Analyzing the Existing Undergraduate Engineering Leadership Skills

Dr. Hamed M. Almalki
(halmalki@Knights.ucf.edu)
Dr. Luis Rabelo
(Luis.Rabelo@ucf.edu)
Charles Davis
(cdavis73@valenciacollege.edu)
Hammad Usmani
(hammad@knights.ucf.edu)
Industrial Engineering & Management Systems, University of Central Florida
4000 Central Florida Blvd, Orlando, FL 32816

Dr. Debra Hollister
(dhollister@valenciacollege.edu)
Psychology Department, Valencia College
1800 South Kirkman Road, Orlando, FL 32811

Dr. Alfonso Sarmiento
(alsavasquez@yahoo.com)
Universidad de la Sabana
Puente Del Comun, Chía, Cundinamarca, Colombia

ABSTRACT

Purpose: Studying and analyzing the undergraduate engineering students' leadership skills to discover their potential leadership strengths and weaknesses. This study will unveil potential ways to enhance the ways we teach engineering leadership. The research has great insights that might assist engineering programs to improve curricula for the purpose of better engineering preparation to meet industry's demands.

Methodology & Findings: 441 undergraduate engineering students have been surveyed in two undergraduate engineering programs to discover their leadership skills. The results in both programs were revealing that undergraduate engineering students are lacking behind in the visionary leadership skills compared to directing, including and cultivating leadership styles.

Recommendation: A practical framework has been proposed to enhance the lacking leadership skills by utilizing the Matrix of Change (MOC), and the Balanced Scorecard BSC) to capture the best leadership scenarios to design virtual simulation environment as per the lacking leadership skills which is the visionary leadership skills in this case. After that, the virtual simulation will be used to provide an experiential learning by replacing human beings with avatars that can be managed or dramatized by real people to enable the creation of live, practical, measurable, and customizable leadership development programs.

Keywords:

Engineering Program, Engineering Leadership Development, Simulation, Framework, Matrix of Change, Balanced Scorecard

1. INTRODUCTION

Due to the important of engineering leadership development, any engineer usually will be hired for her or his technical skills, promoted for leadership and management skills and fired with poor communication skills [1]. Engineering leadership is defined as "the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, implementing, and evaluating products, systems, or services" [2]. The Bernard M. Gordon MIT Leadership Program has developed a white paper summarizing a few of the current undergraduate programs in engineering leadership worldwide, and describing some best practices based on the success of those programs. They define leadership programs as those that develop all or a portion of the following general skill set [14].

- Initiative and decision-making
- Systems thinking
- Networking and relationship building
- Creating a compelling vision
- Teambuilding and management to completion
- Problem solving and critical inquiry.

When it comes to the definition of engineering leadership in job description, it can be said "when companies use the word leadership in a job description for full-time entry-level engineering positions, they have a primary goal to seek individuals with strong communication, teamwork, and interpersonal interaction skills" [3].

The development and coexistence of technical and leadership skills should be forefront in the training of engineering students. The interdependency of technical and socioeconomic problem solving has increased the need for engineers to also prioritize the development of their "soft or professional skills [12]. The

dilemma is that engineering curricula all over the country are not positioned to strategically address this growing challenge. Of all the various types of professional skills, leadership is of particular importance in engineering, as noted in the Engineer of 2020 vision by the National Academy of Engineering [13].

Good leadership in engineering can be the result of the application of certain skills such as communication, teamwork, planning, example-setting, result-driving, innovation-driving, and rapport-building and enablement. Addressing the concerns of the National Academy of Engineering which calls for better leadership development initiatives for engineering students, requires many strategies [13].

Crumpton-Young, McCauley-Bush [2], conducted a study to discover what the important leadership skills that are needed in the engineering industry. The study concluded that it is essential that all universities should develop a complete engineering leadership program. This program should be able to enhance many leadership skills such managing teams, critical thinking, visionary and inspirational skills, communication, and networking. Finally, the study concluded that by gaining the above skills, engineers might be able to handle the challenges of future engineering jobs [2].

When it comes to engineering programs, studies have shown they are lacking in training their students in leadership and management skills. There is a need for leaders in America to be able to overcome the many crises in leadership. Many studies have recommended that there is a necessity to modify the curriculum for the purpose of producing leaders who can bring effective results to businesses. In order to achieve this goal, an exceptional way of education must take place [4]. Engineers of the 21st century must study and practice leadership and management skills prior to graduating due to the importance of these skills [5]. In America, there is a huge need to modify the curriculum for the purpose of producing leaders who can bring practical outcomes to businesses [4]. Leadership skills are the key for progressing in the engineering profession. By earning these skills, an engineer will need to understand and successfully respond to the current global market demand. In order to achieve this goal, companies must invest in educating their engineers to be able to lead teams and combine technical skills with business understanding [1].

The risk in the leadership development process is that even though there is a significantly higher financial return on development investment (RODI) than most decision makers could imagine there might be also huge losses, from −414% to −1341%, if low quality leadership programs have been implemented [6]. It is critical that organizations invest in both development programs and in the quality of those programs [6].

1.1 Reasons for Leadership Development Failure

The traditional method of leadership development is not generating great results. Gurdjiian (2014) mentions that for year's organizations have lost tons of money on leadership development, approximately $14 billion annually. Some leadership development programs can cost $150,000 per person [7]. The Gurdjian's (2014) study identified four reasons for leadership development failure. These reasons are as follows [7]: There was no match between the leadership skills and the context at hand, the leadership development was not simulated nor embedded in real work, hesitancy in investigating the leaders' mind-sets; and there was no way to reflect the real benefits of leadership development over time.

2. CLASSIFICATION SCHEME: 4-D LEADERSHIP SYSTEM

The 4-D System has been illustrated by Pellerin in, *How NASA Builds Teams*. Pellerin has classified leadership attributes to 4 types/dimensions. The name 4-D came from this fact that there 4 dimensions that can classify individual's leadership traits. This 4-D system is based on the leadership social context. Pellerin indicated in his book that "The core idea in this book is that social contexts drive our behaviors" [8]. Pellerin describes four types of leadership styles; "blue: visioning, green: cultivating, yellow: including and orange: directing" that represent the leadership styles. Pellerin described his 4-D system contribution on leadership development to four leadership style. These styles are Blue, Green, Yellow and Orange. The emotional and sensing (also called the including dimension) depends on the emotional capabilities which come from communications and relationships with other people. ***Yellow*** is the color this dimension. The emotional and intuiting (also called cultivating dimension) encourages profound feelings and achieving a better world, and caring sincerely about other people. ***Green*** is the color this dimension. The logical and intuiting (also called the visioning dimension) relies on thinking about the potential future. Visionary leaders are influential leaders and usually create what they want. ***Blue*** is the color of the dimension. The logical and sensing (also called directing dimension) encourages taking actions and directing others. Managing, planning, organizing, directing, and controlling are some actions of this type of leadership. ***Orange*** is the color of this dimension. The 4-D Process for Leadership Development by Charles J. Pellerin, is quite similar in structure to other protocols that are presently on the market for use in personality/temperament and individual/group compatibility training. The protocols that are mostly closely aligned to the 4-D Process are the Myers –Briggs Type Indicator developed by Katharine Briggs and Isabel Briggs Myers to disseminate the logic of type theory to allow the population on whole to understand that decisions that may appear to be random acts and judgments are based on the personality type or preferences of that individual. Since the test was published in 1962, millions of people worldwide have taken this test based on Carl S. Jung's archetypes.

3. METHODOLOGY AND RESULT

3.1 4-D Leadership Test

The 4-D system leadership foundation test is used to identify the leadership style/color for undergraduate engineering students in the Central Florida area. This exam was conducted for more than 2000 workshop participants and its accuracy was better than 90% [8].The test is examining two leadership dimensions which are Innate Deciding Preference and Innate Information Preference [8].

The test has been conducted randomly for two engineering schools for total of 441 students and the results are illustrated in below tables.

Table 1. College Students in the Central Florida area, Undergraduate Engineering Students' 4-D Leadership styles Distribution, 130 Students

Blue Leaders	Green Leaders	Orange Leaders	Yellow Leaders
10%	18%	34%	38%

Table 2. University Students in Central Florida Area, Undergraduate Engineering Students' 4-D Leadership styles Distribution, 311 Students

Blue Leaders	Green Leaders	Orange Leaders	Yellow Leaders
12.5%	28.9%	28.9%	29.6%

University students in Central Florida area, 311 students have been surveyed randomly and the results are shown in the following manner:

1- Table 4- Table 9 show the percentage of the 4-D leaders per grade level.

2- Table 10- Table 14 show the percentage of the 4-D leaders per ethnicity.

Table 3. The 4-D leadership Styles per Grade Level for University Students in Central Florida area

Grade Level	Blue Leaders	Green Leaders	Orange Leaders	Yellow Leaders
Freshmen	13.7%	30.0%	26.3%	30.0%
Sophomore	8.3%	44.4%	19.4%	27.8%
Junior	12.5%	25.0%	37.5%	25.0%
Senior	11.6%	18.8%	39.1%	30.4%

The Leadership Classification Result per Gender for University Students in Central Florida Area

Table 4. The Gender Percentage of each 4-D Leadership

Blue		Green		Orange		Yellow	
F	M	F	M	F	M	F	M
17.9	82.1	27.8	72.2	24.4	75.6	34.8	65.2

Table 5. The Percentage of the 4-D Leadership Styles per Gender for the Entire Sample

Female / Population (86 students-27.7%)				Male / Population (225 students-72.3%)			
Blue	Green	Orange	Yellow	Blue	Green	Orange	Yellow
8.1	29.1	25.6	37.2	14.2	28.9	30.2	26.7

Table 6. The Percentage of the 4-D Leadership Styles in each Gender /Freshmen Year

Female/ Freshmen (57 students-30.0%)				Male/ Freshmen (133 students-70.0%)			
Blue	Green	Orange	Yellow	Blue	Green	Orange	Yellow
7.0	29.8	22.8	40.4	16.5	30.1	27.8	25.6

Table 7. The Percentage of the 4-D Leadership Styles in each Gender /Sophomore Year

Female/ Sophomore (9 students-25.0%)				Male/ Sophomore (27 students-75.0%)			
Blue	Green	Orange	Yellow	Blue	Green	Orange	Yellow
11.1	55.6	11.1	22.2	7.4	40.7	22.2	29.6

Table 8. The Percentage of the 4-D Leadership Styles in each Gender/Junior Year

Female/ Junior (1 students-6.3%)				Male/ Junior (15 students-93.8%)			
Blue	Green	Orange	Yellow	Blue	Green	Orange	Yellow
100	0	0	0	6.7	26.7	40.0	26.7

Table 9. The Percentage of the 4-D Leadership Styles in each Gender/Senior Year

Female/ Senior (19 students-27.5%)				Male/ Senior (50 students-72.5%)			
Blue	Green	Orange	Yellow	Blue	Green	Orange	Yellow
5.3	15.8	42.1	36.8	14.0	20.0	38.0	28.0

The Leadership Classification Result per Ethnicity for University Students in Central Florida Area

Table 10. The Percentage of the 4-D Leadership Styles /Ethnicity- White

Ethnicity- White Students (190 students-61.1%)			
Blue	Green	Orange	Yellow
8.9	29.5	32.1	29.5

Table 11. The Percentage of the 4-D Leadership Styles /Ethnicity- African American

Ethnicity- African American Students (21 students-6.8%)			
Blue	Green	Orange	Yellow
33.3	23.8	19.0	23.8

Table 12. The Percentage of the 4-D Leadership Styles /Ethnicity- Hispanic

Ethnicity- Hispanic Students (60 students-19.3%)			
Blue	Green	Orange	Yellow
13.3	30.0	30.0	26.7

Table 13. The Percentage of the 4-D Leadership Styles /Ethnicity- Asian

Ethnicity- Asian Students (30 students-9.6%)			
Blue	Green	Orange	Yellow
13.3	33.3	16.7	36.7

Table 14. The Percentage of the 4-D Leadership Styles /Ethnicity- Not Mentioned

Ethnicity- Not Mentioned Students (10 students-3.2 %)			
Blue	**Green**	**Orange**	**Yellow**
30.0	**10.0**	**20.0**	**40.0**

It can be noticed the (blue) visionary leadership is mainly lacking in the both engineering schools as shown below, only 10% of the college students in the Central Florida area are visionary leaders and 12.5% for the university students in Central Florida area. The (blue) visionary leadership is mostly lacking in the both engineering schools. It is not great result to conclude that the future engineers are not visionary leaders. This fact simply implies that engineering leadership is almost not existing in the undergraduate students because some researchers define engineering leadership as "Engineering leadership is the process of envisioning, designing, developing, and supporting new products and services to a set of requirements, within budget, and to a schedule with acceptable levels of risk to support the Strategic objectives of an organization" [3].

Pellerin stated that "Similarly, early phase project teams should be mostly blue. These creative idea builders perform trade studies to compare alternatives with out-of-the-box thinking." And also he indicated that "Great scientists and engineers are usually logical deciders."[8]. This indicating that engineers have to have visionary leadership skills in order to be able to perform their roles in the future tasks accurately. Innovation, creativity, critical thinking and seeing the whole picture are visionary leadership skills and without obtaining these skills, engineers will be only using their technical skills in the decisions making and strategy-creations processes and that is totally wrong approach. This finding should encourage engineering programs to invest in enhancing the visionary leadership skills.

4. CONCLUSION AND RECOMMENDATION

In conclusion, this paper has unfolded many insights about the undergraduate engineering students' leadership. The undergraduate engineering students' leadership skills are lacking behind in the visionary leadership (blue) style. This study indicated that engineering schools are not preparing their students for the visionary leadership style. This issue might reduce the creativity and innovation in the next engineering leaders. This fact simply implies that engineering leadership is almost not existing in the undergraduate students because some researchers define engineering leadership as "Engineering leadership is the process of envisioning, designing, developing, and supporting new products and services to a set of requirements, within budget, and to a schedule with acceptable levels of risk to support the Strategic objectives of an organization" [3]. To overcome the lacking engineering leadership color, we should enhance the quality of the engineering leadership development programs to allow students practice practical leadership activates based on approved leadership and managements tools.

Case studies can be used to help students understand leadership styles. A good way to analyze case studies and develop strategic plans is the following set of steps. These steps include Strengths, Weaknesses, Opportunities, and Threats (SWOT), the Matrix of Change (MOC), Balanced Scorecard (BSC), Pellerin's characterization of leadership: (4-D System) and a Virtual Simulation as explained in below Figure.

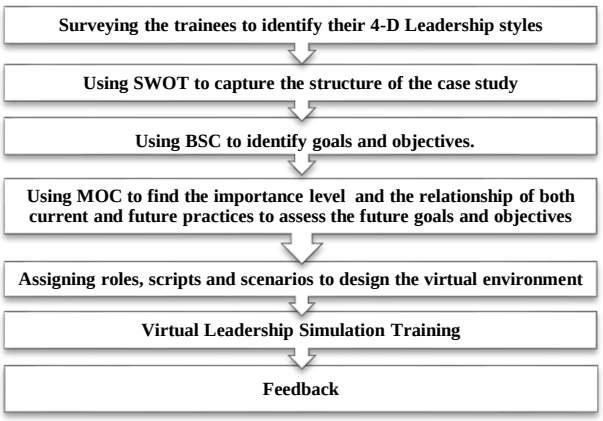

Figure 1: Leadership Development Framework

The first phase is to survey the potential engineers to figure out their leadership style/color. This survey is an essential step to understand the leadership background capability of each engineer. This phase will act as a leadership skill discovery. The second, third and fourth phase is to design a practical virtual leadership case study to be implemented in the virtual simulation phase. The first phase (SWOT analysis) is to capture the structure of the case study. The third phase is using BSC to find the ultimate case study goals in a measurable manner. The MOC in the fourth phase relies on the output of BSC to determine the importance level of leadership practices. MOC is "a visualization tool for capturing the existing and desired states of the proposed change, the complementary and opposing practices and how best to proceed in the implementation of the change" [9]. The role and scripts will be implemented in the virtual simulation environment to illustrate the case study. Companies, such as Microsoft and General Electric, have adapted the use of virtual simulation in their practices as a great tool to help in achieving the business goals [10]. In regards of using avatars as real people in simulations, it has proven that the simulation's users will automatically and unconsciously interact and deal with computers in the same way as they do towards other humans [11]. This concept has been tested and approved by scholars. In the virtual simulation phase, each trainee will be accessing the virtual leadership development world using his own designed avatar. Based on his role, he/she will make decisions, create strategies and motivate other trainees to achieve the organization goals. In the last phase, trainees will practice leadership in a virtual environment and the feedback will be evaluated accordingly. This is a good way to learn how top executives and engineering managers work in their environment.

New methodologies and modifications to the engineering curricula are required in order to bring the changes in the respective mental models. Virtual simulation has the potential to assist the curricula. However, the design of the simulated environment and the performance indicators are important issues to be studied by interdisciplinary teams.

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