



Engineering Leadership Assessment to Action: Development Leadership Profiles for Academic Success

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Engineering Leadership Assessment to Action: Development of Leadership Profiles for Academic Success

Abstract

It is well established by both industry and academics that while the current focus of the engineering curricula focuses on the technical aspects of the student's education, there is a definitive need to incorporate the inculcation of leadership, communication, and professional skills during the course of their undergraduate study. This point is emphasized in several reports, including the Accreditation Board for Engineering and Technology (ABET), the National Academy of Engineers (NAE), and the American Society of Engineering Education (ASEE) among others. In this study, a personal leadership profile instrument was tested that enables students to compare their personalized engineering leadership score with data obtained from a prior study (N=753)¹. This establishes a baseline of leadership skills in comparison to one's peers. This paper describes the development of a personalized leadership profile for students that would aid them in creating their own leadership plan by comparing their responses with the baseline. The leadership profile helps to identify areas for improvement and provides recommendations of relevant courses as a step towards improving upon them. Students empowered with the results of their profile could make informed decisions about future course selection in their program. This study demonstrates one method of aiding students in creating a leadership experience that is unique to their needs. Profile creation could be a model for other institutions to ensure they are meeting the needs of the accrediting bodies and student expectations.

Introduction

Numerous reports by Accreditation Board for Engineering and Technology (ABET)², the National Academy of Engineers (NAE)³, and the American Society of Engineering Education (ASEE)⁴, among others, have been published emphasizing the importance of developing the professional skillset of undergraduate engineering students. Universities have started incorporating resources such as workshops and seminars to hone skills such as communication, teamwork, and leadership in their students. Purdue's Engineering Leadership Minor seeks to address these needs. However, there is a lack of personalized assessment tools incorporated in the program to assess whether engineering leadership courses are meeting desired outcomes. A thorough literature review showed that although a survey had been developed for individual assessment of leadership qualities¹, there was no instrument to assess its results and provide engineering students with comprehensive feedback in comparison to their peers and provide them with actionable feedback regarding their leadership efforts.

This paper introduces a way to translate the empirical results of the engineering leadership survey into a personalized leadership profile that helps students to identify potential areas of leadership improvement by comparing their individual responses to large group responses informed from a previous study¹. Following a brief introduction of Purdue University's Engineering Leadership Minor and a description of the survey instrument used for personal leadership monitoring, the methods section describes how individual leadership profile

scores were calculated, and presents sample individualized student reports and recommendations provided to guide students toward relevant engineering leadership coursework. The results of this study presents how contributions of this profile could inform engineering leadership initiatives.

Background: Engineering Leadership Minor

The Engineering Leadership Minor at Purdue University was inaugurated in 2012 and launched in January 2013 to address the leadership needs in the engineering education community⁵. It was modeled after other successful programs with similar objectives⁶⁻⁸. The goal of this program, however, is to provide undergraduate engineering students with reliable opportunities to engage in scholarly and experiential engineering leadership. It is intended that this preparation will arm students with next-generation engineering and technical leadership knowledge and skills to be applied in the science, technology, engineering, and mathematics (STEM) workplaces of their choosing. Success in the program also awards students a minor in engineering leadership that is recorded on their transcript.

To earn a minor in Engineering Leadership, students are required to complete a set of engineering leadership core classes and other engineering and/or non-engineering courses offered across the University by various departments and colleges and representing one of four concentration areas. The curriculum for the engineering leadership minor is comprised of sixteen credit hours consisting of core and elective courses: Seven credit hours of core courses and nine credit hours consisting of elective courses of their choosing. Three engineering leadership core classes ((1) Engineering Leadership Development, (2) Portfolio for Experiential Engineering Leadership, and (3) Engineering Leadership Capstone) within the minor are developed and taught in-house. The final requirement involves experiential learning engagement. Student progress and leadership development are tracked as they complete the requirements of the minor.

The elective courses are classified into four concentrations: (1) communication, (2) ethics, (3) creativity and innovation, and (4) global and societal impact. The four concentration areas were created following research about other engineering leadership programs and the courses available to engineering students across the university. The ‘communication’ concentration includes courses that focus on the development of students' professional skills and engagement with technical and non-technical audiences. The ‘ethics’ concentration includes courses that align with regulatory and policy-related aspects of engineering. The ‘creativity and innovation’ concentration involves courses that closely relate to entrepreneurship. The ‘global and societal impact’ concentration courses explore the impact of leadership across diverse stakeholders and national and global communities. Students must choose no more than two concentration areas within which to tailor their engineering leadership development. This approach allows students to gain depth and understanding in applying engineering leadership principles, practices, and tools within the contexts that align with their interests and their career paths.

Previously, tools to assess overall student leadership development through the Minor were limited to periodic surveys. This approach has been satisfactory in observing general trends and in identifying organizational issues of concerns. They lack, however, the level of detail needed to comment on the effectiveness of the engineering leadership courses on students’

overall engineering leadership development. For this reason, the student profile assessment tool was created.

This new survey-based instrument described in this study aims to measure an individual's leadership development, based on a previous study performed by Ahn et al.¹ which operationalized the definition of leadership, change management, and synthesis within the context of engineering education. The starting point for the development of individual leadership profiles is the survey instrument that was developed by Ahn et al.¹ This survey was administered to the general engineering student population at Purdue University with a 753 engineering undergraduate students completing the survey. Exploratory Factor Analysis (EFA) of the statistical results was conducted in order to discover the underlying factors behind the large set of survey items. The final survey consisted of 45 items measuring four aspects of engineering leadership, which are summarized in Table 1 but are explored in detail in the original literature¹. Although there are 45 items within the survey, two of the items are represented in two constructs. The instrument was administered as a web-based survey. Students self-reported their agreement with items through a four-point Likert scale survey (1 = rarely, 2 = sometimes, 3 = frequently, and 4 = almost always).

Table 1: Engineering Leadership Factors from Ahn et al¹.

Engineering Leadership Factor	Characteristics and Description
Being an Engineering Leader	Individual knowledge, skills, abilities, and characteristics involved with leadership, including courage, ability to delegate, organization, and communication.
Impact on Society and Economy	Individual's recognition of the interdependencies between engineering work and impact, including awareness of relevant problems, solutions, and change navigation.
Engineering Leadership	Individual's ability to build relationships among a team for mutual benefit and interpersonal cooperation and exchange.
Adaptor to Change	Individual's ability to adapt to change in careers, personal situations, and ability to make decisions that impact project success.

Methods

In this study, we discuss the use of the developed survey to be a self-reported individual leadership development instrument, in which a student's individual engineering leadership score can be compared with the aggregate scores from the large number of engineering students who were surveyed during the validation of the instrument. The reported score itself is a summation of a student's response to the four-point Likert scale items in the survey. An individual student can then compare her or his scores across constructs, or factors, to the average score of the aggregate data, which was collected across 753 students in the previous study¹. Comparing an individual's score with the average score of their peers instead of the obtainable maximum score allows for a realistic assessment of students' engineering leadership skill levels given the

diversity of the population of undergraduate students that the aggregated data was collected from. This comparison helps the individual to identify areas among the four factors for improvement in order to develop a holistic set of leadership skills. This information will be presented to students in both visual and written form.

In order to show the usefulness of comparing an individual’s leadership score with the aggregated data, Table 2 presents a sample result from an undergraduate engineering student. The maximum possible score is the score that an individual could have received for a factor had they responded with “4=almost always” to every survey item in that construct. The student serving as a point of comparison, under the pseudonym “Ken,” is a junior level Mechanical Engineering student who is interested in comparing his leadership characteristics with those of the average engineering undergraduate student. He wants to identify potential areas of improvement so that he can take relevant coursework and undertake leadership initiatives to improve his leadership skills.

Table 2: Comparison of Ken’s Leadership Score to Other Students across Factors

Engineering Leadership Factor (# of survey items in factor)	Ken’s Score	Average Score (N=753)¹	Max Possible Score
Being an Engineering Leader (22)	56	66.06	88
Impact on Society and Economy (12)	39	38.67	48
Engineering Leadership (8)	18	26.5	32
Adapter to Change (4)	8	8.85	16

Figure 1 shows a graphical representation of this data, normalized by the maximum possible score in each factor since the number of items within each construct range from 4 to 22 items per construct. This gives the ability to compare Ken’s proficiency in each of the factors against each other (demonstrated in Table 2). Represented now as scores between 0 and 100, Figure 1 shows how the average engineering student ranks in leadership skills and can be easily converted into a percentage. The comparisons of Ken’s normalized scores to the average normalized scores can give rise to feedback and inferences about the skills which Ken will need to acquire over his engagement in the Engineering Leadership Minor.

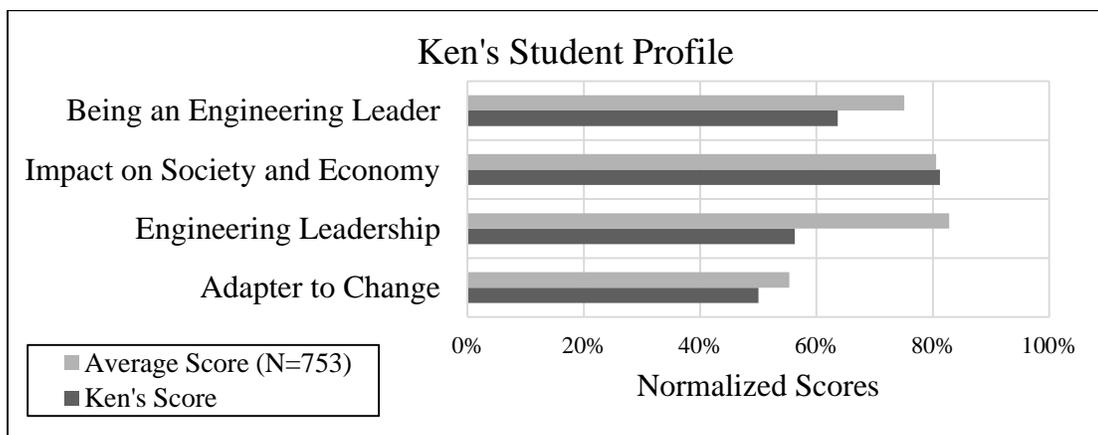


Figure 1: Graphical representation of normalized individual and aggregate survey results

The report provides a general overview of the student's leadership skills relative to that of his of his peers in the four factors. It can be seen that Ken falls near the average engineering students' score on the factors related to societal impact and adaptability to change, while his lack of individual and group team-leading skills associated with being a leader in engineering is also highlighted. This may be due to his experiences (or lack of experiences) in group work, extracurricular activities, or other experiences before college.

In order to better understand the characteristics that the student scored either well or poorly on, the report also provides the individual with a detailed breakdown of individual survey items grouped under each of the four factors. The scale is to 4 because of the four-point Likert scale of the survey. This breakdown is provided in Figure 2 for each of the four factors. Figure 2 provides a more detailed analysis and comparison of the student's scores with that of his peers for each of the traits included in the survey instrument. For example, it can be observed from Figure 2 that Ken fared poorly compared to his peer group in the following traits: Confidence; Goal Setting; People Skills; Organizational Skills; Social Responsibility; Ability to Listen; and Fairness. Identifying these individual traits that require improvement provide valuable feedback for the student that would aid in his self-reflection and in charting a plan for incorporating habits and activities into his daily life that would aid in the development of leadership traits.

The next section of this paper offers formal coursework suggestions that would better student leadership skills by taking advantage of classes in many different departments around campus. However, the results of the personal leadership survey serves to recommend that students to promote their own personal growth by joining strategic extracurricular activities promoting leadership. For example, since Ken needs work in his communication skills, perhaps the Toastmaster's club or other communication club might be an appropriate activity. Similarly, since the leadership survey indicated his lack of organizational and goal-setting skills, perhaps taking project leadership positions in engineering service and outreach projects would give Ken a chance to hone his short- and long-term goal-setting skills, as well as to practice staying organized in a complex environment. Likewise, a solution towards improving upon his social responsibility would be to recommend volunteer work.

Currently, the researchers are working on developing a repository of practices that would aid in the development of the specific traits within the student. Such a repository would be invaluable in providing specific and pointed recommendations to target areas of inadequacy in an individual's arsenal of leadership skills. Thus, it can be seen that the portfolio generated based on a student's response to the survey provides an overview of their leadership skills before breaking it down to specific traits requiring improvement. The next section describes another objective of the tool- personalized course recommendations based upon their leadership survey responses.

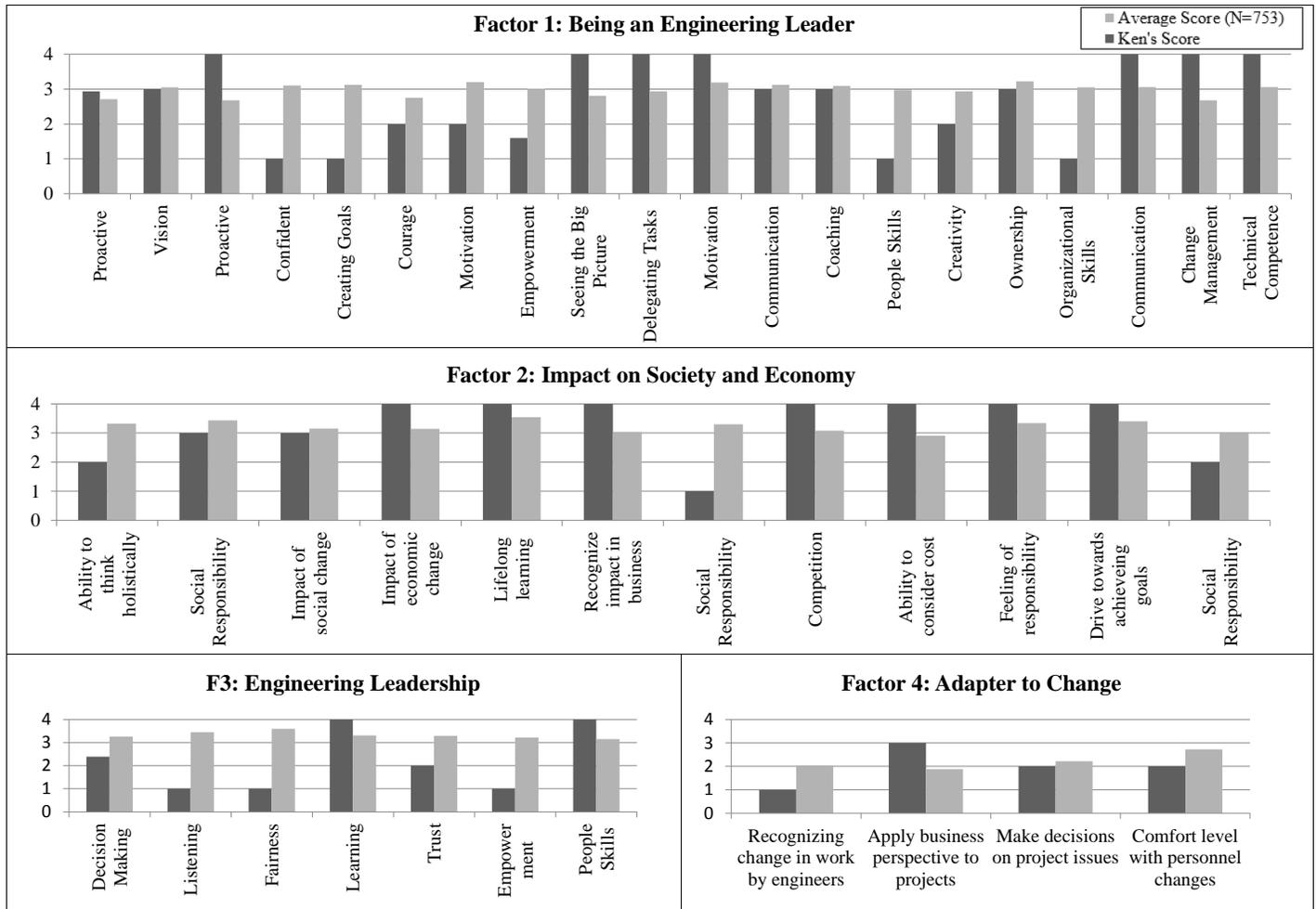


Figure 2: Ken's scores compared to all students across factors

Recommendations on Relevant Coursework

In order to provide personalized recommendations to the individual beyond a mere comparison of scores with the baseline, the researchers classified the required coursework to be taken by students of the Engineering Leadership Minor into the four categories represented by the four factors. This classification would enable the report generated to contain not just areas of improvement but also suggest potential courses based on the survey results.

The program already contains a list of courses that are classified based on the four concentration areas mentioned earlier in the paper (i.e., Communication; Creativity and Innovation; Global and Societal Contexts; and Ethics). Thus, the new classification sought to identify courses in each of these concentration areas that aligned with the four factors. In an effort to identify courses that could be aligned with the four factors, the researchers examined the recommended courses from various departments in the university that were listed in the curriculum of the Engineering Leadership Minor. These courses were already classified according to one of the four concentration areas and count towards the relevant coursework requirements of the minor. The descriptions of these courses were studied to determine and select which of their learning objectives best aligned with each of the four factors. In this manner, a list of 16 current courses that map each factor into each of the concentration areas was compiled, which is shown in Table 2. This list would serve to provide course recommendations to the student based on both their responses to the survey as well as their chosen areas of concentration. For the case of Ken, who has selected Communication as his concentration area, the following courses would be recommended based on his shortcomings in Factor 1 (Figures 1 and 2) relative to his peer group: Student Leadership Development (Educational Psychology); Intercultural Communication (Communication); Collaborative Leadership: Listening (Educational Psychology); and Leadership for Organizational Change and Innovation (Organizational Leadership and Supervision).

Table 3: Sample mapping of engineering leadership courses to four survey factors

Factor Requiring Improvement	Concentration Area in Minor	Course Title & Discipline
1. Being an Engineering Leader	Communication	Student Leadership Development (Educational Psychology)
	Creativity and Innovation	Leadership Principles (Organizational Leadership & Supervision)
	Global and Societal Contexts	Women and Leadership (Entrepreneurship)
	Ethics	Modern Ethical Theories (Philosophy)
2. Impact on Society and Economy	Communication	Intercultural Communication (Communication)
	Creativity and Innovation	Communicating in the Global Workplace (Communication)
	Global and Societal Contexts	Engineering Environmental Sustainability (Civil Engineering)
	Ethics	Contemporary Issues in Civil Engineering (Civil Engineering)

Factor Requiring Improvement	Concentration Area in Minor	Course Title & Discipline
3. Engineering Leadership	Communication	Collaborative Leadership: Listening (Educational Psychology)
	Creativity and Innovation	Leadership through Teams (Organizational Leadership & Supervision)
	Global and Societal Contexts	Critical Thinking in Organizations (Organizational Leadership & Supervision)
	Ethics	Legal Aspects in Engineering Practice (Civil Engineering)
4. Adapter to change	Communication	Leadership for Organizational Change and Innovation (Organizational Leadership & Supervision)
	Creativity and Innovation	Leadership Process (Organizational Leadership & Supervision)
	Global and Societal Contexts	Leadership in a Changing World (Agricultural Economics)
	Ethics	Global Moral Issues (Philosophy)

Limitations and Future Work

The primary limitation of this paper is that it is as yet untested on large numbers of engineering leadership students and therefore is subject to iterative changes upon implementation. While the methodology is grounded upon rigorous and proven work, the presentation of the information and recommendations will need to be revised based on feedback received from students. While the current iteration of the report being generated contains information about the students’ leadership skills as evidenced by the survey and recommended coursework based both on survey results and chosen area of concentration within the minor, future versions of generated reports could include other aspects of the leadership program and leadership development exercises including the a list of recommended extra-curricular activities and student organizations to join, thereby matching individuals with mentors. Other limitations include the self-reported nature of the instrument and the instrument not taking into account prior leadership experiences of the student. These aspects could be addressed in future versions of the tool. Another potential exercise of value that could be borne out of this research would be the comparison of an individual’s scores with subgroups of the population itself that could be narrowed down based on the student’s cohort, major, or geographic location.

The classification of coursework based on the four factors of the survey was done for a set of courses that were listed as relevant coursework that would count towards the completion of the program’s requirements by studying the description of the courses and determining which factor it most closely resembled. However, a more rigorous classification of the coursework would need to be undertaken with the understanding that an individual course could be used to develop skills in one or more of the factors. It is proposed that semi-structured interviews with the course instructors be used for this purpose, which will provide a more accurate list of recommendations to the student based on the survey. It is equally important to validate the recommendations by tracking the observable outcomes of the student after having taken the recommended coursework. This aspect can be built into the overall tracking plan for the

development of students undergoing engineering leadership education. Lastly, the report generation will need to be automated to provide results to the individual immediately upon completion of survey.

While the intent of this tool was to provide students with a personalized portfolio of their leadership skills which could be used for self-assessment and reflection, we also envision the future of this tool to be adapted to an easy-to-read result similar to a personality test like the Big 5 Personality Traits⁹ or Meyer-Brigg's personality test¹⁰ to be used as a general leadership test outside the Engineering Leadership Minor. The primary goal of this test would be classify the respondent into the type of leader that they currently are with the objective of helping them to define the type of leader that they want to become. This would require many iterations of validation, psychometrics, and further instrument develop at the quantitative and qualitative research levels. A more short-term objective towards this end would be the to classify the scores into categories such as "good", "average", or "poor" for individual factors, which would pave the way toward a leadership type classification system described above. Lastly, a note must be made about the reliance on self-analysis that this research is built upon. We suggest that the results obtained by the students be used judiciously in conjunction with other 360 degree instruments and outside evaluations for a more holistic assessment of the individual's skills.

Anticipated Contributions

We expect that the methodology described in this paper to generate a personalized report and provide a recommended list of courses based on their self-assessment will prove to be a valuable addition to the holistic tracking and assessment plan for students engaged in engineering leadership programs. Specifically, the generated report would provide students with an informative roadmap to begin their leadership development journey by shedding light on potential areas of improvement and providing a baseline record of their skillsets, which can then be used for assessment of progress during the course of the program. The level of detail of the generated report, with its comparison of an individual's attributes to a baseline aggregate score generated by a larger population of their peers, allows them to reflect upon and critically examine their leadership and educational experiences. This reflection is of great value in systematically creating one's portfolio of leadership experiences and self-tracking their own development. The detailed comparison of one's leadership attributes in comparison with their peers is also valuable in leading discussions with faculty members or mentors, which could also help to normalize any discouragement a student's who compares poorly to her/ his peers might feel after taking the survey.

The methodology described in this paper extends the utility of the survey instrument created by Ahn et al.¹, which has thus far been used in gaining insights into the general trends of the experiences and observables outcomes of undergraduate engineering students, by providing them with a personalized assessment of their skillset and recommended actions in improving them.

For the broader engineering education research and practice communities, this research has value in shedding light on the importance of adapting previously completed assessment mechanisms to new uses, especially if they enable students to reflect on their own progress as they measure up against aggregate data. In this study, this new instrument will empower

students to make decisions to take courses that will strengthen areas of previous weakness in the engineering leadership area. Similar methods may be extended to other programs, in order to help engineering students make the most out of their undergraduate engineering careers and experiences, teaching them self-motivation and discipline skills.

Conclusions

This study reported the adapting of a validated large-scale assessment tool for the Engineering Leadership Program at Purdue University to be used at the individual level. The tool can show an individual's score in several different factor areas, compared with the average and maximum scores from a previous study. Results can also be broken down into the individual constructs involved in the survey so that student can reflect on knowledge, skills and attributes they need to gain in order to succeed past other engineering students. Additionally, findings indicate that it will be useful to students if the instrument can recommend relevant courses at across the campus that can serve to enhance weaknesses shown in the assessment tool. Future work includes automation of the tool and large-scale testing with undergraduate engineering students in the Engineering Leadership Minor.

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