

Validating an Instrument to Measure Entrepreneurial Self-Efficacy among Engineering Students*

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The presented study validates an engineering-entrepreneurial self-efficacy (E-ESE) instrument among engineering students. Although several survey instruments have been developed to measure entrepreneurship outcomes, they have been developed for and validated with business school students and nascent entrepreneurs, leading to a lack of validated instruments to measure entrepreneurship outcomes in engineering education. The study aims to answer two research questions: First, what is the latent factor structure of an Engineering Entrepreneurial Self-Efficacy (E-ESE) instrument for engineering students? And second, what are the psychometric properties (validity and reliability) of the E-ESE instrument? The analysis was conducted in three phases, with data collected from two institutes in the United States. The first phase involved a review of existing survey instruments and revising the items based on pilot exploratory factor analysis (EFA) results and stakeholder feedback. The second phase includes data collection at Institute 1 (85 responses) and conducting an EFA to identify the latent factor structure. The third phase includes performing a confirmatory factor analysis using data from two institutes (212 responses) to verify the underlying structure of the five latent variables (searching, planning, marshaling, implementing people, and implementing finance), and evaluating reliability using Cronbach's alpha. The findings reveal a five-factor solution for the E-ESE instrument that is refined for engineering education with psychometric properties (validity and reliability) meeting requisite standards. The study discusses the implications of the results for engineering entrepreneurship education and provides guidance for future work.

Keywords: entrepreneurship education; instrument development; entrepreneurial self-efficacy; engineering education

1. Introduction

Recent engineering education efforts to better prepare engineers to be successful in today's technology-driven economies have led to the creation of a variety of educational programs. One relatively recent initiative is in the domain of engineering entrepreneurship education. Acknowledging the economic and social impact of entrepreneurship [1, 2], universities aim to enhance entrepreneurial skills in engineering students by introducing entrepreneurship education (EE) courses [3, 4]. A structured entrepreneurship education endows future engineering graduates with the necessary entrepreneurial skills and capabilities [5]. Even though EE courses are primarily offered by business schools, they are becoming widely acknowledged in engineering education, encouraging engineering and technology schools to offer them [6, 7].

With the growth of engineering EE programming, engineering education literature shows an increased interest and growing research in engineering entrepreneurship education [8–10]. This growth underscores the need for reliable assessment instruments [11]. However, because entrepreneurship education emerged from the business schools, a majority of existing instruments were developed and validated for business school audiences, with business and management students being the primary instrument respondents [12, 13]. Specifically,

while validated instruments measure various aspects of entrepreneurship (e.g., entrepreneurial intention [14, 15], entrepreneurial self-efficacy [16–18], and entrepreneurial education achievement [19]), the instrument development has been centered in business/management-school contexts and participants. Thus, there is a significant lack of instruments validated in the context of engineering EE. The presented study presents the refinement and validation of the engineering entrepreneurial self-efficacy (E-ESE) instrument, to provide researchers, practitioners, and administrators with a valid and reliable tool for assessment and research in engineering entrepreneurship education.

In this presented study, entrepreneurial self-efficacy is described as the confidence a person has in their own ability to undertake and complete an entrepreneurship-related task [18]. Entrepreneurship-related tasks include *searching* (opportunity recognition), *planning* (designing a business plan), *marshaling* (gathering resources), *implementing people* (managing people), and *implementing finances* (managing finances). Several researchers have reported the impact of entrepreneurial self-efficacy on students' entrepreneurial intention [20], entrepreneurial motivations, and entrepreneurial behavior [21, 22], underscoring the need for a valid and reliable engineering entrepreneurial self-efficacy instrument in engineering education [23]. While typical instrument development is initiated

from the item generation stage [24, 25], adapting items from existing instruments that are closely aligned with the targeted area of research is recommended to ground the work in the existing literature [26]. However, it is critical to ensure that the adapted items are made specific to the target population to yield valid and reliable results [23, 27]. Following these suggestions, this paper leverages an existing entrepreneurial self-efficacy instrument [18] to develop and validate the engineering entrepreneurial self-efficacy (E-ESE) instrument. The paper has been structured into three phases in which the study was conducted. The first phase details the foundational work for item generation. The second and third phases include the data analysis involving exploratory and confirmatory factor analysis, respectively. Overarchingly, we examine the following research questions: *RQ1 What is the latent factor structure of an Engineering Entrepreneurial Self-Efficacy (E-ESE) instrument for engineering students? RQ2 What are the psychometric properties (validity and reliability) of the E-ESE instrument?*

2. Literature Review

2.1 Theoretical Underpinnings

Bandura's theory of self-efficacy serves as a seminal work in education literature [28]. Self-efficacy is defined as "people's beliefs about their capabilities to exercise control over their level of functioning and events that affect their lives" [29]. One's self-efficacy beliefs are argued to be determinants of motivation, often reflected as the effort they will exert in an endeavor and/or how long they will persevere when faced with obstacles [28]. The stronger the belief in their capabilities, the greater and more persistent their efforts [30]. Educators and researchers have widely acknowledged the importance of instilling self-efficacy among higher-education students [31]. Furthermore, self-efficacy is often conceptualized as a trait that is not innate; rather, it can be developed in students by engaging them in effective educational interventions [32].

In the context of entrepreneurship education, self-efficacy is referred to as entrepreneurial self-efficacy (ESE). ESE is the self-efficacy of a person to perform an entrepreneurial-related task and has emerged as a key psychological construct in entrepreneurship research [33] as it impacts entrepreneurial motivation, intention, behavior, and performance. Therefore, ESE has been pointed out as an essential outcome of entrepreneurship training and education. Shapero's entrepreneurial event model (SEE) [34] and the theory of planned behavior (TPB) [35] provide theoretical grounding for ESE in the domain of entrepreneurship educa-

tion. Both SEE and TPB highlight the importance of self-efficacy as a key element in a person's intention to pursue any given task.

Specifically, SEE structures describe intentionality as the central element in the entrepreneurial event creation, and this intentionality originates from an individual's perception of feasibility and desirability [34]. The model acknowledges that one's perceived feasibility or self-perception of their own ability to start and sustain a business (equivalent to ESE) is a catalyst in influencing the entrepreneurial event formation or behavior [34]. Along similar lines, TPB incorporates the theory of self-efficacy [36], identifying the factors that are related to entrepreneurial intentions in an individual [37]. TPB asserts that a person's intent to pursue entrepreneurship as a career and their entrepreneurial behavior are guided by the individual's attitude, beliefs, and perception of the level of difficulty in pursuing the entrepreneurial tasks (i.e., ESE). Cumulatively, these theories underscore the importance of ESE as a key theoretical construct for entrepreneurship education.

2.2 Existing Measures of Entrepreneurial Self-Efficacy

While researchers have contributed to measuring entrepreneurial self-efficacy, the key instruments validated are for nascent entrepreneurs, students from non-engineering disciplines (e.g., business administration, psychology), business executives [16–18], and middle/high school students [38]. Multiple methods of analysis have also been used to validate the instrument in these studies, such as Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and a combination of both methods. The following sections summarize the seminal ESE instruments and their recent adaptations. To scope the literature review, we describe key existing instruments (Summarized in Table 1) and their adaptations in the sections below.

2.2.1 Key Developed Instruments

First, grounded in previous work on entrepreneurial self-efficacy [39–41], Chen et al. (1998) developed an instrument conceptualizing entrepreneurial self-efficacy in terms of six fundamental entrepreneurial roles – innovator, risk taker and bearer, executive manager, relation builder, risk reducer, and goal achiever. Under these entrepreneurial roles, 30 entrepreneurial tasks were recognized, leading to a 36-item instrument. The instrument validation was conducted using a sample comprising 140 undergraduate senior students of entrepreneurship, management, and organizational psychology courses. Based on the EFA results, 22 items were finalized, and five factors were identified (marketing, innova-

Table 1. Summary Of The Key Developed Instruments To Measure Entrepreneurial Self-Efficacy

Instrument	Number of Factors (factor name)	Sample
Entrepreneurial Self-Efficacy Construct [16]	5 (marketing, innovation, management, risk-taking, and control of the finances)	140 undergraduate senior students of entrepreneurship, management, and organizational psychology courses
Entrepreneurial Self Efficacy Measure [17]	6 (Risk and uncertainty management skills, Innovation and product development skills, Interpersonal and networking management skills, Opportunity recognition, Procurement and allocation of critical resources, and Development and maintenance of an innovative environment.	272 undergraduate students and 87 MBA students
Your Efficacy [45]	19 items-grouped in one construct of Self-Efficacy	10,326 undergraduate and postgraduate students
Entrepreneurial Self-Efficacy Tool [46]	7 (Innovation, Financial Value, Teamwork, Product Development, Startup Processes, Leadership, and Creativity)	1086 from 28 enterprise program dedicated to entrepreneurship for the post-graduate students
Entrepreneurial Self-Efficacy Instrument [18]	5 (Searching, Planning, Marshaling, Implementing People and Implementing Finance)	Students and the nascent entrepreneurs (303)

tion, management, risk-taking, and control of the finances). The scale has been used in entrepreneurship education either by modifying it or in its original form [42]. A systematic literature review [43] notes Chen et al.'s (1998) instrument as the most widely used measure of entrepreneurial self-efficacy.

Second, similar to the previous study [16], an instrument was developed to differentiate between managers and entrepreneurs by emphasizing specific *skills* [17]. They categorized the 35 skills into six dimensions – Risk and Uncertainty Management Skills, Innovation and Product Development Skills, Interpersonal and Networking Management Skills, Opportunity Recognition, Procurement and Allocation of Critical Resources, and Development and Maintenance of an Innovative Environment. The instrument was validated using a sample of undergraduate students taking introductory business classes and MBA students. Also, the instrument has been validated by other researchers using a sample of MBA students [44].

Third, following a similar focus on entrepreneurial *skills*, a study [45] developed and validated a 19-item instrument among a diverse sample of undergraduate and graduate students from different academic disciplines. Validated using CFA, the survey measures ESE as a single construct with items such as coming up with ideas for products and services that may be needed in a market, planning a business (including market analysis, pricing, finances/costs, marketing/sales), and developing and training future leaders for an organization.

Fourth, a tool [46] was developed focusing on the measurement of *skills and abilities* related to entrepreneurship. The instrument relates to entrepreneurial self-efficacy through seven factors: *Innovation, Financial Value, Teamwork, Product Development, Startup Processes, Leadership, and*

Creativity. The sample size for this study was post-graduate students from different enterprise programs dedicated to entrepreneurship.

Lastly, guided by previous scholarship [47, 48], McGee et. al. developed an instrument to measure entrepreneurial self-efficacy based on the different phases of the entrepreneurial *process* [18]. Through a sample of senior-level undergraduate business students and nascent entrepreneurs, the survey was validated using EFA to generate the final list of 19 items representing the five factors – *searching, planning, marshaling, implementing people, and implementing finance*. Moreover, various researchers have validated this ESE scale in various contexts, such as analyzing the responses of nascent entrepreneurs and business school students [49], and in research based on different cultural settings, validating it for an audience outside the population of the original instrument [50]. Due to its focus on the entrepreneurial process, this instrument forms the basis for the presented work.

2.2.2 Modified Entrepreneurial Self-Efficacy Instruments

Various studies have refined the seminal instruments by modifying a few items or merging several instruments. For instance, one study [51] combined two instruments [16, 17] and evaluated the convergent and divergent validity of the entrepreneurial self-efficacy measure. The data was collected from MBA students enrolled in entrepreneurship and management courses. Another study [52] used the existing instruments [16, 17, 53] to construct a new instrument with an 18-item ESE scale that was used to measure the impact of ESE on self-employment. In addition to existing items, one more self-constructed item in the scale was included. Finally, one recent work [54] presents a 54-item entrepreneurial self-efficacy instrument, using the existing

scales [16–18] to measure factors related to perseverance, skills, risk and uncertainty, and technology and business self-efficacy. The pilot instrument was validated among graduate management students.

3. Phase 1 – Item Generation

Following best practices for instrument design recommended in the literature [25, 26], the item generation for E-ESE first involved a literature search to determine relevant survey instruments. The search identified commonly used instruments measuring ESE in entrepreneurship education [16–18]. Upon consultation with administrators and faculty engaged in engineering entrepreneurship education, McGee's ESE instrument [18] was short-listed because its factors aligned with the different phases of the entrepreneurial process most relevant to engineering entrepreneurship education – *searching* (opportunity recognition), *planning* (designing a business plan), *marshaling* (gathering resources), *implementing people* (managing people), and *implementing finances* (managing finances). While this [18] scale has been validated for business schools and nascent entrepreneurs [55, 56], it has not been validated in the engineering education context. We administered the instrument among undergraduate engineering students, and the EFA results indicated the lack of consistency in factor structure with the original instrument, especially for the *planning* construct [57]. The planning items had low communality values (less than 0.4), factor loadings less than 0.3, and cross-loadings in two different factors (factor 2 and factor 4). This reiterated the need to revise the instrument items and perform subsequent validation in the context of engineering education. The findings suggest that when administered among engineering students, the instrument was perceived differently, plausibly because the instrument was designed specifically for management/business school students [57].

Furthermore, when revising the items, we sought to ensure content validity to ensure that the items are measuring what they are supposed to measure [25] and consequently enhance the quality and representation of the instrument items [58]. Particularly, we revised the items by incorporating feedback from experts with teaching and research experience in engineering entrepreneurship education. Also, we presented the items to the potential respondents (engineering students) to analyze misjudgments the respondents might make in understanding the instrument items [26]. This feedback assisted in revising the survey items for engineering education. For example, the question “*How much confidence do you have in your ability to determine a*

competitive price for a new product or service?” was reworded to “*How much confidence do you have in your ability to estimate potential revenue for a new product or service?*” Some questions were divided into two sub-questions for more clarity, for example, the marshaling item from the original instrument “*How much confidence do you have in your ability to get others to identify with and believe in my vision and plans for a new business?*” was divided into two sub-questions “*How much confidence do you have in your ability to get others to identify with your vision for a new product or service?*” and “*How much confidence do you have in your ability to get others to identify with your plan for a new product or service?*”. The revised instrument consisted of 22 items, mapped to five factors that is searching (3), planning (6), marshaling (4), implementing people (6), and implementing finance (3).

4. Phase 2 – Exploratory Factor Analysis

To explore the preliminary latent structure underlying the items, we conducted an exploratory factor analysis (EFA) using SPSS version 28. For conducting EFA, all factors must utilize the same point scale for recording values. In our instrument, a five-point Likert scale was used, with a rating of 1 indicating ‘not confident at all,’ 2 representing ‘a little confident,’ 3 for ‘somewhat confident,’ 4 for ‘confident,’ and 5 for ‘very confident’. The instrument was administered among 85 undergraduate engineering students at a research-focused institution in the U.S. The demographic distribution of the respondents is represented in Table 2. The respondents identified as men (80%) and women (20%). The data had diverse respondents belonging to various ethnicities such as Hispanic/Latinx (32.94%), Asian/Asian American (22.35%), White/Caucasian (20%), Black/African American (11.76%), multiracial students who responded to more than one ethnicity (10.60%), and others (2.35%). The sample included students enrolled in 7 different engineering majors, such as electrical and

Table 2. Demographics of Phase 2

Variables	Category	N	Percent (%)
Gender	Man	68	80
	Woman	17	20
Ethnicity	White/Caucasian	17	20
	Hispanic/Latinx	28	32.94
	Asian/ Asian American	19	22.35
	Black/African American	10	11.76
	Multiracial	9	10.60
	Others	2	2.35

computer engineering technology, mechanical engineering technology, biomedical engineering technology, construction engineering, industrial engineering technology, concrete industry management, and software and data engineering technology.

4.1 Assumptions

To ensure that our data meets the necessary assumptions for EFA [59], we first assessed normality by examining skewness and kurtosis. The results indicated that the values for the kurtosis and skewness were all in the range of ± 3 , indicating the normality of the data set [60]. Second, we conducted the Kaiser-Meyer-Olkin (KMO) test to measure the suitability of the sample size to undergo EFA. The value of the KMO is in the range of 0 to 1, with a KMO value closer to 1 indicating that the sample size is suitable for performing factor analysis [61]. The value of KMO obtained for our sample was 0.874, indicating that the data is suitable for performing the factor analysis. Third, commonality for the sample represents the shared variance of the items with each other. The data set used for this study has a communality value of 0.50 and above, implying that items account for a considerable variance shared with the other items. Fourth, Bartlett's sphericity test was implemented to examine the similarity between an observed correlation matrix and an identity matrix. Recommended when performing EFA [62], this test evaluates whether the correlation among the variables in the data set is sufficient to conduct factor analysis. Bartlett's Test of Sphericity for the given sample was significant (χ^2 (df) = 1381.135 (231), $p < 0.05$), implying some correlation between the items, making the data suitable for factor analysis.

4.2 Identification of the Factors

To identify the factors, we follow the steps described next. First, reliability for all items was measured using Cronbach's alpha for each construct. The Cronbach's value for all the factors was 0.70 or above, indicating moderate to high internal reliability [59]. Second, we used Principal Axis Factoring for the rotation and the Kaiser Criterion and Scree Plot for factor extraction. Following recommended practices [63], we used the Kaiser criterion to retain the factors. The Kaiser criterion selects factors based on eigenvalues greater than 1. This criterion suggests that an eigenvalue below one cannot account for the variability of a single item within the instrument being used [64]. Additionally, the scree plot is a widely used representation of eigenvalues on the x-y axis [65]. The point at which the curve decreases and straightens out (i.e., the elbow of the graph) is where all factors before and at the elbow are included [66]. Initially, five factors had eigenvalues greater than 1.0, explaining 72.77% of the total variance. The scree plot (Fig. 1) also confirmed a five-factor solution. The absolute values of the final pattern matrix were all above 0.40 for most of the items.

5. Phase 3 – Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was performed to verify the five-factor structure identified in Phase 2 using MPlus software. For conducting CFA, the data were collected from two different institutes. The instrument was administered online among undergraduate engineering students.

5.1 Participants

The demographic distribution of the 160 respon-

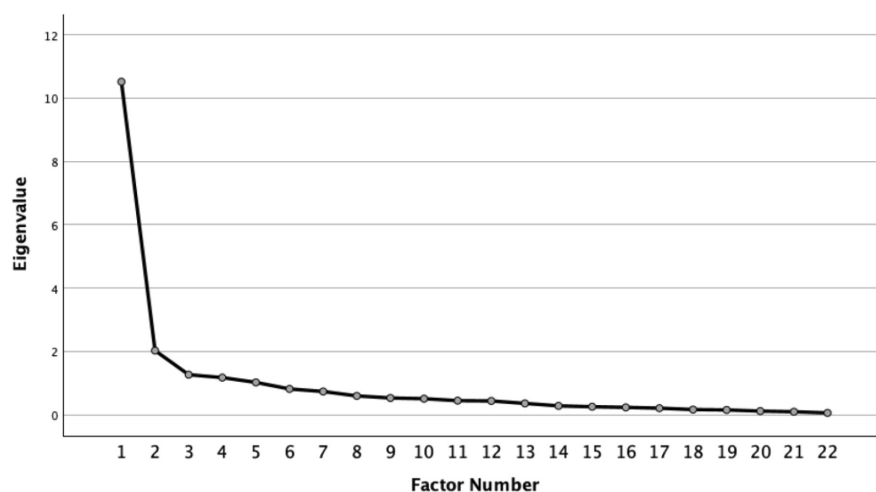


Fig. 1. Scree Plot indicating 5-factor solution.

Table 3. Demographics Of The Respondents In Institute-1 And Institute-2

Variable	Category	Institute-1		Institute-2	
		N (160)	Percent (%)	N (52)	Percent (%)
Gender	Male	131	81.9	41	78.9
	Female	29	18.1	10	19.2
	Non-Binary	–	–	1	1.90
Ethnicity	White/Caucasian	16	10.0	8	15.4
	Hispanic/Latinx	80	50.0	18	34.6
	Native Hawaiian/ Pacific Islander	1	0.60	–	–
	Asian/ Asian American	36	22.5	13	25
	Black/African American	4	2.5	5	9.6
	Multi Racial	19	11.9	7	13.5
	Others	4	2.5	1	1.9

dents from Institute-1 is shown in Table 3. First, the gender distribution was 81.9% male and 18.1% female. Second, for race/ethnicity, a majority of participants were Hispanic/Latinx (50%), and the other respondents identified as Asian/Asian American (22.5%), White/Caucasian (10%), Black/ African American (2.5%), Native Hawaiian/ Pacific Islander (0.60%), and others (2.5%). We grouped the responses in Multiracial, where respondents chose more than one ethnicity; there were 19 (11.9%) responses in this category. The students were enrolled in mechanical engineering and computer science majors.

The demographic distribution of the 52 respondents from Institute-2 is also shown in Table 3. The

respondents self-identified as men (78.9%), and women (19.2%), with 1.9% of non-binary respondents. The data had diverse respondents belonging to various ethnicities such as Hispanic/Latinx (34.6%), Asian/ Asian American (25%), White/ Caucasian (15.4%), Black/African American (9.6%), multiracial students who responded to more than one ethnicity (13.5%), and others (1.9%). The sample included students enrolled in different majors: electrical and computer engineering technology, mechanical engineering technology, engineering technology, construction engineering, concrete industry management, software and data engineering technology, and biomedical engineering technology.

Table 4. Values Of Cronbach's Alpha Of Phase-3

Factors		Items	Cronbach's Alpha
Searching	S1	Brainstorm (Come up with) a new idea for a product or service	0.79
	S2	Identify the need for a new product or service	
	S3	Design a product or service that will satisfy customer needs and wants	
Planning	P1	Identify stakeholders interested in a new product or service	0.91
	P2	Identify the target market for a new product or service	
	P3	Estimate potential revenue for a new product or service	
	P4	Estimate the amount of financial investment necessary to scale a new product or service	
	P5	Identify potential partners necessary to scale a new product or service	
	P6	Identify potential resources necessary to scale a new product or service to scale	
Marshaling	M1	Get others to identify with your vision for a new product or service	0.83
	M2	Get others to identify with your plan for a new product or service	
	M3	Network (make contact and exchange information with others)	
	M4	Clearly explain verbally/ in-writing a new product or service idea in everyday terms	
Implementing People	IP1	Recruit team members	0.90
	IP2	Assign tasks to your team members	
	IP3	Deal effectively with day-to-day problems among your team members	
	IP4	Encourage team members	
	IP5	Motivate team members	
	IP6	Train team members	
Implementing Finance	IF1	Develop the budget for a new product or service	0.91
	IF2	Manage the budget for a new product or service	
	IF3	Interpret the budget for a new product or service	

5.2 Reliability

Reliability for all items was examined using Cronbach's alpha (Table 4). The values of the Cronbach's Alpha for the five factors were – searching (0.79), planning (0.91), marshaling (0.83), implementing people (0.90), and implementing finance (0.91), indicating moderate to high internal consistency [59].

5.3 Model Fit

To assess how well the hypothesized model fits data, the model fit was analyzed by calculating several fit indices: Chi-square, root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) [25]. The difference in the covariance matrices of the model and the actual data is measured by the chi-square (χ^2). For our model, the value of χ^2 is

317.972 ($p < 0.05$), indicating a strong association. RMSEA measures how poorly the model fits the data; the values considered as the ideal fit are zero, and the values less than 0.06 are considered a good fit [67]. The findings revealed the RMSEA for this model to be 0.05. SRMR is an approximate fit index, and the acceptable range of it is considered to be 0 to 0.06 [67]. The value of SRMR in the study is 0.06, indicating a good model fit. CFI and TLI measure the model's goodness of fit. For both CFI and TLI, a value above 0.90 is considered an excellent model-data fit [68, 69]. In the presented study, CFI and TLI are both greater than 0.95, indicating adequate model fit. The values of the model indices are reported in Table 5.

Table 5. Model Fit Indices

Model Fit Indices	
Chi Square	317.972
RMSEA	0.05
CFI	0.95
TLI	0.95
SRMR	0.06

5.4 Factor Loadings

The factor loading of each item exceeded 0.60, as shown in Table 6. This indicated that the items are validly measuring five factors related to E-ESE. The first factor is *searching*, which is conceptualizing new ideas for the business. It consisted of three questions, with all factor loadings exceeding 0.70. The second factor, *planning*, involves transforming ideas into viable plans with six items, each showing factor loadings above 0.64. *Marshaling*, the third factor, refers to assembling resources, with all items showing factor loadings above 0.70. Factor load-

Table 6. Factor Loading Of The Measurement Model

Factors	Items	Factor Loadings	Composite Reliability (CR)	Average Variance Extracted (AVE)
Searching	S1	0.73	0.79	0.55
	S2	0.74		
	S3	0.75		
Planning	P1	0.78	0.91	0.64
	P2	0.64		
	P3	0.84		
	P4	0.85		
	P5	0.85		
	P6	0.82		
Marshaling	M1	0.74	0.82	0.53
	M2	0.70		
	M3	0.73		
	M4	0.74		
Implementing People	IP1	0.70	0.90	0.60
	IP2	0.79		
	IP3	0.87		
	IP4	0.77		
	IP5	0.72		
	IP6	0.77		
Implementing Finance	IF1	0.95	0.94	0.85
	IF2	0.83		
	IF3	0.97		

ings for the fourth factor, *implementing people* (managing human resources), are all above 0.70, while those for the fifth factor, *implementing finance* (managing company finances), are near 0.83.

Furthermore, the convergent validity of the instrument is assessed by the Average Variance Extraction (AVE) [70]. AVE compares the variance due to measurement error to the variance captured by the factor. For the construct to be adequate, the value of AVE should be above 0.5, indicating that the latent factor explains at least 50% of the factor variance [71]. Calculation of AVE using the factor loadings indicated adequate factors, with the value for all the factors above 0.5, individually: *searching* (0.55), *planning* (0.64), *marshaling* (0.53), *implementing people* (0.60), and *implementing finance* (0.85). Also, the internal consistency of a scale was assessed using composite reliability (CR). The CR for all the factors is above 0.75, indicating good internal consistency – *searching* (0.79), for *planning* (0.91), *marshaling* (0.82), *implementing people* (0.89), and *implementing finance* (0.94).

To summarize Phase 3, the findings indicated a valid five-factor structure for the E-ESE measure. The values of the modification indices RMSEA (0.05), CFI (0.95), TLI (0.95), and SRMR (0.06) indicated a good model fit. The factor loading of all the items is above 0.70, confirming strong construct validity of the instrument with the value of AVE above 0.5 and CR above 0.75 for all the factors.

6. Discussion

The study was executed in three phases. In Phase 1, the items were refined, following the recommended process for the decision of selecting the items for the instrument, including a literature search, and strengthening the content validity by experts and the target audience. In Phase 2, the latent factor structure of an Engineering Entrepreneurial Self-Efficacy (E-ESE) instrument for engineering students was evaluated. Phase 2 results identified a five-factor structure with loadings above at least 0.40 for the factors – *searching*, *planning*, *marshaling*, *implementing people*, and *implementing finance*. In Phase 3, to analyze the psychometric properties (validity and reliability) of the E-ESE instrument, we performed a CFA that confirmed a 5-factor solution. The factor loadings above 0.64 for all survey items and the Cronbach's alpha value above 0.75 for each construct demonstrated instrument validity and reliability, respectively. In the following sections, we discuss the implications of the study for research and practice.

Entrepreneurship education emerged from business and management schools, and its expansion into engineering education is relatively recent [72].

As a result, most of the instruments designed and developed for the measurement of entrepreneurial self-efficacy were developed for and validated with the students in management schools and/or nascent entrepreneurs [16–18]. As noted in Phase 1 results, these instruments may differ in psychometric properties when used in engineering education, and thus, need refinement and validation for engineering students. We refined the instrument to better align the items in the context of engineering education using student and faculty feedback. Furthermore, the results of Phase 2 indicated a good factor loading of above 0.4 for most of the items and the reliability of all the factors above 0.70. This instrument refinement process provides implications for entrepreneurship-related instrument development in engineering education.

First, the question “How much confidence do you have in your ability to *determine* a competitive price for a new product or service” was rephrased to be more specific: “How much confidence do you have in your ability to *estimate* potential revenue for a new product or service?” Entrepreneurship education in engineering is often a scaffolded learning environment where students learn about entrepreneurship in experiential learning environments that imitate the entrepreneurial process but do not engage in actual business creation during the course. The determination of revenue is better suited for business students since they are likely to engage in coursework on finance and accounting and undergo detailed training on these topics. Thus, in contrast with business school-based incubators, engineering students are more likely to be in a position to ‘estimate’, rather than precisely determine revenue for a product/service.

Second, based on student and instructor feedback, we refined the items by replacing terms, such as “customers” with “stakeholders”. For example, the planning item “How much confidence do you have in your ability to *estimate customer demand* for a new product or service” was changed to “How much confidence do you have in your ability to *identify stakeholders* interested in a new product or service”. A plausible reasoning is that the venture creation process may differ for engineering students compared to business students. Business students are more likely to work towards customer satisfaction, but engineering students are often working towards making an impact on the stakeholders with their engineering designs, creating a societal and environmental impact [73]. In the context of entrepreneurship education taught within the engineering curriculum, the courses are often structured around stakeholders as a whole [74], rather than solely focusing on customers, as in the case of business fields [75].

Third, the item related to implementing people construct from the original instrument was refined from “. . . ability to recruit and hire *employees*” to “. . . ability to recruit *team members*”. In contrast to business-based entrepreneurship education, entrepreneurship education for engineering students involves classroom-based experiential opportunities wherein students work collaboratively in teams to bring engineering solutions to potential stakeholder problems [76]. In other words, engineering students are more likely to encounter team members than employees in entrepreneurship education environments. Thus, from an instrument development perspective, while the ESE construct – implementing people, is also applicable for engineering students, engineering students are more likely to resonate with the term ‘team members’ rather than ‘employees’.

Lastly, from a theoretical standpoint, entrepreneurial self-efficacy (ESE) plays a key role in commonly used theoretical works. For example, the theory of planned behavior [35] asserts that a person’s intent to pursue entrepreneurship as a career and their entrepreneurial behavior are influenced by their ESE. Similarly, Shapero’s entrepreneurial event model [34] acknowledges that one’s self-perception of their ability to start and sustain a business (equivalent to ESE) is a catalyst in influencing the entrepreneurial event formation or behavior. Ample entrepreneurship education (EE) literature has empirically examined these two theories [77-80]. However, based on our findings, we posit that while there is a need to validate EE theories in engineering education, it is critical to ensure that the instruments used to measure these different theoretical factors are valid for engineering student audiences. For example, commonly used entrepreneurial intent instruments [14, 81] measure/describe entrepreneurial intent solely focused on the intention of a person to start a venture. However, recent STEM education research recognizes several intentions (such as translation intent, innovation intent, intent to engage students, and personal intent) in addition to entrepreneurial intent [82].

With the continued advancement of entrepreneurship education in the engineering curriculum, there is a need for quality assessment tools that help in improving educational programs [83]. While the entrepreneurship constructs noted in the literature are relevant for entrepreneurship education (EE), their operationalization is likely to differ in non-business fields, particularly in engineering education. The presented study provides an example of refining existing instruments and encourages similar refinement and validation of other EE-focused instruments. Thus, we call for engineering educa-

tion researchers to (re)examine factors and (re)design instruments for valid assessment and research. The operationalization and assessment of the entrepreneurial mindset in the engineering education context is one significant effort from the engineering education community [84], where the entrepreneurial mindset construct has been explored and reconstructed from an engineering education perspective [85].

7. Limitations and Future Work

Although the presented instrument for measuring E-ESE contributes to engineering education, the study’s limitations provide directions for future work. First, while the data was collected from a diverse sample from two different institutions within the United States, to enhance the cross-cultural relevance of the E-ESE instrument, future research can focus on the psychometric analysis encompassing different geographical locations. Second, the factors of the E-ESE instrument are grounded on the entrepreneurial process, which is often a basis of the pedagogical approaches implemented in the EE courses. While this framework provides a way to measure the ESE from a process perspective, future research could validate the instruments specific to the engineers that are based on the skills and roles that are deemed essential for entrepreneurial engineers. Third, the study has provided support for a five-factor structure, indicating a robust latent structure for the E-ESE instrument. Further research can be performed with a large sample to extend the results and enhance the generalizability of the instrument.

8. Conclusion

Assessment of entrepreneurial skills is essential in today’s world and therefore needs an instrument designed for the context of engineering students. Despite extensive research on entrepreneurial self-efficacy, existing instruments have not been contextualized and validated for engineering education, and have been focused on the business and management school audience. The objective of the presented study was to refine and validate an Entrepreneurial Self-Efficacy for Engineering (E-ESE) instrument in the context of undergraduate engineering students. The lack of valid and reliable instruments for E-ESE creates a gap in the rigorous examination of students’ perception of their ability to complete entrepreneurial tasks and consequently impacts the quality of assessment and research in engineering entrepreneurship education. Furthermore, this lack of assessment and research is likely to impact the effective improvement of educational

interventions in engineering entrepreneurship courses that focus on enhancing students' entrepreneurial skills. The results of the study show a validated five-factor latent structure. We call for further research in the validation/refining of other entrepreneurship-related factors such as entrepreneurial intent and behaviour. As engineering education continues to draw from entrepreneurship education literature and educational efforts, we encourage researchers and educators to contextualize entrepreneurship education to align with the needs of engineering students.

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