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A Systematic Review of Academic Self-Concept Measures in First-year Engineering Education

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Background/Motivation

The research on self-concept has been occupying a significant portion of the studies contributing to the advancement of educational psychology. As much as the topic has gained popularity in the past decades, it suffered due to the lack of a concrete definition in its early years of advent [1]. As interest in it grew, self-concept also gained strength, clarity, and structure. It grew strong as it gained a definition explaining how it might play an important role for a student and for an educator [1]. Clarity was provided when it was differentiated from some parallel concepts in self-theory and affixing a space for self-concept in an individual's perceptions, and not a just placeholder [2]. Structure was added by delving into the depths of the construct and understanding its multidimensional and hierarchical properties [3]. As the gray areas began to fade away, self-concept gained popularity.

However, debates sparked about how different self-concept and self-efficacy were, in their assessment areas and outcomes. After deeper digging, it was found that there were some fundamental differences in the literature dealing with each of the two constructs [2]. Despite constant conceptual developments and growing popularity, the adoption of self-concept in engineering education remains sparse. Instances of self-concept being referred to as confidence [4] or self-efficacy (as discussed in further sections) is still found in recent engineering education literature.

Educational psychology literature has distinguished between self-concept and self-efficacy. It was established that self-concept is important for building ability perceptions [1] and self-efficacy important for producing desired behaviors or performance [2]. However, in engineering education literature, we do not see a clear differentiation between the concepts. This study posits that the two constructs are disparate and attempts to demonstrate that they are critical in addressing engineering student attrition. They are among the prominently noted reasons for persistence [5], but we need a clear definition and structure for the two in the context of engineering, conforming to the theoretical frameworks presented in educational psychology. Identifying which factors or sub-constructs commingle to form the self-concept of a student in engineering undergraduate education is the crux of this study. To accomplish that, a systematic review was performed over recent studies, related to engineering education, that assessed self-concept as part of their methodology.

This paper first introduces self-concept and self-efficacy, the two constructs that are often used interchangeably in literature, followed by a database search for recent studies measuring self-concept. Based on the results this study enlists the variables assessing either of the constructs that were introduced. Then a detailed analysis of the differences between the two constructs is provided. Extensions to the current structure of self-concept and explanations about how it can be adapted to self-referent domains of an individual is discussed. The distinctions between the terms posed in this study are then used to identify which sub-constructs are most pertinent for measuring self-concept in engineering education.

Identifying the variables (sub-constructs) within self-concept has beneficial applications in first-year engineering education due to the noted levels of attrition in the first two years of an engineering curriculum [6]. Building a scale and consequent interventions to influence those sub-constructs will help improve student retention due to the direct relation of self-concept with academic achievement; less importantly in terms of high grades but more so as an active contributor to human attainment [2], [7].

Self-Concept and Self-Efficacy

Self-Concept

Self-concept is defined as the broad view of one's own abilities that are formed by self & social evaluations and interactions [1]. The multifaceted and hierarchical properties of self-concept were later studied by Marsh and Shavelson [3]. These properties were examined, supported, and validated in other following studies along with describing self-concept in a multidimensional structure [8], [9], [10], [11]. This research laid a reliable foundation for future considerations, in that self-concept is multifaceted, hierarchical, and multidimensional – meaning that it varies with age, education, vocation, and one's social standing. These dimensions and facets can be self-referent or as established by an authority/institution.

The multifaceted property states that a person's self-concept will be categorized by "self-referent" domains/activities in which the individual shows interest [3]. Hierarchal nature of an individual's self-concept puts general self-concept at the apex of ability inferences, and distinguishes it into domains like academic and non-academic, followed by further distinction into sub-domains (e.g., non-academic self-concept is further categorized into physical and social self-concepts) [3]. The multidimensionality of self-concept posits that these perceptions and inferences are volatile, vary with age and/or achievement levels of an individual, and display varied properties at each dimension [10].

Self-Efficacy

Bandura, in his work involving Social Cognitive Theory [12], defined self-efficacy as one's expectancy to perform and produce desired results in a task. Efficacy expectations reflect confidence in producing certain patterns in a behavior [13] and do succeed in achieving the desired results [14]. In the domain of academic attainment, the role of self-efficacy was extended to utilizing learning strategies, setting effective goals, endurance, and success [15]. Self-efficacy in individuals is known to be affected by several factors. Psychological reactions (nervousness or excitement before a big meeting) are known to negatively influence self-efficacy. Social persuasion, i.e., belief, feedback, and support received from peers positively influences self-efficacy. Lastly, mastery experiences – a known record of one's previous grades/results, and vicarious experiences – skill or content acquired by observing advanced peers and role models play a large role in improving self-efficacy [16].

However, it should be noted that self-efficacy once improved, say through factors listed before, does not hold constantly at that level. Research has found that when an individual has a high perceived self-efficacy, it could result in less preparation or effort from the individual, leading to undesired results, and eventually low self-efficacy [16]. Critical differences between self-concept and self-efficacy, that are considered crucial for this study are discussed in the following chapters.

Method

Early researchers [1] posited that there was a lack of an agreed upon standard definition and assessment for self-concept, which is still the case for assessing self-concept in science and technology majors [17]. A possible reason is, assessment of self-concept in the domain of engineering requires a multi-facet amalgamation within academic self-concept, i.e., a combination of science, math, and technical self-concept.

A Google Scholar search with “academic self-concept” and “engineering education” as Boolean terms produced 548 results. The search criterion was restricted to the years 2020 to 2022, to capture the current and state of the art methods to assess self-concept in STEM fields. Using Google Scholar as the search database allows for coverage across global research publications, leaving room for the researchers to shortlist suitable publications focused on relevant disciplines. Initial results consisted of a mixed bag of instruments that were dedicatedly assessing self-concept, but were thought to be assessing self-efficacy, and vice-versa. But, they qualified as research related to STEM and didn’t exactly match criterion of engineering education.

After excluding the manuscripts that didn’t deal with measuring self-concept among engineering or STEM undergrads, and the ones that weren’t translatable, a total of 16 research (empirical) studies were available for analysis. The selected studies used some form of survey to assess self-concept. It included 2 critical case articles were selected, that did not quite qualify for the criterion of measuring self-concept among stem undergraduates but were worth studying.

This systematic review sought to find the essence of the construct measured in the identified surveys. This study investigated which component(s) the survey claimed to measure, and to which construct, self-concept or self-efficacy, the component was described to represent. The components and their associated construct(s) are listed in the results. Although the search was limited to papers assessing self-concept, the search revealed papers that measured self-efficacy using scales that the authors described as self-concept. So, it seemed befitting to classify both constructs in the analysis.

It is likely that these components or sub-constructs would vary for any given domain due to the multidimensionality of self-concept and self-efficacy. So, the key to this review is to identify which components are suitable for a scale to measure self-concept in engineering education. The analysis consists of a re-classification to align components based on which constructs they measure, according to the established theories identified in the literature.

Results

The selected papers utilized documented surveys formulated questions targeted towards specific sub-constructs. The goal and methods in these papers were examined to classify the measured constructs. Table 1 below shows the sub-constructs, referred to as variables from here on, and the classification of whether they were described to assess self-concept or self-efficacy.

Table 1: Classification of variables, as provided by the shortlisted studies, to be assessing either self-concept or self-efficacy.

Self-concept	Self-Efficacy
Math ability [18], [19]	Academic self-description [20]
College persistence [21], [33]	STEM intrinsic value [22]
STEM interest [18], [30]	Academic competence [24]
Perceived competence [25], [30]	
Perceived STEM performance [18]	
Belief in performance [25]	
Professional identity (vocational identity) [21]	
STEM identity [30]	
Sense of belonging [23], [26]	
Resiliency [23]	
Future goals/intentions [23]	
Academic ability [18], [19], [31], [32]	
Intellectual self-confidence [19], [27], [32]	
Drive to achieve [19], [32]	
Self-acceptance [27]	
Self-esteem [27]	
Academic involvement [28], [32]	
Expectancy for success [29]	
Attainment value [30]	
Utility value [30]	
Recognition [30]	
Motivation [26]	

Discussion

Differences and similarities

As mentioned in the previous section, there is research that postulates the structural and functional differences between self-concept and self-efficacy. This paper uses the previous research to elucidate differences between the two concepts and proceeds to differentiate them in terms of the current study considerations. Clarity about which construct a given scale is assessing is sometimes confounded so distinguishing between the two is especially important. The results of this discussion can provide insights for any future work dealing with self-efficacy and self-concept in engineering education. Given that a theoretical framework distinguishing between the two constructs exists in educational psychology literature, extending it to engineering education would ensure consistency and adaptability. The applications can be extended to considering pedagogical techniques targeted at a certain sub-construct.

Although the terms self-concept and self-efficacy were prevalent through the 20th century, attempts to classify the two began close to the turn of the century. Bong and Clark [2] posited that academic self-efficacy has a comparatively more straightforward structure than self-concept. One of the major differences between academic self-concept and academic self-efficacy is the presence of social component in the former, and absence of same in the latter. Self-concept is largely dependent on the degree of both self and socially perceived competence. Influences of stereotypes, age, confidence levels, and experiences can be found among such feedback. Additionally, self-concept relies heavily on one's social standing and comparison. Behavioral differences in predicting academic accomplishments were expected to be because of academic self-efficacy's prominent use of past experiences and mastery levels. This study also highlighted that the two constructs may share a similar "within-construct network", referring to the strong support for the multifaceted and hierarchical structure of self-concept and the limited but present evidence received for the multidimensionality and hierarchical structure of self-efficacy. But it was insisted future studies should verify these findings [2].

The study by Bong and Skaalvik [34] clarified the findings in the work of Bong and Clark [2]. Their study stated that a central element to both self-concept and self-efficacy is an individual's view of their competence. However, they remarked that the similarities in the perceptions of competence should be studied further. Domain-specific previous experiences are posited to be driving both self-efficacy and self-concept but differentiating that the conclusion formed by the individuals through either of the constructs may not be the same. "Temporal stability" and "malleability" of self-concept was established while self-efficacy was considered the dynamic variable. By definition, self-concept is the "knowledge and perceptions about oneself in achievement situations" while self-efficacy is "convictions for successfully performing given academic tasks at designated levels." Among pertinent task-specific demonstrations, a comparison of the two constructs was tabulated in terms of definition, centrality, composition, influence of competence, domain-specificity, structure, time orientation, dimensionality, temporal, and predictive qualities. The other dimensions of comparisons stated self-concept operates with "perceived competence" as its central element, comprising both mental and emotional assessment of oneself, forcing judgment of past events with a normative lens based on domain. Self-concept embodies a multidimensional and hierarchical structure, stable through passing time and events with "motivation, emotion and performance" as predictive outcomes. Self-efficacy's central element is "perceived confidence", comprised of only mental assessment of oneself in comparison to a norm or a set goal. It is domain specific like self-concept but is also task specific. Self-efficacy embodies a multidimensional but loosely hierarchical structure that is unstable or easily influenced, and the predictive outcomes are "motivation, emotion, cognitive and self-regulatory processes, and performance" [34].

Analyses performed on assessment data of 15-year-old Belgian students [34] identified conceptual differences between academic self-concept and academic self-efficacy, along with causal and predictive properties within them. This lent support to the findings of Bong and Skaalvik [33]. Self-concept has a strong causal influence on academic self-efficacy beliefs and is predictive in the sense that academic self-concept was found to be a predictor of motivational variables among an individual. On the other hand, academic self-efficacy was found to mediate (or contribute to) one's academic achievement [35].

In a recent study by Marsh and colleagues [36], the subtle and clear differences between the two constructs were documented. Self-concept was said to be formed through environmental, personal, and experiential influences. Self-efficacy on the other hand is influenced by comparison with an absolute criterion and was said to lead to success in activities. The task specificity of self-efficacy was emphasized. One of the crucial findings of this study was that "generalized self-efficacy" and "outcome expectancies", which by definition and functionality were considered a measure for self-efficacy, closely represent self-concept. Another valuable finding was a clear guideline for identifying which construct the data represent. It was found that data that are "purely descriptive and future oriented" represent self-efficacy while "descriptive, evaluative and based on past accomplishments" data point towards self-concept [36].

Previous research sparks the thought of whether the construct that is being considered gets mixed up process of interpretation or the measurement process. This was said to be the case in some instances where data was labelled to be representing self-efficacy, while in actuality, self-concept was being measured. Clear instructions were laid out in the recent study by Marsh and colleagues [36], about how future researchers can be wary of selecting the appropriate measure for the construct that is being studied, while also avoiding misinterpretation of data.

Based on the studies listed above, this study was guided by the representation that self-efficacy measures are particularly task-specific, but this is valid only if the "focus of prediction" is also narrow. A way to identify and assign a measure/response to either of the constructs is using the "rule" that self-efficacy responses are descriptive in nature, while self-concept responses are broad opinions [36]. Otherwise, the assessment of which construct a response represents gets confounded by lack of clarity. It is also crucial to note that self-concept references are focused on one's perceived competence, formed by past experiences and are relatively stable. Whereas self-efficacy relates to one's perceived confidence, focus on future activities, and is easily influenced [34].

Develop definitions for the study

For the sake of this paper, research and findings about self-concept and self-efficacy over the years were studied to form an identifying criterion for the related assessors. Additionally, only the academic dimension of self-concept, based on the hierarchical model [1], is considered. Self-concept is a general conception of one's abilities, wherein a global self-concept (e.g.: I am a good human being) is considered self-esteem [37]. Domain specificity, in reference to the hierarchical model of self-concept discussed above, gets streamlined based on the activities an individual is involved in on a regular basis. For example, a student has perceptions that range from "I am an adept student" to "I perform well in biology", which hints at the streamlining within academic self-concept. Furthermore, if a student is actively involved in extra-curricular activities, those perceptions are refined toward non-academic self-concept, which also get streamlined according to the non-academic activities one is involved in (e.g.: sports, debates, etc.). Perceptions of one's self-concept get stronger as one grows older because as a child there is minimal or no past evidence or performances and a limited peer network, which is essential for comparisons among others which helps form their self-concept [38], [39]. Self-efficacy, however, is competence judgements pertaining to a specific task (e.g.: I will score well in the math exam). It is known to be unstable with experience, time, and situations, hence age is not an accurate comparison dimension [34]. Knowing that readiness, knowledge acquisition, and one's self concept in that domain influences their self-efficacy score (probably not in equal or regular degrees) is a key point to note when performing response interpretations.

Considering the domain-specific nature of self-concept and task-specific (within the said domain) nature of self-efficacy, there exists a possibility of causality among the two. Figure 1 presents a simple model of the proposed causation. It shows self-concept as the overarching perception of oneself in a certain domain, and self-concept as the task-specific construct within that domain. This was also referenced by [35], like in the example, "I generally enjoy my history class and I am confident that I will score well in the upcoming history test." While this is true in most cases there is a possibility of the contrary, as illustrated in the hypothetical statement, "I have struggled in my statistics class since the beginning of the year, but I have worked hard for the final exam, and I am confident that I will score well." The causality between the two constructs is also described as the self-expansion model, which posits that the strength and specificity of self-concept directly influences self-efficacy [40].

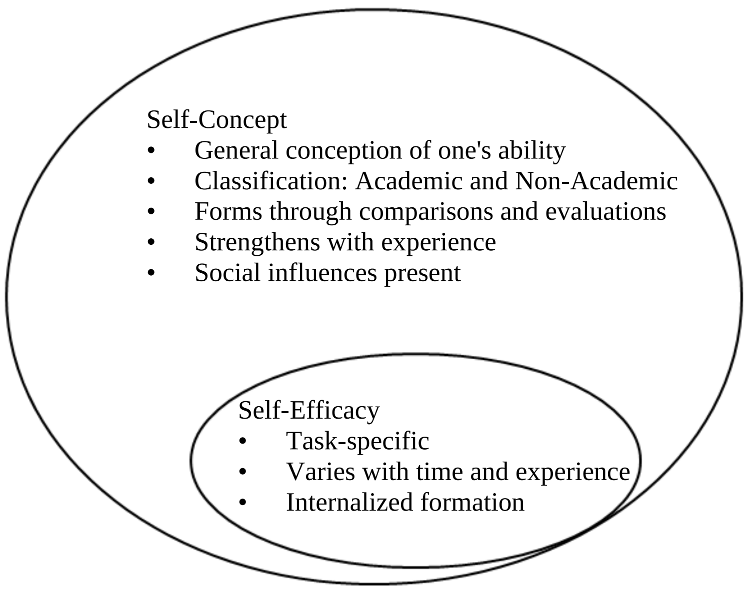

Figure 1. A Venn-diagram depicting the perceived causality among self-concept and self-efficacy

The situation of "most cases" is best illustrated through the dimensional comparison theory (DCT) [41], which is an extension to the internal and external frame of reference (I/E) theory [42] – a theory stating that an individual's self-concept is influenced by both social (peer) and self-feedback. The DCT states that academic self-concept in an individual is formed by temporal and social comparisons in the various subjects/classes they are enrolled in school. Digging further, self-concept operates on the reciprocal effects model (REM) – self-concept is formed through prior domain standing and prior self-concept [42].

Based on the differences between self-concept and self-efficacy discussed above and the operational and influential definitions of self-concept, this study proposes an extension to the hierarchical model offered by Marsh and Shavelson [3]. The original model offers a clear separation between academic self-concept and non-academic self-concept, but keeps it at a general level by listing english, history, math, and science as the facets of academic self-concept. This work focuses on extending the hierarchical model, but with a focus on engineering education (Figure 2). Extension was performed specifically on engineering-relevant math classes. The other contribution of this study is the hypothetical line drawn across the chart between the math classes and tasks in that class. This line indicates the extent of each of the constructs on perceptions/judgements at the different levels. This extension follows the representation in [43] but differs in the context of target application – school versus engineering education.

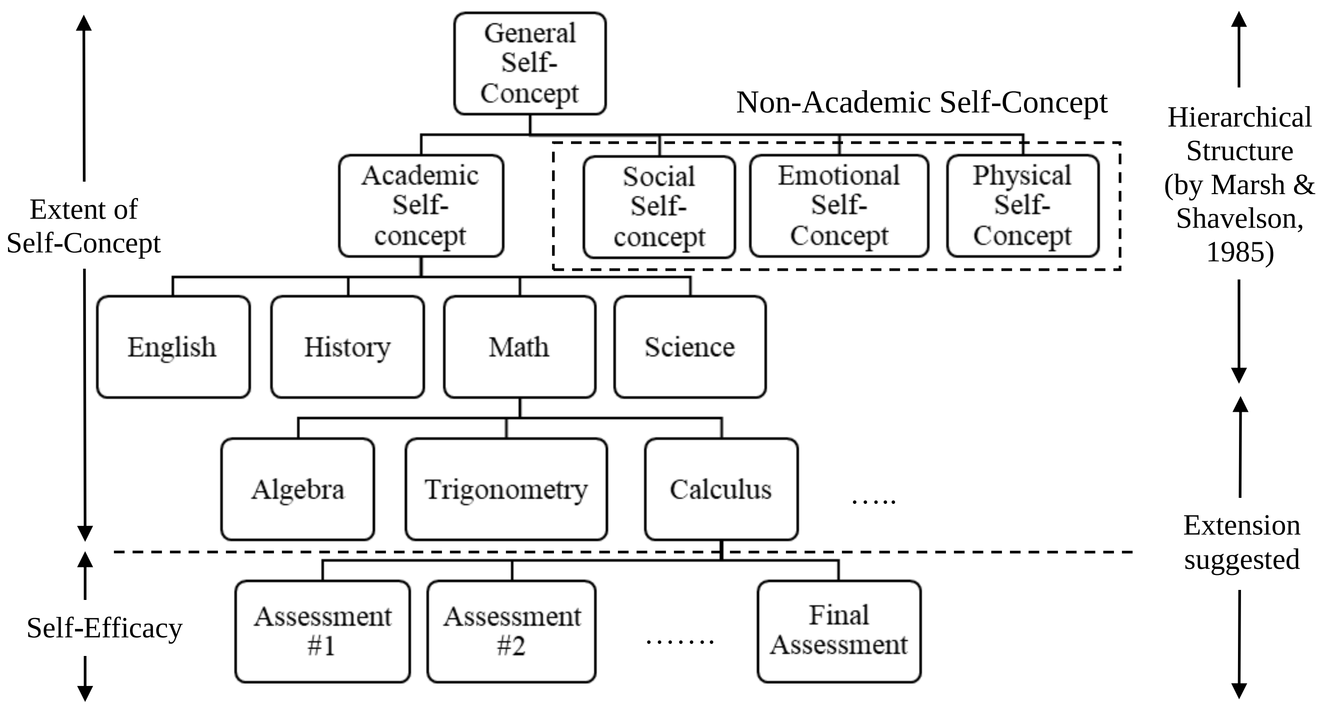

Figure 2. Hierarchical structure of self-concept (adapted from Marsh & Shavelson, 1985) with a coursewise extension to mathematics self-efficacy.

The level below math represents the first level in the proposed extension and includes various domains of math relevant to engineering education (i.e., algebra, trigonometry, and calculus). These domains still lie within the influential range of self-concept, with self-concept driving opinions, perceptions, motivations, and achievements in those domains. The second level extension represents the highest level of specificity in a given domain. This level includes exemplars of tasks (i.e., assignments, tests, or quizzes) relevant to the domain from which it extends. It is at this level where self-efficacy is understood to be driving self-perceptions and eventually performance in those tasks. For instance, self-concept in calculus (i.e., a domain) can be expressed as “I am able to understand and follow along the calculus classes”, and self-efficacy in calculus (i.e., task performance) can be expressed by “I am confident I can score at least a B in the upcoming test”.

The above definitions for both constructs are adapted from previous research and validating or verifying them is not within the scope of this project. This study agrees with previous findings [7], [44], [45], [46], that state self-concept is a prime predictor for favorable academic outcomes and well-being as a student. Self-efficacy, although crucial for an individual's academic success, is only connected with specific outcomes, i.e., scores/performance in a task. For a well-rounded and ethical education, an individual must identify with what they are learning, see the value in their learning outcomes and acquire significant knowledge. From the perspective of an educator, self-efficacy is a critical construct that helps students progress through the curriculum by passing prerequisite courses, while self-concept drives the student forward towards achievement of a greater goal of graduating as an engineer.

Table 2 consists of the variables condensed from table 1, but re-categorized into which construct this review has deemed as appropriate. It should be noted that table 1 had two columns based on interpretations in literature, while table 2 has three based on the foundational knowledge and distinctions discussed between self-concept and self-efficacy. This re-classification focuses on the variables that are task-specific in regard to the assessment of outcomes essentially. For instance, academic self-description was used to measure self-efficacy in the paper it was picked up from [20]. However, because Marsh [43] used academic self-description questionnaire to assess self-concept, it was adapted and reflected in this review. It was an added advantage that Marsh [43] had used the academic self-description questionnaire to assess self-concept in the original paper.

Table 2: Re-classification of variables as pertaining to either academic or non-academic self-concept, or self-efficacy.

Academic Self-concept	**Non-Academic Self-Concept**	**Self-Efficacy**
Academic self-description	College persistence	Perceived academic (STEM) performance
STEM intrinsic value	Professional identity (vocational identity)	Academic ability & interest
Perceived academic (STEM) competence	STEM identity	Future goals/intentions
	STEM interest	Expectancy for success
	Sense of belonging	
	Resiliency	
	Self-confidence	
	Self-acceptance	
	Drive to achieve	
	Attainment value	
	Utility value	
	Recognition	

The variables in table 2 were re-classified based on definitions and descriptions offered in the literature and the synthesis this study completed to clarify and differentiate the terminology. Academic self-concept refers to the broad perceptions or opinions of oneself in academic domains [1]. This study considers non-Academic self-concept refers to ability perceptions in non-academic domains (emotional, social, and physical). Self-efficacy is the expectancy of performance in a particular task [47]. The following section discusses those terms that were re-classified.

The first step in the re-classification identified which of the sub-constructs were classified as self-concept but were categorically more fitting under "non-academic self-concept". Identity in the context of STEM & professional identity is the degree to which an individual identifies themselves with STEM and their current profession as a STEM student. It is associated with the benefits they would reap with continuing in the program [17]. In simple words, it is a perception about how suitable STEM seems to the individual, and how they see themselves fitting in the field. It has social and emotional components – the effect of peers, role models, and educators can be a heavy influence, and hence justified as non-academic self-concept.

Attainment and utility value can loosely be described as the value a student finds in learning a specific derivation or getting that future degree. Attainment value, especially, becomes very apparent when a student weighs the importance and weightage of multiple upcoming deadlines, to decide which one is worth working harder. They possess both emotional and personal components, so an obvious choice for non-academic self-concept.

Academic self-description, which was set under academic self-concept in the re-classification table, can be put in the same terms as is the definition of self-concept. Marsh [43] described it as the broad perception or description of oneself in a particular domain being inspected, which in this context is academic. It is justified to be re-classified under academic self-concept, having moved it from under self-efficacy in table 1.

STEM intrinsic value is the joy an individual has while performing an activity and the interest one has in a field, specifically academic in STEM [48]. This was listed under self-efficacy in table 1 based on immediate findings (See results), but this sub-construct is influenced by past-orientation and perceived competence, hence is a good fit for academic self-concept.

Perceived academic (STEM) performance aims at depicting context specific performance, performance in an exam for instance. Previous studies classified it as a sub-construct of self-concept [18], but it is better suitable to be classified as self-efficacy due to its specificity in assessment outcomes.

Sub-constructs for instrument in engineering education as future work

After having examined recent studies and differentiating the suitable variables for self-concept and self-efficacy, this study proceeds towards identifying how these concepts relate to freshman engineering persistence. Although all the identified variables are important for general success, advancement, and persistence of a student, the context of engineering education calls for a modified framework. High schools educate students in math and science which is important preparation for an engineering curriculum. Students develop perceptions about their ability and standing with respect to their classes, i.e., their domain level self-concept within the school. They carry this academic self-concept when they move on to college, but literature shows that both academic and non-academic self-concept are critical to perform and persist in an engineering institution. The lack of preparation in this direction could be causing the freshman engineering students experience challenges leading to attrition/diversion [5].

Research in educational psychology found that developing self-concept in K12 students resulted in academic and personal growth [7], [17], [49]. The main distinction to observe between this view of self-concept and that for engineering education is academic self-concept in the former is postulated to only have academic facets, but academic self-concept within engineering education is constructed from both academic and non-academic components. It is further proposed that developing engineering self-concept in first-year engineering students could be a critical factor in improving first-year retention in engineering. In the case of K12 education, the model (figure 2) showed distinct pathways for academic and non-academic self-concepts and held academic performance separate from non-academic perceptions. This study proposes a modified framework for engineering self-concept where the pathways seem to converge (figure 3). In addition to academic self-concept, non-academic self-concept is critical for commitment to and identifying with the discipline, and both can have positive effects on retention.

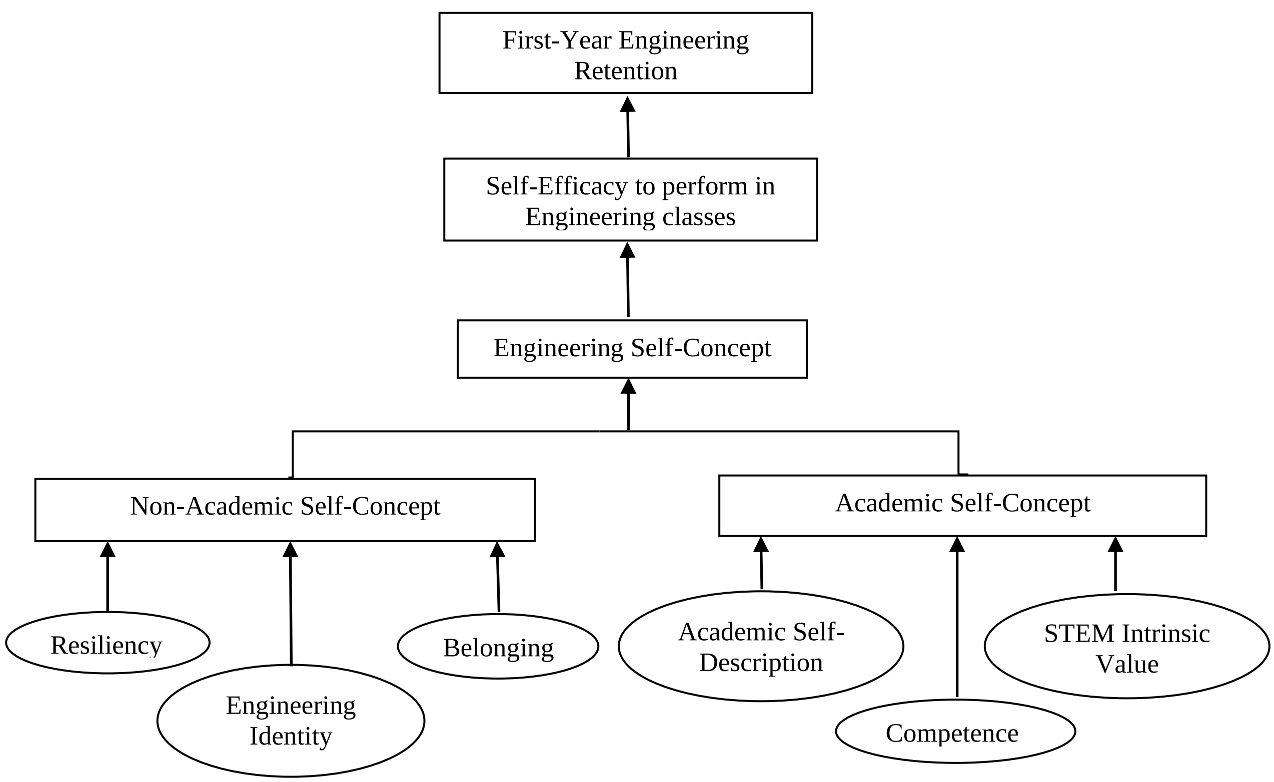

Figure 3. Framework for First-Year Engineering retention through Engineering Self-Concept and Self-Efficacy

This study opines that professional identity (i.e., engineering identity), sense of belonging, and resiliency are key to building non-academic self-concept within engineering. Similarly, academic self-description, competence, and STEM intrinsic value are relevant components for academic self-concept within engineering. These sub-constructs together help build engineering self-concept in an individual, the strength of which is an indicator for self-efficacy to perform in an array of tasks, assignments, and instances in the capacity of an engineering student. This study proposes that this domain specific engineering self-concept and the resultant self-efficacy can have direct effects on first-year retention in engineering with its cognitive and non-cognitive components.

Among all, engineering identity is a dominant sub-construct that could be influencing the other key components mentioned. For instance, the resiliency of a student to stay in engineering can be influenced by the engineering identity they possess. Similarly, one's sense of belonging and fulfilment (i.e., intrinsic value they find in an engineering program) is largely influenced by the engineering identity they hold. However, self-concept in an engineering student can be formed by the combined effects of all the 4 components (i.e., resiliency, sense of belonging, fulfilment, engineering identity). Eventually, the causal relationship between self-concept and self-efficacy as illustrated in figure 1, might adapt the components of self-concept as long-term influencers for self-efficacy. For instance, when a college student in a math major with high mathematics self-concept enrolls in a trigonometry class and feels confident about performing well in a test, the causality between self-concept perceptions and self-efficacy judgements are observed. The empirical validity of this theory is to be tested in future work.

Implementation of the measurement and improvement of engineering self-concept within the freshman engineering environment has strong potential. Engineering attrition is frequently observed in the freshman and sophomore years [5] & [6]. So, designing a freshman program aimed at improving engineering self-concept is comparable to subduing the issue at its point of origin. Having educators administering such mindful techniques to influence and build engineering self-concept aims for the benefit of students. Improving engineering self-concept among freshmen requires that we educate future engineers to identify with the field, understand why their job is important for humankind, and have the motivation to persist in their career.

Conclusion

The sampling of relevant research based on the set criteria for this systematic review resulted in 16 papers that addressed the constructs of self-concept or self-efficacy. The analysis in this paper carefully delineated the features of these constructs into a more precise characterization of each construct. The re-classification drew directly from the knowledge gained from the analysis of the previous research. The research included in the analysis showed a distinct contrast between the two constructs that sometimes is confounded in the assessment and evaluation. The discussion following the distinction and identification of sub-constructs presented a framework for freshman engineering retention through engineering self-concept and self-efficacy.

Limitations and Future Scope

Future work would be to examine how these re-classified constructs can inform design interventions that can improve self-concept and self-efficacy within the engineering education environment. A specific limitation exists in applying it to other educational disciplines, because the structure of self-concept differs per domain. The search term for this study did not include self-efficacy because the focus of this work was to extract the components of self-concept to provide a clear distinction between self-concept and self-efficacy. It must also be noted that table 2 does not contain an exhaustive list of the influencers for the two constructs, it provides clarity on those variables considered in the most recent research. Future work could replicate this study upon literature that directly assesses self-efficacy or uses scales of self-concept to measure self-efficacy.

References

[1] R. J. Shavelson, J. J. Hubner, and G. C. Stanton, “Self-Concept: Validation of Construct Interpretations,” Review of Educational Research, vol. 46, no. 3, pp. 407–441, Sep. 1976, doi: 10.3102/00346543046003407.

[2] M. Bong and R. E. Clark, “Comparison between self-concept and self-efficacy in academic motivation research,” Educational Psychologist, vol. 34, no. 3, pp. 139–153, Jun. 1999, doi: 10.1207/s15326985ep3403_1.

[3] H. W. Marsh and R. Shavelson, “Self-Concept: Its Multifaceted, Hierarchical Structure,” Educational Psychologist, vol. 20, no. 3, pp. 107–123, Jun. 1985, doi:10.1207/s15326985ep2003_1.

[4] D. Ifenthaler, Z. Siddique, and F. Mistree, “Designing for Open Innovation: Change of Attitudes, Self-Concept, and Team Dynamics in Engineering Education,” Emerging Technologies for STEAM Education. Educational Communications and Technology: Issues and Innovations, pp. 201–215, Sep. 2015, doi: https://doi.org/10.1007/978-3-319-02573-5_11.

[5] E. Seymour and A.-B. Hunter, Talking about leaving revisited : persistence, relocation, and loss in undergraduate STEM education. Cham, Switzerland: Springer, 2019

[6] N. H Desai and G. Stefanek, “An Introductory Overview of Strategies used to Reduce Attrition in Engineering Programs,” in American Society for Engineering Education, Jun. 2017.

[7] H. Wu, Y. Guo, Y. Yang, L. Zhao, and C. Guo, “A Meta-analysis of the Longitudinal Relationship Between Academic Self-Concept and Academic Achievement,” Educational Psychology Review, Mar. 2021, doi: 10.1007/s10648-021-09600-1.

[8] H. W. Marsh, “The Hierarchical Structure of Self-Concept and the Application of Hierarchical Confirmatory Factor Analysis,” Journal of Educational Measurement, vol. 24, no. 1, pp. 17–39, Mar. 1987, doi: 10.1111/j.1745-3984.1987.tb00259.x.

[9] H. W. Marsh, B. M. Byrne, and R. J. Shavelson, “A multifaceted academic self-concept: Its hierarchical structure and its relation to academic achievement.,” Journal of Educational Psychology, vol. 80, no. 3, pp. 366–380, 1988, doi: 10.1037/0022-0663.80.3.366.

[10] H. W. Marsh, “A multidimensional, hierarchical model of self-concept: Theoretical and empirical justification,” Educational Psychology Review, vol. 2, no. 2, pp. 77–172, Jun. 1990, doi: 10.1007/bf01322177.

[11] B. M. Byrne, “Methodological Approaches to the Validation of Academic Self-Concept: The Construct and Its Measures,” Applied Measurement in Education, vol. 3, no. 2, pp. 185–207, Apr. 1990, doi: 10.1207/s15324818ame0302_4.

[12] A. Bandura, "Social Cognitive Theory and Exercise of Control over HIV Infection," AIDS prevention and mental health. Preventing AIDS: Theories and methods of behavioral interventions, pp. 25–59, 1994, doi: 10.1007/978-1-4899-1193-3_3.

[13] A. Bandura, "Reflections on self-efficacy," Advances in Behaviour Research and Therapy, vol. 1, no. 4, pp. 237–269, Jan. 1978, doi: 10.1016/0146-6402(78)90012-7.

[14] A. Bandura, Self-efficacy: The exercise of control. New York: Freeman, 1997.

[15] J. Miller, W. Coombs, and D. Fuqua, "An examination of psychometric properties of Bandura's multidimensional scales of perceived self-efficacy," Measurement and Evaluation in Counseling and Development, vol. 3, no. 4, p. 186, Jan. 1999.

[16] A. Rittmayer and M. Beier, "Overview: Self-Efficacy in STEM," SWE-AWE CASEE Overviews, vol. 1, no. 3, p. 12, 2009.

[17] L. Rüschenpöhler and S. Markic, "Self-concept research in science and technology education – theoretical foundation, measurement instruments, and main findings," Studies in Science Education, vol. 55, no. 1, pp. 37–68, Jan. 2019, doi: 10.1080/03057267.2019.1645533.

[18] R. Bringula, J. J. Reguyal, D. D. Tan, and S. Ulfa, "Mathematics self-concept and challenges of learners in an online learning environment during COVID-19 pandemic," Smart Learning Environments, vol. 8, no. 1, Oct. 2021, doi: 10.1186/s40561-021-00168-5.

[19] L. Carroll, C. Finelli, and S. DesJardins, "Academic Success of College Students with ADHD: The First Year of College," Collaborative Network for Engineering and Computing Diversity, Feb. 2022

[20] S. Qiu et al., "'All Together Now' - Integrating Horizontal Skills in Career Technical Education Classes with Making and Micromanufacturing," in American Society for Engineering Education, Jun. 2022. [Online]. Available: https://peer.asee.org/all-together-now-integrating-horizontal-skills-in-careertechnical-education-classes-with-making-and-micro-manufacturing.pdf

[21] T. McKoy, C. Beane, M. Oyeteju, M. Hammond, and K. Hargrove, "Persistence of African American Females in Engineering: The Mathematics Identity Factor," Urban education research and policy annuals, vol. 7, no. 1, pp. 68–79, Jan. 2020

[22] B. Bradford, M. Beier, M. McSpedon, and M. Wolf, "Examining STEM Diagnostic Exam Scores and Self-efficacy as Predictors of Three-year STEM Psychological and Career Outcomes," American Society for Engineering Education, Jun. 2020, doi: 10.18260/1-2-34614.

[23] A. R. Betz, B. King, B. Grauer, B. Montelone, Z. Wiley, and L. Thurston, “Improving Academic Self-Concept and STEM Identity Through a Research Immersion: Pathways to STEM Summer Program,” Frontiers in Education, vol. 6, Jul. 2021, doi: 10.3389/feduc.2021.674817

[24] Jin, Seonmi, Jeon Seok-jean, and Byung Shik Rhee, “Does ‘Women Friendliness’ Matter in STEM Education?: Differential Effects of High-Impact Practices on Career Aspiration of STEM College Students by Gender,” Journal of Engineering Education Research, vol. 23, no. 4, pp. 37–51, Jul. 2020

[25] J. Mahadeo, Z. Hazari, and G. Potvin, “Developing a Computing Identity Framework: Understanding Computer Science and Information Technology Career Choice,” ACM Transactions on Computing Education, vol. 20, no. 1, pp. 1–14, Mar. 2020, doi: 10.1145/3365571

[26] S. Gulati, C. Strickland-Hughes, E. Brienza-Larsen, and E. Sparks, “Work in Progress: An Integrative Learning-Centered Advising Experience for First Year Students,” in American Society for Engineering Education, Jun. 2022

[27] R. M. Yullyaningsih, S. Wahyuni, and R. Sulistiyanti, “Contributing to the intention factors of cheating behavior in students of SMA NEGERI 2 Jakarta,” European Journal of Psychological Research, vol. 9, no. 1, pp. 38–51, 2022.

[28] S. Sajid, “Factors influencing female intention to participate in science technology engineering mathematics (STEM) education in Pakistan,” Thesis, Universiti Tunku Abdul Rahman, 2022

[29] E. Wille, G. Stoll, T. Gfrörer, J. Cambria, B. Nagengast, and U. Trautwein, “It Takes Two: Expectancy-Value Constructs and Vocational Interests Jointly Predict STEM Major Choices,” Contemporary Educational Psychology, vol. 61, p. 101858, Apr. 2020, doi: 10.1016/j.cedpsych.2020.101858

[30] L. Salgado, “Motivations of Low-income Engineering Transfer Students Influencing Choice and Pursuit of Baccalaureate Degree Attainment,” University of California, Irvine, 2020

[31] S. I. Hofer, F. Reinhold, F. Loch, and B. Vogel-Heuser, “Engineering Students’ Thinking About Technical Systems: An Ontological Categories Approach,” Frontiers in Education, vol. 5, May 2020, doi: 10.3389/feduc.2020.00066.

[32] J. Pawlecki, “Factors Influencing Female Engineering Students’ Social Self-Confidence,” Dissertation, The University of Toledo, 2022. [Online]. Available: https://etd.ohiolink.edu/apexprod/rws_olink/r/1501/10?clear=10&p10_accession_num=toledo165149888887032

[33] M. D. Chatzinikolaou and A. Tsirides, “Academic Self-Concept and Critical Thinking Dispositions: Devising a Predictive Model of College Students’ Degree Commitment,”

Journal of Advanced Research in Social Sciences, vol. 3, no. 3, pp. 1–13, Dec. 2020, doi: 10.33422/jarss.v3i3.516

[34] M. Bong and E. Skaalvik, “Academic self-concept and self-efficacy: How different are they really?,” Educational Psychology Review, vol. 15, no. 1, pp. 1–40, Mar. 2003, doi: 10.1023/A:1021302408382.

[35] J. Ferla, M. Valcke, and Y. Cai, “Academic self-efficacy and academic self-concept: Reconsidering structural relationships,” Learning and Individual Differences, vol. 19, no. 4, pp. 499–505, Dec. 2009, doi: 10.1016/j.lindif.2009.05.004.

[36] H. W. Marsh et al., “The murky distinction between self-concept and self-efficacy: Beware of lurking jingle-jangle fallacies.,” Journal of Educational Psychology, vol. 111, no. 2, pp. 331–353, Feb. 2019, doi: 10.1037/edu0000281.

[37] H. W. Marsh, “Academic Self-Concept: Theory, Measurement, and Research,” in Psychological Perspectives of the Self, 1st ed., vol. 4. J. M. Suls, Hillsdale, N.J.: L. Erlbaum, 1993, ch. 3, pp 59-95.

[38] H. W. Marsh, “Verbal and Math Self-Concepts: An Internal/External Frame of Reference Model,” American Educational Research Journal, vol. 23, no. 1, pp. 129–149, Mar. 1986, doi: 10.3102/00028312023001129.

[39] H. W. Marsh, R. Walker, and R. Debus, “Subject-specific components of academic self-concept and self-efficacy,” Contemporary Educational Psychology, vol. 16, no. 4, pp. 331–345, Oct. 1991, doi: 10.1016/0361-476x(91)90013-b.

[40] B. A. Mattingly and G. W. Lewandowski, “An Expanded Self is a More Capable Self: The Association between Self-concept Size and Self-efficacy,” Self and Identity, vol. 12, no. 6, pp. 621–634, Nov. 2013, doi: 10.1080/15298868.2012.718863

[41] J. Möller and H. W. Marsh, “Dimensional comparison theory.,” Psychological Review, vol. 120, no. 3, pp. 544–560, 2013, doi: 10.1037/a0032459

[42] H. W. Marsh et al., “An integrated model of academic self-concept development: Academic self-concept, grades, test scores, and tracking over 6 years.,” Developmental Psychology, vol. 54, no. 2, pp. 263–280, Feb. 2018, doi: 10.1037/dev0000393

[43] H. W. Marsh, “The structure of academic self-concept: The Marsh/Shavelson model.,” Journal of Educational Psychology, vol. 82, no. 4, pp. 623–636, 1990, doi: https://doi.org/10.1037/0022-0663.82.4.623.

[44] H. W. Marsh, “Content specificity of relations between academic achievement and academic self-concept.,” Journal of Educational Psychology, vol. 84, no. 1, pp. 35–42, 1992, doi: 10.1037/0022-0663.84.1.35.

[45] F. Guay, H. W. Marsh, and M. Boivin, “Academic self-concept and academic achievement: Developmental perspectives on their causal ordering.,” Journal of Educational Psychology, vol. 95, no. 1, pp. 124–136, 2003, doi: 10.1037//0022-0663.95.1.124

[46] H. W. Marsh and A. J. Martin, “Academic self-concept and academic achievement: Relations and causal ordering,” British Journal of Educational Psychology, vol. 81, no. 1, pp. 59–77, Mar. 2011, doi: 10.1348/000709910x503501.

[47] M. M. Chemers, L. Hu, and B. F. Garcia, “Academic self-efficacy and first year college student performance and adjustment.,” Journal of Educational Psychology, vol. 93, no. 1, pp. 55–64, Mar. 2001, doi: https://doi.org/10.1037/0022-0663.93.1.55.

[48] J. S. Eccles and A. Wigfield, “Motivational Beliefs, Values, and Goals,” Annual Review of Psychology, vol. 53, no. 1, pp. 109–132, 2002, doi: 10.1146/annurev.psych.53.100901.135153

[49] H. Marsh and R. Craven, “A reciprocal effects model of the causal ordering of self-concept and achievement: New support for the benefits of enhancing self-concept,” International advances in self research, vol. 2, pp. 17–51, Jan. 2005.

Appendix

List of the studies (since 2020) that used surveys as their method to examine self-concept among STEM undergraduate students.

Title	Year	Method
Mathematics self-concept and challenges of learners in an online learning environment during COVID-19 pandemic	2021	Used a survey that focused on math ability, interest, and perceived math performance, rating them on a 5-point scale. (Bringula et al., 2021)
Academic Success of College Students with ADHD: The First Year of College	2022	Academic self-concept was measured as part of the student disposition measures. Constructs like academic ability, math ability, intellectual self-confidence, and drive to achieve as constructs for self-ratings (Carroll et al., 2022).
‘All Together Now’ - Integrating Horizontal Skills in CareerTechnical Education Classes with Making and Micromanufacturing	2022	Used the academic Self-Description Questionnaire II (ASDQ2) but did not explicitly state that they were measuring self-concept (Qiu et al., 2022)
Persistence of African American Females in Engineering: The Mathematics Identity Factor.	2020	Individual’s professional identity is deemed synonymous to professional self-concept. Utilized the My Vocational Situation (MVS) scale, which comprised of three sub-scales – vocational identity, occupational information, and barriers (McKoy et al., 2020).
Examining STEM Diagnostic Exam Scores and Self-efficacy as Predictors of Three-year STEM Psychological and Career Outcomes	2020	Items to measure self-concept were adapted from the Academic Self-Description Questionnaire II [28], as well as a STEM intrinsic value scale [14], to make them STEM-specific (Bradford et al., 2020)
Improving Academic Self-Concept and STEM Identity Through a Research Immersion: Pathways to STEM Summer Program	2021	Survey is designed by the affiliated institution addressing STEM identity, STEM interest, sense of belonging, resiliency, and future goals/intentions (survey items were based on previous research) (Betz et al., 2021)
Does "Women Friendliness" Matter in STEM Education?: Differential Effects of High-Impact Practices on Career Aspiration of STEM College Students by Gender	2020	Measured SE by posing a single question, asking students to assess their academic competence in comparison to other students of the same age, on a 5-point scale. It was acknowledged that this question indicated self-concept, and not self-efficacy (Jin et al., 2020)

Developing a Computing Identity Framework: Understanding Computer Science and Information Technology Career Choice	2020	Indicated to have been examining a sub-construct of self-concept – “belief in one’s performance/competence”. Used the following questions: “I can do well on computing tasks (e.g., programming and setting up servers)” “I understand concepts underlying computer processes” “Others ask me for help with software (applications/programs)” (Mahadeo et al., 2020)
Work in Progress: An Integrative Learning-Centered Advising Experience for First-Year Students	2022	Surveys were based on mindset, goal orientation, and motivation (Gulati et al., 2022)
Contributing to the intention factors of cheating behavior in students of SMA NEGERI 2 Jakarta	2022	Found that SC influences cheating behavior intentions. The scale for measuring academic self-concept in this study was compiled based on aspects of academic self-concept, namely: 1. self-confidence; 2. self-acceptance; 3. self-esteem (Yullyaningsih et al., 2022)
Factors influencing female intention to participate in science technology engineering mathematics (STEM) education in Pakistan	2022	15 survey questions on a 5-point scale were used to assess self-concept. All the items were focused on STEM performance and confidence (Sajid, 2022)
It Takes Two: Expectancy-Value Constructs and Vocational Interests Jointly Predict STEM Major Choices	2020	Math self-concept was measured with 4 items adapted from self-description questionnaire III (SDQ3) (Marsh, 1992). English self-concept was measured with 4 other items from SDQ3 and a well-known German self-concept inventory (Wille et al., 2020)
Motivations of Low-income Engineering Transfer Students Influencing Choice and Pursuit of Baccalaureate Degree Attainment	2020	Used self-concept and expectancies for success interchangeably. Measured constructs are: Competence, Interest, Attainment value, Utility value (as parts of expectancy value theory), interest, recognition, performance (as part of Engineering Identity), and sense of belonging (Salgado, 2020)
Engineering Students' Thinking About Technical Systems: An Ontological Categories Approach	2020	Considered self-concept as “one’s own beliefs regarding technical systems” and adapted standardized measures for participants’ self-concept based on the work of Marsh and Martin from 2011 (Hofer et al., 2020)

Factors Influencing Female Engineering Students' Social Self-Confidence	2022	CSS survey was used. It is comprised of academic ability, math ability, intellectual self-confidence, and drive to achieve. Described academic self-concept as one of the variables that influence academic involvement, which directly influenced social self-confidence (Pawlecki, 2022)
Academic Self-Concept and Critical Thinking Dispositions: Devising a Predictive Model of College Students' Degree Commitment	2020	A 5 question survey formed by the Adaption of the academic self concept questionnaire (ASCQ) (Chatzinikolaou & Tsirides, 2020)