community at my institution.	[14]
	I feel that I am a member of the engineering community at my institution.	
	I feel a sense of belonging to the engineering community at my institution.	
Self-Efficacy	I can do well in the physics/mathematics/chemistry exam.	[8]
	I will succeed in my math/physics/chemistry courses.	[11], [12]
	Exams are usually not challenging for me.	[9]
	I am confident while taking tests.	

To validate the alignment, SMEs were asked to group the statements into various constructs. Each of the 43 statements were printed on individual cards along with the 5 constructs printed on "title" cards. Ten SMEs were instructed to read the statement on each card and group it with the construct they believed to best described by the statement. Ultimately, each SME sorted all 43 statements to one of 5 constructs. This task took between 7 to 12 minutes to complete. These results were collected and grouped across all experts leaving the respondent anonymous.

This sorting task resulted in clarity on certain constructs, but confusion on others. Survey statements for academic self-description, belonging, and engineering intrinsic value received clear agreement among SMEs, enabling the researchers to identify 5 statements for each of those constructs. Table 2 shows the statements that had high agreement among the SMEs and which sub-construct each statement was mapped into.

Table 2. Results of Sorting Task for Statements with High SME Agreement

Sub-Construct	Survey Statement	Agreement (%)
	My academic goals are clear to me.	100

Academic Self -Description	My study habits are poor.	90
	I often expect to do poorly on exams.	80
	I schedule my study time well.	70
	Courses are usually not challenging for me.	70
Engineering Intrinsic value	The future benefits of studying engineering are worth the effort.	100
	I expect that studying engineering will be rewarding.	100
	I expect that engineering will be a rewarding career.	100
	A degree in engineering will allow me to get a job where I can use my talents and creativity.	90
	A degree in engineering will allow me to obtain a job that I like.	90
Belonging	I can relate to the people around me in my class.	100
	I feel that I am a member of the engineering community at my institution.	100
	The other students in my classes share my personal interests.	100
	I see myself as a part of the engineering community at my institution.	100
	I have a lot in common with the other students in my classes.	100

However, SME judgements were overall inconclusive for statements representing perceived competence and self-efficacy. This indicates possible confounded interpretations of the two constructs. Although research exists that differentiate among the two [4], [16], [17], [18], the general perceptions of the SMEs regarding the two constructs are indistinct. Table 3 displays the statements in which the SMEs did not agree on the classification into a single construct. The most distinct alignment for perceived competence (statement #1: "I can excel in an engineering major during the current academic year"), still yielded some uncertainty. Specifically, this statement was selected by 7 SMEs to represent perceived competence and by 1 SME to represent self-efficacy (and 2 additional SMEs assigned it to academic self-description). Other statements indicated greater confusion of constructs. For instance, statement #5 ("I can persist in an engineering major during the next year") had an equal number of SMEs align it with each of the two constructs.

Table 3. Results of Sorting Task for Statements with Poor SME Agreement

Survey Statement	**Perceived Competence**	**Self-Efficacy**
I can excel in an engineering major during the current academic year	7	1
I can succeed in an engineering curriculum	6	3
I can understand concepts I have studied in chemistry/math	5	3
I will succeed in my math/chemistry courses	5	4
I can persist in an engineering major during the next year	5	5
I may not do well in my major	4	1
I can overcome setbacks in chemistry/math	3	7
I am confident that I can understand chemistry/math outside of class	4	6
I can complete any engineering degree at this institution	3	6
If I try, I will get good grades	3	6
I can do well in the chemistry/math exam	3	6

Due to the lack of clarity in the original SME sort task for perceived competence and self-efficacy, a re-sort was conducted with the same SMEs using 11 of the 43 initial statements as listed in Table 3. Adopting the operating definitions from [1], self-efficacy refers to an individual's confidence in producing desired behavior or results in an upcoming task. Perceived competence, on the other hand, is an underlying construct of self-concept and indicates an individual's view of their general standing and abilities in a domain or field. The researcher arranged individual meetings with each of the SMEs to review these operational definitions. SMEs were then instructed to perform a re-sort of the 11 individual statement cards into the two sub-constructs identified on the "title" cards. This process took between 5 to 8 minutes.

The second sorting task revealed a discernible agreement among SMEs for survey statements representing perceived competence (Table 4). However, self-efficacy was not consistently identified through the included survey statements. This meant that the sample of survey statements used for this research are not in consistent alignment with self-efficacy, and that the researchers must look for other sources to sample survey statements for this construct.

Table 4. Results of Second Sorting Task for Perceived Competence and Self Efficacy

Survey Statement	First Sort		Second Sort	
	Perceived Competence	Self-Efficacy	Perceived Competence	Self-Efficacy
I can excel in an engineering major during the current academic year	7	1	8	2
I can succeed in an engineering curriculum	6	3	7	3
I can understand concepts I have studied in chemistry/math	5	3	6	4
I will succeed in my math/chemistry courses	5	4	4	6
I can persist in an engineering major during the next year	5	5	6	4
I may not do well in my major	4	1	9	1
I can overcome setbacks in chemistry/math	3	7	6	4
I am confident that I can understand chemistry/math outside of class	4	6	6	4
I can complete any engineering degree at this institution	3	6	6	4
If I try, I will get good grades	3	6	6	4
I can do well in the chemistry/math exam	3	6	2	8

Discussion

Self-concept and self-efficacy are constructs that originated and were established in educational psychology but have been incorporated into the field of engineering education. However, there is a scarcity of research where engineering self-concept has been validated with measures within the field of engineering education. It is likely that when developmental constructs are assessed among individuals of different ages and experiences, so researchers must take initiative to make the instrument suitable for the population. This paper is a step towards creating an instrument to

evaluate self-concept within engineering freshmen while also distinguishing it from self-efficacy in practice.

A sorting task was conducted with 43 survey statements and 5 theoretical concepts towards building a survey instrument to assess engineering self-concept among first-year engineering students. Due to the nature of results obtained, the task was conducted twice sequentially. The results obtained from the first sorting task strengthen our reservation that there indeed is a lack of distinction in the way perceived competence and self-efficacy are understood.

The second sorting task was conducted after reviewing both constructs with the SMEs and the results were stronger. SMEs had higher agreement for statements aligned with each construct. This study has yielded robust survey items that can be used to assess engineering self-concept through evaluation of the associated sub-constructs. The resulting items have been demonstrated to be clear and consistently interpreted by SMEs.

It was observed that academic self-description, engineering intrinsic value, and belonging got very strong votes with almost a clear choice of survey statements for belonging and engineering intrinsic value. The 3 sub-constructs in focus here have clear boundaries in their theoretical understanding and that is reflected in the resultant votes of the sorting task. But looking at the split of votes between perceived competence and self-efficacy in round #1 of sorting, there was an almost equal split of votes between them, to the extent of one statement "I can persist in an engineering major during the next year" receiving 5 votes each for perceived competence and self-efficacy. This was expected as was evident of the existing literature [4], and the researchers had included self-efficacy to account for this confounded understanding.

Prior to performing the round #2 of the sorting, the operating definitions of perceived competence and self-efficacy were discussed with the SMEs, and 11 statements were presented to sort. This round helped clarify statements aligned with perceived competence and the researchers were able to determine survey statements based on high agreement and by avoiding the ones that highlight task specificity. Only one statement "I can do well in the chemistry/math exam" received a high agreement of its alignment with self-efficacy. Although it fits the task specific elucidation of self-efficacy, overall interpretation of sorting data convey that further research is required to construct a survey instrument for engineering task-related self-efficacy. The established sample of survey statements post both rounds of sorting are provided in Table 5.

Table 5. Resulting survey statements after two rounds of sorting.

Statement	Sub-Construct
My academic goals are clear to me	Academic Self-Description
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	
The future benefits of studying engineering are worth the effort	Engineering Intrinsic value
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	
I can relate to the people around me in my class	Belonging
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	
I can excel in an engineering major during the current academic year	Perceived Competence
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	

This paper is an exploratory step towards implementing survey pre-testing through a sorting task, to promote accurate assessment of behavioral constructs. Research shows that survey pre-testing with SMEs can aid in building clear survey instruments, with the number of SME's ranging from two to over twenty [19]. In the survey pre-testing context, SMEs are individuals with "theoretical knowledge or practical experience" in that domain, making them eligible for evaluating a questionnaire in its development stage [19], [20]. Such experts are indicated to be crucial in the process of building strong survey instruments with good questions [19].

Conclusion

The sorting experiment was planned as a single round procedure to identify appropriate survey statements for the sub-constructs of engineering self-concept. But the confounded interpretations of perceived competence and self-efficacy among the SMEs resulted in a re-sort with a subset of the initial sample of survey statements. Strong agreement was found for academic self-description, engineering intrinsic value, belonging, and perceived competence through the experiment, helping the researchers to establish survey statements for those respective sub-constructs. However, only a single statement for self-efficacy was identified within the current sample.

Future Directions

Future directions for this research include completing the survey instrument by expanding the research for self-efficacy and to sample statements for resilience, one of the underlying constructs for engineering self-concept, and performing a confirmatory factor analysis to gauge the strength of the final resultant instrument. While the sample of SMEs was small, findings are worth documenting as they solidify the evidence that better understanding and specificity of self-efficacy, such as language to indicate the task specificity of self-efficacy should be strengthened in engineering education research and practice.

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