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Development of the Leadership Self-efficacy Scale for Engineering Students

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Abstract

The purpose of this research paper is to develop and validate a leadership self-efficacy scale for engineering students. As the National Academy of Engineering identified leadership as one attribute that engineering students must develop by the time of graduation, at the university level, institutions have provided supplemental leadership programs that engineering students can take during college education period. However, there has been a lack of appropriate instruments to understand and diagnose the current approach and efforts of institutions to develop engineering students' leadership. Therefore, the 69 items for a leadership self-efficacy scale was constructed to indicate six factors as representative aspects of leadership in engineering. With data from 173 engineering students, exploratory factor analyses identified an underlying factor structure of the scale with 38 items loaded onto one of five factors (Leadership Opportunity, Team Motivation, Engineering Practice, Innovative Changes, and Ethical Actions and Integrity), along with good reliability evidence.

I. Introduction

> *"Our aspiration is to shape the engineering curriculum for 2020 so as to be responsive to the disparate learning styles of different student populations and attractive for all those seeking a full and well-rounded education that prepares a person for a creative and productive life and positions of* ***leadership****"* (p. 52)[1].

As we face rapid changes in technology, society, and the world, the National Academy of Engineering identified leadership as one attribute that engineering students must develop by the time of graduation along with the following traits: strong analytical skills, creativity, ingenuity, and professionalism[1]. This is because of the growing number of opportunities for engineers who work in the multidisciplinary environments to take a leadership role as their career advances in the social-political-economic world[1]. Similarly, in the report entitled *Educating the engineer of 2020: Adapting engineering education to the new century* published by National Academy of Engineering reinforced importance of engineering students' leadership development as reforms for engineering educators[2].

While engineering experts in academia and industry considered leadership as one of important professional skills to be developed, engineering students seem to perceive the values of engineering skills and knowledge items differently. According to the longitudinal Academic Pathways Study (2003-2010) conducted by the Center for the Advancement of Engineering Education (CAEE), engineering seniors ranked leadership as the 12th in order of importance among 20 engineering skills and knowledge items with top priorities in problem solving, communication, and teamwork[3]. This gap of perceptions between engineering experts and students suggests reinforcement of leadership education at the undergraduate level to have engineering students prepared for the needs of leadership skills during their careers. Therefore, it is vital for students to equip with leadership skills by the time of graduation[4].

Since this society and industry need engineers who can be a leader of multidisciplinary teams for their stakeholders, development of leadership capacity for engineering students becomes important for engineering education institutions. Therefore, at the university level, institutions have provided supplemental programs that engineering students can take during college education period. However, there has been a lack of appropriate instruments to understand and diagnose the current approach and efforts of institutions to develop engineering students' leadership[5].

A. Theoretical Background

The literature regarding engineering leadership frequently addresses various skills and personal traits as antecedents to be a good leader[6, 7]. For example, McCloskey, Reel, and Gabriele[7] listed the following skills to define leadership: "effective communication, both verbal and nonverbal, public speaking, listening, leadership styles, personal values, corporate values, effective team work, decision making, group dynamics, ethics, multiculturalism, self-awareness, and critical thinking" (p. 1116). Similarly, Cox et al.[6] identified constellation of intrapersonal and interpersonal skills for leadership through interviews with 23 industry and academic professionals in engineering, along with the elements of two related constructs: recognizing and managing change, and synthesizing engineering with other multi-perspectives. Further, through an exploratory study founded in the prior study[6], Ahn, Cox, London, Cekic, and Zhu[8] identified indicators (e.g., proactive, motivation, communication, input driven, ability to listen, and fairness) of being an engineer leader and engineering leadership, commonly perceived by undergraduate students. Those intrapersonal or interpersonal attributes or skills can be considered as antecedents of being a good leader in any fields. In other words, those attributes would be necessary conditions as qualifications to be a good leader. However, the antecedents of being a good leader may not be sufficient to directly indicate leadership in engineering.

According to the Bandura's[9] theory of social learning, self-efficacy can be phrased as "one's personal belief about his or her capability to take an action toward an attainment" (p 464)[10]. Therefore, leadership self-efficacy can function as a source of motivation to be a leader in a team setting[11]. Similarly, Paglis and Green[11] defined leadership and leadership self-efficacy, respectively, below.

> *"**Leadership** is the process of diagnosing where the work group is now and where it needs to be in the future, and formulating a strategy for getting there. Leadership also involves implementing change through developing a base of influence with followers, motivating them to commit to and work hard in pursuit of change goals, and working with them to overcome obstacles to change"* (p. 217)[11].

> *"**Leadership self-efficacy** is a person's judgment that he or she can successfully exert leadership by setting a direction for the work group, building relationships with followers in order to gain their commitment to change goals, and working with them to overcome obstacles to change"* (p. 217)[11].

Therefore, based on the literature about engineering leadership and self-efficacy, we defined leadership self-efficacy for engineering students as their personal belief in their capability to demonstrate leadership for a team with a vision through goal setting, team motivation, and innovative changes, while applying engineering practice and considering ethical actions and integrity. Therefore, such an instrument to assess leadership self-efficacy can provide evidence-based information regarding engineering students' leadership development.

B. Purpose of the Study

With increasing awareness about the necessity of leadership development in undergraduate engineering education, this study proposed to present development and validation process of a leadership self-efficacy scale for engineering students. As "there is no all-purpose measure of perceived self-efficacy" (p. 307)[12], we only included several aspects of leadership considered to be necessary for engineering students. By exploring the responses on the leadership self-efficacy scale, researchers and educators will be able to investigate the progress in engineering students' leadership development and assess their preparedness as a leader in engineering community.

II. Method

A. Instrument Development

Based on the literature review on leadership theories and development, six factors necessary for engineering students' leadership development were considered for assessing leadership self-efficacy: (a) leadership opportunity, (b) goal setting, (c) team motivation, (d) innovative changes, (e) ethnical action and integrity, and (f) engineering practice. Table 1 describes the definition of each construct.

Table 1. *Six Factors that constitute the Leadership Self-efficacy Scale for Engineering Students*

Construct (Abbreviation)	Definition
Leadership Opportunity (LO)	Students' personal belief in their ability to develop their own leadership by taking the initiative in a team.
Goal Setting (GS)	Students' personal belief in their ability to demonstrate leadership with vision to set a direction for where their team should be headed.
Team Motivation (TM)	Students' personal belief in their ability to demonstrate leadership that motivates others to enhance their performance.
Engineering Practice (EP)	Students' personal belief in their ability of exerting leadership to apply engineering practice for their team.
Innovative Changes (IC)	Students' personal belief in their ability to demonstrate leadership by introducing innovative changes for their team.
Ethical Actions and Integrity (EI)	Students' personal belief in their ability to demonstrate leadership by taking responsibility on ethical issues with integrity as well as results.

For item constructions, we generated 105 items to be content specific for engineering students. The 105 items represent a combination of new items based on the engineering leadership literature and modified items from the existing leadership instruments[8, 11]. All the items in the initial pool were judged by a panel of eight professors and graduate students in engineering and education disciplines, as well as nine undergraduate engineering students. To confirm face and content validity of the scale, the panel has reviewed, discussed, and nominated 69 items for the six factors. The level of scale was determined to be a six-point Likert type scale (strongly disagree, moderately disagree, disagree slightly more than agree, agree slightly more than disagree, moderately agree, and strongly agree).

B. Sample and Procedure

For the scaling procedures of the engineering leadership self-efficacy scale (ELSS), we targeted engineering undergraduate students as a population of the scale. A web-based survey software, Qualtrics, was used to construct the scale and a background survey online. For this study, engineering students at a large southwestern university were invited via email to respond to the scale and the background survey for their demographic information in fall 2015. Table 2 shows the demographic information of the 173 participants who completed their responses on the scale. Participants' mean age was 18.9 with a standard deviation of 1.8 (n = 169). Four students did not respond on age. On average, students took around 9.4 minutes to complete the surveys including both the scale with 69 items and the demography survey (n = 168). Here five respondents who spent more than 30 minutes were excluded to calculate the average survey response time.

Table 2. *Characteristics of the Participants who responded on the ELSS*

Category	*n*	%
Gender		
Female	44	25.4
Male	129	74.6
Race/Ethnicity[a]		
Hispanic	47	28.0
American Indian or Alaska Native	1	0.6
Asian	19	11.3
Black	6	3.6
Native Hawaiian or other Pacific Islander	0	0.0
White	94	56.0
Multi-racial	2	1.2
Residence		
Domestic	168	97.1
International[b]	5	2.9
Level		
Freshman	142	82.1
Sophomore	11	6.4
Junior	12	6.9
Senior	8	4.6
Total		

Note. [a]Race/Ethnicity category includes only domestic students; [b]International students' race/ethnicity was not categorized.

C. Data Analysis

To investigate underlying factor structures of the new scale and to identify irrelevant items that do not fit into any factors, an exploratory factor analysis (EFA) was conducted with the data from 173 engineering students. As students' responses were scaled on a six-point Likert scale for each item, which is naturally categorical, robust weighted least squares (WLSMV) was utilized as an estimator to obtain parameter estimates of the factor analysis, using the Mplus 7.11 program[13]. The EFA was carried out by the calculation of polychoric correlation coefficients, eigenvalues, and factor loadings after oblique rotation of GEOMIN, which is the default rotation of the Mplus. After the identification of the factor structure of the scale, the reliability coefficient of internal consistency, Cronbach's α, was calculated for each factor to investigate how items are interrelated within the factor.

III. Results

A. Exploratory Factor Analysis Modeling

Polychoric correlation coefficients among the 69 items, which are ordered categorical variables, showed that the coefficients were all positively correlated, meaning that putative factors identified through an EFA were not independent. In addition, there were no multicollinearity (strong correlations over .85) among the items, implying that each item seems to measure slightly different aspect of the constructs. Based on the point of inflection of the curve in the scree plot[14] and eigenvalues greater than one[15], we extracted seven factors considered for inclusion as an underlying putative factor structure of the ELSS.

We considered items with a factor loading greater than 0.38 significant for the designated factor, according to Stevens' (2002)[16] guideline about the relationship between the sample size and cutoff factor loading. Therefore, any irrelevant items, which did not fit well into the designated factor, were suppressed by the cutoff criterion. In addition, if an item loaded onto more than one factor, then the item was excluded. This resulted in exclusion of two factors because of the multiple loadings of the items across two factors and more. As shown in Table 3, 38 items out of the original 69 items had significant factor loadings onto one of five factors, indicating each item's unique contribution to one of the factors.

Table 3. *Exploratory Factor Analysis Results for the ELSS* (*N* = 173)

Item	Factor Loading
Leadership Opportunity (LO)	
1 I can attempt to develop my leadership skills.	0.716
2 I can strive to develop my leadership.	0.592
3 I can actively seek leadership opportunities in and out of the classroom.	0.576
4 I can exhibit leadership skills when necessary.	0.524
5 I can actively seek opportunities to demonstrate my leadership.	0.507
6 I can learn how to lead a team.	0.488
Team Motivation (TM)	
7 By demonstrating leadership, I can encourage my team members to think of new ways of doing things.	0.816
8 By demonstrating leadership, I can fulfill my responsibilities to my team members.	0.708
9 By demonstrating leadership, I can find several ways to motivate people on a team.	0.680
10 By demonstrating leadership, I can influence my team members to work together.	0.620
11 By demonstrating leadership, I can actively encourage others to solve problems.	0.565
12 By demonstrating leadership, I can encourage my team members to get involved in a project.	0.557
13 I can lead others to develop and apply their talents for the established goals.	0.545
14 By demonstrating leadership, I can develop plans for change that will take my team in important new directions.	0.507
15 By demonstrating leadership, I can influence others to be enthusiastic about working toward the established goals.	0.470

16	By demonstrating leadership, I can encourage my team members get involved in a project.	0.456
17	By demonstrating leadership, I can influence others to take positive action to further the team's reputation and interests.	0.406
Engineering Practice (EP)		
18	By demonstrating leadership, I can encourage my team to apply a professional code of ethics to analyze an ethical problem.	0.742
19	As an engineer, I can lead the employment of engineering practices for team effectiveness.	0.680
20	As an engineer, I can lead the application of sustainable development concepts to my team projects.	0.653
21	As an engineer, I can lead better approaches toward projects with consideration of environmental costs, impacts, and conditions.	0.626
22	As an engineer, I can lead a team with sustainable design approaches.	0.580
23	By demonstrating leadership, I can apply new technologies in my field for team projects.	0.530
24	As an engineer, I can initiate a leadership role that will advance my career.	0.415
Innovative Changes (IC)		
25	By demonstrating leadership, I can provide flexibility to enhance and encourage new thinking.	0.675
26	Exerting leadership, I can adopt reengineering as a useful improvement process for the benefit of my team.	0.662
27	By demonstrating leadership, I can restructure and challenge the traditional methods of accomplishing a team goal.	0.627
28	By demonstrating leadership, I can explore ways to implement innovation for the team benefit.	0.546
29	I can exhibit leadership to improve effectiveness of the team.	0.541
30	By demonstrating leadership, I can seek continuous improvement in the way that work gets done.	0.525
31	I can lead a team toward my vision for the team goals.	0.517
32	By demonstrating leadership, I can clearly visualize a project goal even when limited information is available.	0.492
33	By demonstrating leadership, I can apply different ethical frameworks to analyze a problem of my team.	0.490
34	By demonstrating leadership, I can seek innovative ways to improve the team performance.	0.413
Ethical Actions and Integrity (EI)		
35	By demonstrating leadership, I can take ownership of a project in which I am involved.	0.563
36	As an engineer, I can lead a team that saves time, money, and other resources for the team efficiency.	0.518
37	Demonstrating leadership, I can take responsibility for the success and failure of a project.	0.465
38	By demonstrating leadership, I can take on responsibilities that are not assigned to me.	0.385

Note. 38 items with significant factor ladings onto one of five factors were only listed.

Based on the original instruments of the items and theories applied to develop items, we matched the constructs to the factors clustered with a group of items. Table 3 shows that the first six items loaded on a factor related to self-efficacy in leadership opportunity that indicates students' personal belief in their ability to develop their own leadership by taking the initiative. The next eleven items were associated with students' personal belief in their ability to demonstrate leadership that motivates others to enhance their performance (i.e., leadership self-efficacy in team motivation). The following seven items related to students' belief in their ability of exerting leadership to apply engineering practice for their team (i.e., leadership self-efficacy in engineering practice). The fourth factor with ten items represents students' personal belief in their ability to demonstrate leadership by introducing innovative changes for their team (i.e. leadership self-efficacy in innovative changes). Finally, the last four items were grouped together as indicators of leadership self-efficacy in ethical actions and integrity. Interestingly, the items designed to indicate leadership self-efficacy in goal setting were not aggregated to be the components of a factor. In addition, some items did not seem to fit the theme of a construct.

B. Reliability Evidence

Table 4 shows internal consistency reliability coefficients of five factors structured in the ELSS, which appeared to have good internal consistency, ranged from Cronbach's α =.810 to .943. The overall reliability of the ELSS with 38 items as a whole was Cronbach's α = .973 from N = 173. All items of the ELSS were worthy of retention because removal of any item for each factor would not increase the reliability coefficient, Cronbach's α[17].

Table 4. Internal Consistency Reliability Coefficients of the Factors structured in the ELSS

	Leadership Opportunity	Team Motivation	Engineering Practice	Innovative Changes	Ethical Actions and Integrity
Abbreviation	LO	TM	EP	IC	EI
No. of Items	6	11	7	10	4
Cronbach's α	.865	.943	.926	.926	.810

IV. Discussion

The purpose of the study was to develop and validate a scale to measure students' self-efficacy in demonstrating leadership in the context of engineering. To do this, we identified six factors to represent engineering leadership self-efficacy and constructed items for each factor based on the literature review about leadership theories and engineering leadership. However, the EFA with the data from 173 engineering students at the southwestern university resulted in five factors of leadership self-efficacy (leadership opportunity, team motivation, engineering practice, innovative changes, and ethical actions and integrity), significantly loaded by 38 items.

Interestingly, the items generated to indicate leadership self-efficacy in goal setting were not clustered together: some items were loaded onto two to three factors and some items were loaded onto other factors. Since goal setting as a leader for a team is one important aspect of leadership that needs to be measured in the scale, there is a need of revision of the items for self-efficacy in goal setting and another round of factor analysis modeling. In addition, some items, such as items, 8, 24, 31, 33, 36, and 38 need to be examined for revision, because of possible potential of misfits. Therefore, the second round of data collection is planned for another EFA after revision of items with possible misfits and items for goal setting.

To finalize the items and factor structure of the instrument, a confirmatory factor analysis will be applied with the second round of data collection. In addition, item analyses based on classical test theory are planned to evaluate overall psychometric properties of the newly developed instrument.

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