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A Holistic Framework for Effective Engineering Leadership Development Using 3D Virtual World Simulation

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A HOLISTIC FRAMEWORK FOR EFFECTIVE ENGINEERING LEADERSHIP DEVELOPMENT USING 3D VIRTUAL WORLD SIMULATION

by

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ABSTRACT

Problems associated with the limited success of traditional engineering leadership development are the absence of embedded real-life industry case studies in leadership development and incorrect applications of leadership strategies in the various contexts. Though recommended programs for enhancing leadership development exist, they lack an examined framework, especially when it comes to leadership development of undergraduate engineering students. In this research effort, the impact of a framework using 3D virtual world simulation and the 4-D Leadership System to enhance the leadership abilities of undergraduate engineering students at the individual and team levels based on industrial leadership case studies was investigated. The 3D virtual world simulation was used to provide experiential learning by replacing human beings with avatars that could be managed or dramatized by real people. This framework was examined and validated by a randomized pretest-posttest control group design. Paired and two-sample t-tests revealed a significant development in the average team leadership skills of the experimental group, but no significant change occurred in the control group teams. There was a reduction in the mean of individuals' tests which indicated there was a small enhancement in an individual's leadership skills; however, the change was small and not statistically significant. Also, the administration of the 3D virtual world leadership simulation on the undergraduate engineering students had a significant effect on a team's average leadership skills. There was a small, but insignificant effect of the 3D virtual world simulation for individuals. The findings of the study supported simulation as having potential to strengthen the leadership development of undergraduate engineering students, thereby preparing them to meet industry's demands for engineering leadership.

To my entire family

for their support, love, and encouragement.

My parents, for their prayers and support throughout my life

My wife, Layan, for her love and support

My children, Eilaf, Jana, Muhammad, Ibrahim, Abdurrahman

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CHAPTER 1: INTRODUCTION

1.1 Background of the Study

In this chapter, the main problem that disrupts leadership development is identified. In addition, the benefits of using virtual simulation in education and training are addressed. Furthermore, the research objectives, potential contributions, and the research hypothesis are presented.

Leadership development has gone through several stages and practices. Even though enterprises spend exorbitant amounts in training their leaders, technological/engineering leadership development in general has not made significant strides. In this chapter, the researcher discusses the problems that contribute to the failure of engineering leadership development. The effect of leadership styles on the decision making process is extremely significant. Without effective leaders, organizations cannot achieve their ultimate goals. By reviewing the history of many companies, one learns that the inability to make correct decisions usually results in an organization's failure to choose the best strategies. Decisions usually vary from one leader to another based on many factors including context as well as the background, experience, and education of the leader. For example, Jeff Immelt has shown different leadership styles than his predecessor, Jack Welch, and Tim Cook has exhibited a style different from that of Steve Jobs (Elattar, 2014). For this reason, leadership skills are considered one of the essential traits for success in many avenues of life. Great leaders can have a very positive impact on companies. When David Maxwell became the CEO of Fannie Mae, he was able to move the company from a $1 million per day loss to one earning $4 million every day (Collins, 2001). Similarly, Darwin Smith, who became the CEO of Kimberly-Clark in 1971, transformed the company over the next 20 years, turning the company into the leading paper-based consumer products company in the world (Collins, 2001). In 1991, the cumulative value of $1 invested in Kimberly-Clark was $39.87 but only $9.81 for the General Market (Collins, 2001). The conception of leadership is said to be the “great man” theory (McCleskey, 2014).

The importance of leadership development has come from the great value and outstanding impact of leadership on the success of any organization. Leaders carry the responsibility of making difficult decisions. Because leaders are considered the face of their organizations, their impact on industry is incomparable. (Elattar, 2014).

At the time of the present study, the methods of teaching leadership for engineering students were traditional and somewhat lacking in innovation and creativity. Leadership strategies were conveyed through the traditional university structure via certificate programs, minors, and workshops, all with the same basic components: coursework, team projects, and industry experience (Crumpton-Young et al., 2010). Crumpton-Young et al. (2010) have noted a gap in the preparation of engineers with regard to leadership skills. They have confirmed that in order to ensure that future engineers are fully prepared to be great leaders, the current traditional engineering leadership development must include a holistic engineering leadership program. That program should encompass a variety of leadership skills such as the ability to control a group, critical thinking, how to be a visionary, inspirational, influential, adaptable, and action-oriented (Crumpton-Young et al., 2010). Kotnour, Hoekstra, Reilly, Knight, and Selter (2014) identified three considerations associated with this approach to leadership training: (a) having specific focus or mission; (b) targeting specific student populations to be served; and (c) providing a method of recognition to help students distinguish themselves to employers such as certificates.

In spite of all the efforts to enhance engineering leadership, engineering graduates have tended to be ill prepared in leadership (Özgen, Sánchez-Galofré, Alabart, Medir, & Giralt, 2013). Due to the failure of current engineering leadership development to equip engineering students with leadership skills, the National Academy of Engineering has suggested that engineering curricula should include all the skills needed to prepare engineering students for leadership positions (Özgen et al., 2013).

There is a potential for artificial intelligence and virtual reality to enhance engineering leadership preparation for both teams and individuals by using either agents or avatars. Avatars are controlled by humans to be virtual representations. In contrast, an agent is an acting entity that includes artificial intelligence making control by a human unnecessary (von der Pütten, Krämer, Gratch, & Kang, 2010). The difference between avatars and agents are that an agent is controlled by computer algorithms but an avatar is controlled by humans (Fox et al., 2015). Fox et al. concluded in his study that avatars are more influential in that avatars are typically perceived to produce stronger responses than agents when cooperative and/or competitive tasks are required. Fox et al. also recommended that future researchers "acknowledge that the mere perception of humanity in a digital representation can be powerful enough to amplify social responses within virtual environments." When it comes to interaction with humans in the virtual world, avatars have proven to have a higher response rate than bots and intelligent agents (Hasler, Tuchman, & Friedman, 2013). This can be important in particular for leadership education in team-based environments which are ubiquitous in engineering.

Many empirical studies recommend simulation-based education as an effective method that can enhance a students' education (Showanasai, Lu, & Hallinger, 2013). Furthermore, education that includes virtual simulation can introduce the students to real challenges in the virtual environment, allowing them to confront those challenges in both individual and team settings. Virtual worlds have been successfully employed as tools for educational, simulation and training use" (Sequeira & Morgado, 2013a). Virtual simulation has the capability to provide students with shared, simultaneous experiences and offers opportunities to open discussions. Virtual simulation encourages students to take more risks and explore while learning new ideas and techniques (Siewiorek, Saarinen, Lainema, & Lehtinen, 2012). In contrary to traditional teaching methods, virtual simulations contribute a learner-centered approach to training and this approach allows the trainees to control the learning through interaction with the virtual simulation using an active, live and interactive approach (Williams-Bell, Kapralos, Hogue, Murphy, & Weckman, 2015). Due to the educational benefits of 3D virtual world, 3D virtual simulations have been used as a method of teaching in many occupational settings, such as medicine, rehabilitation, baseball, and firefighting (Williams-Bell et al., 2015) and also in aviation training, software engineering, military and nuclear power systems training, and healthcare (Lemheney et al., 2016).

1.1.1. Effective Engineering Leadership

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" (Crumpton-Young et al., 2010). According to Farr and Brazil (2009), due to the importance of engineering leadership, engineers will usually be hired for their technical skills, promoted for leadership and management skills, and fired with poor communication skills. If future engineers are not well trained to handle team management issues, or not able to perform basic leadership skills such as motivating workers and inspiring others to accomplish the organizations goals, they will not be effective and may be replaced with more qualified leaders. Engineering leaders usually prefer to deal with problem solving issues and logical processes. However, they often need leadership and communication skills as they cultivate a leadership style that permits them to build strong relationships with employees and customers. Enhancing engineering leadership development has become more crucial to success than ever before due to the critical roles and tasks that engineers are performing in almost all enterprises.

Effective leaders are capable of acting according to the context of the opportunity at hand. Therefore, effective leaders must be well-balanced leaders with fully developed leadership skills, possessing a variety of skills and abilities to enable them to do a task well. "Every successful project team is a balanced team" (Wysocki, 2002). Team members have always been chosen based on technical skills, and other skills such as leadership, and personal skills have been ignored. According to Wysocki, there are four critical team success factors (Wysocki, 2002): (a) a balanced problem-solving capability; (b) a balanced decision-making capability; (c) a balanced conflict management capability; and (d) a balanced skill profile (i.e., diversity)

Pellerin (2009) described the effective leader as a 4-D-able leader. 4-D leaders are those who supports their innate strength with the other three leadership dimensions. "The 4-D (coordinate) System simplifies leadership into four dimensions that you must address to be an effective leader" (Pellerin, 2009). 4-D able leaders are those who have a balance of visionary, cultivating, directive, and including leadership styles. Effective leaders are also described as Level 5 leaders who combine unlimited personal humility with profound professional will. Level 5 leaders have no ego or self-interest other than building a great company (Collins, 2001).

In team leadership development, the intervention targets the team as a unit rather than individual team members. This creates the vision of team leadership development as a process where individuals are trained for their specific needs while actually carrying out their collaborative work (Overfield, 2016). Due to the importance of having effective teams in the industry, Pellerin detailed, in *How NASA Builds Teams,* the problems with the Hubble Telescope Program: “Leadership failure caused the flawed mirror in our $1.7 billion telescope.” Overfield (2016), in his research, found that under the right circumstances, team-based structures with a fast-paced and interconnected characteristic can lead to greater outcomes in a complex operating environment. Due to the essential effect of leadership on organizations, engineers must be trained to the highest level of leadership because not only are they the designers of the current and future technologies but they also manage, inspect, and create projects, tasks, and teams. Even though there are huge benefits from teams, many organizations do not gain these benefits because managers demonstrate ineffective leadership (Overfield, 2016).

At the time of the present study, leadership development in the engineering and technological industries was in high demand, and it has been considered a growing concern for the 21st century engineers. Though engineering schools have taught both technical knowledge and engineering principles to prospective engineers, they have ignored many skills such as communication, management, and leadership. This level of training has left many engineers and scientists with insufficient competencies for greater future achievements (Schuhmann, 2010). In any industry, when it comes to developing new products or services, there is a great demand for the engineers' capability to work within a team setting and, in some cases, lead groups of people from various backgrounds and cultures.

1.2 Problem Definition

Researchers have shown that postsecondary engineering programs have fallen short in inculcating leadership and management skills in their students (Kotnour et al., 2014). Engineers of the 21st century need to study and practice leadership and management skills prior to graduating (Özgen et al., 2013). Engineering leaders need to be prepared to overcome crises that occur in their organizations. In order to achieve this goal, an exceptional way of educating engineers must take place (Kotnour et al., 2014).

Many researchers in the United States have shown that there is a huge demand for leadership development and that there is a commensurate need to modify the curricula for the purpose of producing leaders who can bring effective outcomes to industries (Kotnour et al., 2014). To achieve this, at present, companies must invest in educating their engineers to be able to lead teams and combine technical skills with industry and social understanding (Farr & Brazil, 2009) as they have not obtained these skills in their college and university preparation. Leadership skills are the key for progressing in an engineering profession.

Richard, Holton and Katsioloudes (2014) observed that leadership development programs have a significantly higher financial return on development investment (RODI) than most decision makers could imagine. Richard et al. (2014) found that organizations could suffer huge losses, ranging from 414% to 1,341%, when low quality leadership programs have been implemented. The study also suggested that it is critical that organizations invest in both development programs and in the quality of those programs (Richard et al., 2014).

Because engineers usually work in teams to accomplish most of their required tasks, leadership education in engineering must consider the use of team approaches. In order to achieve leadership capabilities to satisfy the industry demand, engineers must possess the soft skills necessary to solve industry challenges. They need to be able to be effective in dealing with customer relations, making decisions, and working as members of a team (Crumpton-Young et al., 2010). It is recommended that engineering curricula should include activities that foster creativity among engineers such as collaboration in a problem and project based environment (Ibn-e-Hassan, Talib, Riaz, & Iqbal, 2014).

1.2.1 Reasons for Leadership Development Failure

The traditional method of leadership development has not generated great outcomes. In 2014, Gurdjian, Halbeisen, and Lane reported that, historically, many organizations have lost a great amount of money on leadership development, and that approximately, $14 billion annually were spent on leadership development programs. Gurdjian et al. indicated that despite the huge investment, with tuition for such programs sometimes reaching $150,000 per person, 500 managers surveyed ranked leadership development as one of their most important human resource needs. Gurdjian et al. identified four reasons for leadership development failure: (a) no match between specific leadership skills and traits to the context at hand, (b) leadership development was not embedded in real work, (c) there was a fear of questioning the leaders' mind-sets; and (d) there was no way of monitoring the impact of improvements over time.

Pellerin (2009) acknowledged that in the engineering field, the "intellectual knowledge is insufficient to create behavioral change." This research was conducted in an effort to not only put forth a solution to the current engineering leadership failure, but also to suggest innovative ways to enhance the engineering leadership development strategies and approaches by utilizing 3D virtual world simulation to visualize the real working environment. In order to design an effective virtual leadership simulation, there are certain steps that should be followed to mimic the real working environment. These steps are explained in the framework that guided this research.

1.3 Research Objectives

The main objective of this research was to enhance the quality of engineering leadership development programs by proposing an engineering leadership development framework using 3D virtual world simulation. Using this framework, the virtual environment can be carefully designed, based on a unique planning process and a classification of engineering leadership styles. The design of the virtual environment was based on a carefully selected industrial case study. The virtual environment, sometimes called the "region layer," is the environment where all virtual activity occurs and may contain a flat piece of land, an island, mountains, a plain, buildings, a combination of all of these, or simply be a vast ocean space." (Lesko & Hollingsworth, 2013). As per ISO 9000:2000 Quality Management Principle, Principle 2, "Leaders establish unity of purpose and direction of the organization. They should create and maintain the internal environment in which people can become fully involved in achieving the organization's objectives." (Cianfrani, Tsiakals, & West, 2002).

To create the virtual environment for research in engineering leadership development, the researcher selected an industrial case study approach to enable organizations to offer the best leadership development scenarios based on deeply investigated problems, current market demand, and customer voice and value. Pellerin's (2009) 4-D Leadership System was used to assess the leadership style.

As Pellerin (2009) noted, leaders with different leadership styles execute tasks differently. Thus, leadership assessment is important. There are many reasons for differences, and assessment provides the status of the leadership qualities of specific students. Leadership assessment reveals students' leadership capabilities. It shows the strength and weaknesses of their leadership styles. The second objective is to tie the engineering leadership development to real context by using Pellerin's characterization of leadership, the4-D system. Researchers have shown that some leaders do not perform well in all situations; they might lead amazingly in one situation and fail in others (Gurdjian et al., 2014). The great advantage of using the 4-D system is its skill in "improving performance within teams by changing the internal context. These processes also potentially enhance team performance across institutions by changing the context of the relationship." (Pellerin, 2009). Pellerin emphasized that the 4-D System is able to change the context, defining it as "everything, shaping the customer's perceptions of what you say and what you do." (Pellerin, 2009). Using 4-D system to quantify leadership styles enables one to visualize leadership improvement in all four leadership styles.

The third objective of this research was using the 3D virtual world simulation to achieve two major goals in undergraduate engineering students' leadership development: training leaders in several contexts in simulated working environments and having the leaders exercise real decisions in real cases in a simulated industrial environment. Combining the two can help leaders improve their contextual skills in less time and in a more authentic manner.

The fourth objective was to enhance engineering leadership development with practical steps to make the journey clearer with fewer leadership mistakes. It has been observed that 21st century engineering graduates tend to be ill-prepared when it comes to adequate leadership skills, and that places a burden on the engineers and the industries that employ them. Engineering leadership is considered "as the largest gap of all the perceived gaps in the value of the organization versus preparedness for the new BS engineers" (Özgen et al., 2013).

The final objective of the research was to validate the engineering leadership development framework. This was accomplished by conducting a randomized pretest-posttest control experiment to examine the effectiveness of the framework to enhance undergraduate engineering students' leadership preparedness.

1.4 Research Hypothesis

The basic premise of this research was that if the 3D virtual world simulation is applied to create a 3D virtual industrial environment that permits engineers to practice leadership, communication, and decision-making virtually, the participants' leadership capability may well be enhanced. The effect of the simulation was measured using the 4-D leadership test. In this research, the target was to enhance leadership styles to be fully developed in a balanced manner for both teams and as well as individuals.

The 4-D system consists of four leadership styles: emotional and sensing (yellow), emotional and intuiting (green), logical and intuiting (blue) and logical and sensing (orange). An effective leadership style is determined to exist when all the previous leadership styles co-exist in a balanced fashion. This means that all the 4-D leadership styles within an individual and a team should have close percentages with a minimum of slandered devotion as possible.

The null hypothesis and the research hypothesis for teams/individuals are as follows:

For the paired t-test, the null hypothesis and the research hypothesis for team/individual are as follows:

Null Hypothesis: H_0 : 3D virtual simulation will not enhance the leadership to become more effective.

Research Hypothesis: H_1 : 3D virtual simulation will enhance the leadership to be more effective.

Hint, Effective Leadership Indicator (ELI) is the standard deviation between the leadership styles; and the smaller the ELI the more effective the leadership is.

$$H_0 : \mu_{(ELI)after} - \mu_{(ELI)before} = 0$$

$$H_1 : \mu_{(ELI)after} - \mu_{(ELI)before} < 0$$

Where $\mu_{(ELI)after}$ denotes to the mean of ELIs posttest results team/individual. $\mu_{(ELI)before}$ is the mean of ELIs of the pretest results team/individual.

By the above test, the researcher was trying to determine whether virtual leadership simulation enhanced leadership or not. The paired t-test was used to test the null hypothesis within the same group. The independent t-test was used to evaluate the score difference between the experiment and control group.

$$H_0 : \mu_{(ELI)after} - \mu_{(ELI)before} = 0$$

$$H_1 : \mu_{(ELI)after} - \mu_{(ELI)before} \neq 0$$

1.5 Contributions

In this study, the researcher sought to identify and test innovative techniques that might be useful in improving leadership development for undergraduate engineering students. The contributions of this dissertation are as follows:

1. The framework designed for this study integrates industrial case studies with the design of a 3D virtual world simulation environment using a 4-D Leadership System classification scheme. It is the first framework that provides for a comprehensive, holistic, and practical virtual leadership development training activity. The purpose of the framework was to implement practical, customized and innovative engineering leadership development that might be of assistance to engineering schools and leadership development institutions as they strive to prepare prospective engineers for leadership roles.
2. The framework enables team leadership development for undergraduate engineering students that targets individuals as members of a team. Individuals are trained as team members and individual growth is expected for students while they are actually carrying out their assigned responsibilities as team members.
3. Wysocki (2002) emphasized the importance of four team success factors: (a) a balanced problem-solving capability; (b) a balanced decision-making capability; (c) a balanced conflict management capability; and (d) a balanced skill profile (i.e., diversity). The balanced 4-D Leadership approach implemented in this research was designed to enhance the four engineering leadership styles (visionary, cultivating,

including, and directive) so as to allow teams and individuals be able to lead different teams and projects effectively.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter contains a review of the literature and research related to the problem of this study. Numerous books, articles, websites, videos and mobile applications have been dedicated specifically to the training of future leaders. The literature reviewed in this chapter focuses on three main areas directly related to this study: (a) leadership classification systems in technical organizations, (b) engineering leadership development and team-based leadership development; and (c) the use of simulation (especially 3D virtual world simulation) in education and training.

The three major topics of this review are presented to reveal gaps in existing research. Also in this chapter, many concepts related to the engineering leadership framework are explicated to identify the benefits of prior research initiatives and the potential of the present research. By identifying the research gaps, the framework put forth in the present study is revealed as the first of its kind in this area of knowledge and important in solving current engineering leadership development problems.

2.2 Technological Leadership Classification Schemes

There are several classification schemes which have been used to understand, quantify, and measure leadership style and identify personality and leadership traits. Tremendous information can be gained about the current leadership style of the participants using tests related to these classification schemes, and they can also be used to measure the progress of leadership development for students. The most relevant of these schemes for engineering leadership development are discussed in the following subsections.

2.2.1 4-D Leadership System

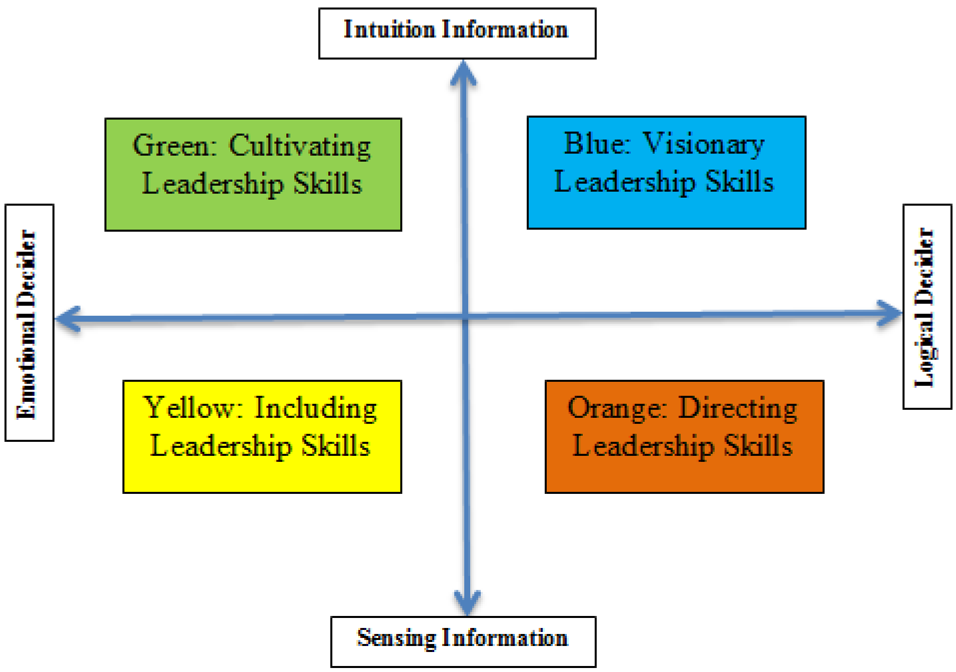
The 4-D leadership system is a great contribution in the modern leadership literature. This philosophy of leadership was developed by Pellerin (2009), a former director of the Astrophysics Division at NASA in his book about team building at NASA. His approach to innovative leadership thinking stems from his role in the Hubble space telescope crisis. The main problem with the Hubble telescope, launched in 1990, involved a flawed mirror which finally had to be repaired in space. Pellerin claimed that the root cause of this malfunction was not so much a technical issue from the contractor side but, more importantly, a failure of leadership. The nature of NASA's relationship with this contractor was so antagonistic that it prevented the contractor from reporting this technical problem (Pellerin, 2009). Pellerin was appointed to lead the Hubble repair team. Even though he successfully repaired the Hubble, he was greatly distraught at being part of the original leadership problem. He focused in his book on how to solve the problem of overlooking social contexts that many leaders commit while dealing with engineering projects.

The 4-D System illustrated by Pellerin (2009) was based on leadership social context. Pellerin indicated his principal conviction that "social contexts drive our behaviors, and hence drive a technical team's ability to perform or not." In addition, Pellerin stated that a 4-D leadership system can be used as a guide "to reduce or remove social context risk from your team." (Pellerin, 2009). Pellerin further explained that

> social (that is, relating to the interactions of people) context drives behavior and perception. Flawed social contexts cause space disasters, airplanes to crash, and

dysfunctional families. You can manage your contribution to your work and family contexts by managing your behaviors.

Pellerin illustrated four types of leadership styles as shown in Figure 1:



Source. Adapted from *How NASA Builds Teams: Mission Critical Soft Skills for Scientists, Engineers, and Project Teams* by C. J. Pellerin (2009).

Figure 1. 4-D Leadership System.

Pellerin (2009) described his 4-D system's contribution to leadership development as follows:

- Blue Leadership is the visionary style in which the leader uses his/her logical and intuiting dimension more than the other dimensions. This style relies on thinking about the potential future. Visionaries are influential leaders with a desire to create what they envision.

- Green Leadership is the cultivating style which relies on emotional and intuiting dimensions. This style encourages profound feelings, the desire to create a better world, and sincere concern for humanity.
- Orange Leadership is the directing style that drives its decisions by using the logical and sensing dimension to encourage taking actions and directing others. Managing, planning, organizing, directing, and controlling are some actions of this type of leader.
- Yellow Leadership is the including style that depends on emotional and sensing capabilities derived from communications and relationships with others.

In his book, Pellerin (2009) claimed that his 4-D leadership system contribution was validated in Kouzes and Posner's study of leadership effectiveness, conducting (a) a 1,500-person survey by the American Management Association; (b) a follow-up study of 80 senior executives in the federal government; and (c) a study of 2,600 top-level managers who completed a checklist of superior leadership characteristics. Only one question was asked: "What do you most admire in leaders?" These results were as follows (Pellerin, 2009):

- 80% of the respondents supported being an honest leader. This answer demonstrates the value of being truthful to others and relating openly with others by including them. This is a great match to the Yellow (including) leadership style;
- 67% of respondents indicated that leaders should be productive and efficient. This style of leadership best matches the Orange (directing) leadership;

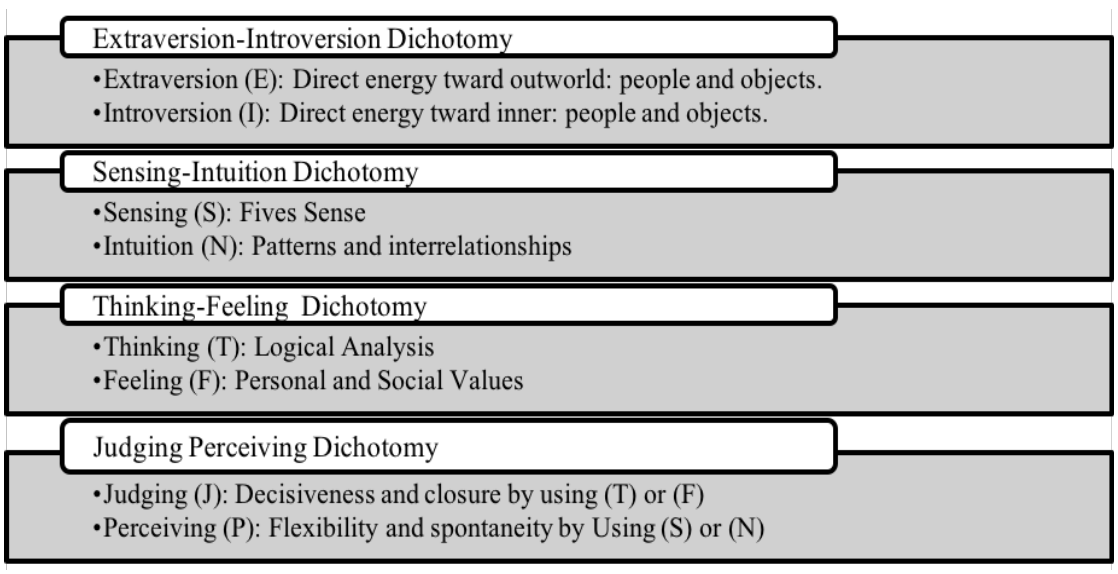
- 62% of the respondents chose the forward-looking leadership trait as the most important. This corresponds with the Blue (visioning) leadership; and
- 58% of the respondents believed an inspirational leader was the best. In this leadership style, leaders usually care about other people. This quality is a good match to the Green (cultivating) leadership style.

The 4-D Process is not a new classification tool in leadership; it is quite similar in structure to other protocols, (e.g., the Myers-Briggs), that are presently on the market for use in personality/temperament and individual/group compatibility training (D. Hollister, personal communication, December 23, 2015). Myers-Briggs Type Indicator developed by Katharine Briggs and Isabel Briggs Myers was published in 1962; millions of people worldwide have taken this test based on Carl S. Jung's archetypes (D. Hollister, personal communication, December 23, 2015). "The 4-D Process for Leadership Development by Charles J. Pellerin is also based on Carl S. Jung's innate archetypes." (D. Hollister, personal communication, December 23, 2015).

The 4-D test has been administered on numerous occasions to government agencies as well as private agencies resulting in increased productivity for managers/supervisors/employees. Also Dr. Hollister described the 4-D as a process and tool providing a good framework to introduce leadership skills training to students in an undergraduate engineering program. She expressed the belief that students must be trained in leadership to be aware of how leading teams of engineers might involve making crucial decisions that could affect many people who rely on the products and services that these engineers are responsible for implementing in the future (D. Hollister, personal communication, December 23, 2015).

2.2.2 The Myers-Briggs Type Indicator (MBTI)

Leadership styles based on MBTI personality test as shown in Figure 2, can be classified to sixteen styles. “The MBTI theory has also been applied in characterizing leadership and the personality of project managers.” (Rodríguez Montequín, Mesa Fernández, Balsera, & García Nieto, 2013). The MBTI has been shown to improve personnel management in many areas such as identifying leadership styles, training employees to work better with each other, and forming good teams (Varvel, Adams, Pridie, & Ruiz Ulloa, 2004).



Source. Adapted from *Essentials of Myers-Briggs type Indicator Assessment* by N. L. Quenk (2000).

Figure 2. The four dichotomies of Myers-Briggs Type Indicator (MBTI)

MBTI’s main purpose was to make the psychological types described by Jung clear, useful and understandable (Briggs Myers, McCaulley, Quenk, & Hammer,1985). Jung’s comprehensive theory revealed that humans use four basic mental functions and processes on a daily basis. These are sensing (S), intuition (N), thinking (T) and feeling (F) (Briggs Myers et al., 1985)

The MBTI was based on Jung's philosophy about perception, judgment and attitude (Briggs Myers et al., 1985) and that people are motivated to strive for excellence in their lives (Quenk, 2000). The Myers Briggs psychological test categorizes personalities into 16 types similar to the 4-D leadership system only in the fact that both emerged from interpreting Jung's papers (Pellerin, 2009). The MBTI 16 types vary from Jung's classification only in the priorities of Jung's functions and in the attitudes (Introversion (I), and extraversion (E) (Briggs Myers et al., 1985).

Rodríguez Montequín et al. (2013) used the MBTI to assess the success of engineering teams in project-based learning. Their final conclusion suggested that the leadership style associated with the MBTI profile of the student playing the role of group coordinator and the members' profile combinations had an influence on the group's success.

Varvel et al. (2004) conducted a study in engineering senior design class using MBTI and Team Effectiveness Questionnaire (TEQ).

They concluded that there was no statistical correlation between MBTI and TEQ. The study highlighted the importance of MBTI in training team members on the type of personality needed to help them improve communication, trust, and interdependence so as to enhance understanding and tolerance of individuals' behaviors for the purpose of increasing the team's effectiveness.

Bradley and Hebert (1997) indicated that the factors that produce effective teams are leadership and effective intra-team communication. They used the MBTI in their study, concluding that, “Personality types are an important factor in successful team performance. Organizations that desire to develop effective teams need to analyse the personality-type compositions of these groups and help team members understand” (Bradley & Hebert, 1997)

Table 1

Myers Briggs Typology Instrument (MBTI) Personality and Leadership Styles (Briggs Myers et al., 1985)

MBTI Profile	Leadership Style Description
ISTJ	ISTJ leaders are quiet, serious; earn success by thoroughness and dependability. They decide logically what should be done and work toward it steadily, regardless of distractions. They are organized and hard workers
ISFJ	ISFJ leaders are quiet, friendly, responsible, and conscientious. They are committed to their obligations. They strive to create an orderly and harmonious environment at work and at home.
INFJ	INFJ leaders seek meaning and connection in ideas, relationships, and material possessions. They motivate people and are insightful about others. They are organized and decisive in implementing their vision.
INTJ	INTJ leaders have original minds and great drive for implementing their ideas and achieving their goals. They recognize patterns in external events and develop long-range explanatory perspectives. They are skeptical and independent, and have high standards.
ISTP	ISTP leaders are tolerant and flexible, quiet observers until a problem appears, then act quickly to find workable solutions. They are interested in cause and effect, organize facts using logical principles, value efficiency.
ISFP	ISFP leaders are quiet, friendly, sensitive, and kind. They enjoy the present moment, what's going on around them. They like to have their own space and to work within their own time frame. They dislike disagreements and conflicts, and they do not force their opinions or values on others.
INFP	INFP leaders are idealistic, and loyal to their value and people. They see possibilities and can be catalysts for implementing ideas. They seek to understand people and to help them fulfill their potential. They are adaptable, flexible.
INTP	INTP leaders are quiet and seek to develop logical explanations for everything that interests them. They have unusual ability to focus in depth to solve problems. They are skeptical, sometimes critical, and analytical.
ESTP	ESTP leaders are flexible and tolerant, they take a pragmatic approach focused on immediate results. They enjoy material comforts and style. Learn best through doing.
ESFP	ESFP leaders are outgoing, friendly, and accepting. They enjoy working with others to make things happen. They learn best by trying a new skill with other people.
ENFP	ENFP leaders are enthusiastic and imaginative. They see life as full of possibilities. They make connections between events and information.
ENTP	ENTP leaders are quick, ingenious, stimulating, alert, and outspoken. They adept at generating conceptual possibilities and then analyzing them strategically. Good at reading other people.

MBTI Profile	Leadership Style Description
ESTJ	ESTJ leaders are practical, and realistic with decisive, quick decisions. They like to organize projects and people to get things done with a clear set of logical standards. They are forceful in implementing their plans.
ESFJ	ESFJ leaders are warmhearted, conscientious, and cooperative. They want harmony in their environment, work. They like to work with others to complete tasks accurately and on time. They want to be appreciated for who they are and for what they contribute.
ENTJ	ENTJ leaders are frank, decisive, assume leadership readily. They quickly see illogical and inefficient procedures and policies, and develop and implement comprehensive systems to solve organizational problems. They enjoy long-term planning and goal setting. Usually well informed, and enjoy expanding their knowledge and passing it on to others.
ENFJ	ENFJ leaders are warm, empathetic, responsive, and responsible. They attuned to the emotions, needs, and motivations of others. They may act as catalysts for individual and group growth. Loyal, responsive to praise and criticism. They are sociable, facilitate others in a group, and provide inspiring leadership.

2.2.3 Five Factor Model of Personality (FFM)

The "Big Five," or the five-factor model (FFM) of personality, is a well-known measure with a comprehensive method that has been used frequently to evaluate normal personality traits (Strang & Kuhnert, 2009). FFM's five personality dimensions are referred to as extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience (Strang & Kuhnert, 2009). Team leadership and effectiveness can be also influenced by these traits (Clinebell & Stecher, 2003). A team's leadership is very important, and a substantial number of researchers have confirmed that specific traits typically make for a good leader (Kichuk, 1999). The five personality traits identified by Strang & Kuhnert (2009) are as follows: (a) extraversion describes a leader who is active, assertive, enthusiastic, outgoing, and talkative; (b) agreeableness describes a leader who is appreciative, forgiving, generous, kind, sympathetic, and trusting; (c) conscientiousness describes a leader who is efficient, organized, reliable, responsible, and thorough; (d) neuroticism describes a leader who is anxious, self-pitying, tense, touchy, unstable, and worrisome; and (e) openness describes a leader who is artistic, curious, introspective, imaginative, insightful, original, and has a wide range of interests.

2.2.4 Bass Classification of Leadership

Bass divided leadership style into transactional leadership and transformational leadership (Nanjundeswaraswamy, 2014). Transactional leadership occurs when the relationship between the leader and the followers is based on the "trades" between the two by which followers are compensated for meeting specific goals or performance criteria (Nanjundeswaraswamy, 2014). It occurs when leaders reward or discipline followers depending on their performance (Bass, 1998). Transactional leaders depend on contingent rewards, management by exception, and laissez-faire leadership (Bass, 1998).

In contrast, transformational leaders are characterized by their individual influence, charisma, spiritual encouragement, and intellectual stimulation (Nanjundeswaraswamy, 2014). Transformational leaders use the four components shown in Table 2 to inspire followers (Bass, 1998; Brown & Reilly, 2009):

According to Brown and Reilly (2009), Bass and Avolio have developed the most valid, reliable, and widely used measure of transformational leadership, the Multifactor Leadership Questionnaire (MLQ). The MLQ utilizes the four categories of transformational leadership behavior described in Table 2, and the four subscale measures comprise the overall measure of transformational leadership (Brown & Reilly, 2009).

Table 2

The Four Factors of Transformational Leadership

Factor	Factor Description
Individualized Consideration	Gives personal attention to others, making each individual feel uniquely valued
Charismatic Leadership	Provides vision and a sense of purpose; elicits respect, trust, and confidence from followers
Inspirational Motivation	Increases optimism and enthusiasm; communicates high expectations; points out possibilities not previously considered
Intellectual Stimulation	Actively encourages a new look at old methods; stimulates creativity; encourages others to look at problems and issues in a new way

Source. Brown & Reilly (2009).

Widmann (2014) used the MLQ in his study of the impact of leadership style on the level of work engagement of knowledge workers in an engineering organization. His findings suggested that there was (a) a positive and significant correlation between the transformational and charismatic leadership and work engagement, (b) a negative correlation between laissez-faire leadership style and work engagement, and (c) no significant correlation between transactional leadership style and work engagement of knowledge workers in an engineering organization.

In comparison to the other classification schemes described, the 4-D leadership system has a clear, accurate and easy approach in evaluating the leadership. Pellerin (2009) stated that the 4-D coordinate system "simplifies the key components of high-performance teams and effective leaders." Both the 4-D system and MBTI were derived from Jung's classification of personality types. The 4-D leadership system classifies leadership using four leadership styles that can be easily evaluated. In contrast, the MBTI uses a more complex 16 styles to classify leadership and personality which is not convenient to measure progress. Another important consideration in selecting an assessment system is that it accurately can assess the engineering and technological leadership for teams and projects. 4-D has the ability to select the best leader for any engineering project team. Dr. Anthony J. Calio, former vice president and general manager of the Raytheon Corporation, stated:

> The 4-D assessment methodology, honed through 15 years of teambuilding with NASA project, engineering, and management teams, has the potential to improve team performance in almost any enterprise. This book emphasizes the importance of understanding cultural norms and social behaviors which are often overlooked in technical projects, and yet can play a critical role in their success. (Pellerin, 2009)

Also, Pellerin reported that the 4-D system has been used for more than 2000 workshop and its accuracy is more than 90%.

2.3 Engineering Leadership Development

Due to the vast importance of engineering leadership to current and the future graduate engineering students, many researchers reflected the need to enhance engineering programs with leadership development. The National Academy of Engineering (NAE) emphasized, in *The Engineer of 2020: Visions of Engineering in the New Century*, the importance of current and future engineering graduates possessing leadership skills needed to solve business and industry challenges. The book encouraged engineers to expand their knowledge and experience in the leadership area:

> engineers must understand the principles of leadership and be able to practice them in growing proportions as their careers advance. . . . In the past those engineers who mastered the principles of business and management were rewarded with leadership roles. (National Academy of, 2004).

Companies that hire engineering leaders look for "individuals with strong communication, teamwork, and interpersonal interaction skills" (Hartmann & Jahren, 2015). Hartmann and Jahren presented three definitions for engineering leadership that were used frequently in the literature. The first definition is 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". The second definition is "the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, implementing, and evaluating products, systems, or services" The third definition describes engineering leadership as "the technical leadership of change: the innovative conception, design and implementation of new products/processes/projects/materials/molecules/software/ systems, supported by the invention of enabling technologies, to meet the needs of customers and society" Hartmann and Jahren concluded in their study that when companies post job descriptions seeking engineers with leadership skills for full-time entry-level engineering positions, they are usually seeking individuals with strong communication, teamwork, and interpersonal interaction skills. They also noted that construction and electrical engineering companies often seek engineers who have conflict resolution skills as an additional leadership skill in interpersonal interactions.

Farr and Brazil (2009) wrote that due to the importance of engineering leadership, engineers usually will be hired for their technical skills, promoted for leadership and management skills and fired with poor communication skills. Unfortunately, though leadership skills have been viewed as the key to advancement in an engineering career, engineering programs have shown that they are lacking in developing leadership and management skills in their students. By obtaining these skills, engineers will be connected with their co-workers internally and customers externally and be better able to adapt to the current demand for outsourcing and global competition. Companies committed to maintaining a competitive edge, according to Farr and Brazil, are investing in educating their engineers to be able to lead teams and combine technical skills with business insights.

Farr and Brazil (2009) explored the nature of engineering in a globally competitive environment and explained why leadership must be a key issue in the professional development of engineers. In their research, Farr and Brazil presented a literature review of leadership models as well as solutions for promoting leadership skills as part of the career development process. They presented recommendations on how to nurture leadership attributes in the engineering profession. They reviewed three major publications in field of engineering education in the last 50 years: The Grinter Report, The Green Report (1994), and Educating the Engineer of 2020 (National Academy of Engineering or NAE, 2005). The Grinter Report focused on the foundation of modern engineering education, (e.g., mechanics of solids, fluid mechanics, thermodynamics, transfer and rate mechanisms, electrical theory, and nature and properties of materials). The report argued that these areas should be included in all engineering curricula. At the time of the present study, this more than 50-year-old report remained unchanged as the guideline for modern engineering education and accreditation. Both the Green Report and The NAE emphasized many leadership skills such as team communication, ethical reasoning, and commitment to quality, timeliness, continuous improvement and societal and global contextual analysis skills as well as comprehending work strategies. Farr and Brazil stated that "Unfortunately, many of these skills have been taught under the guise of senior design while the basic and engineering sciences advocated by the Grinter Report have remained literally unchanged in engineering curricula for over 50 years." This highlights one of the weaknesses of 20^{th}- (and now 21^{st}-) century engineering education. Farr and Brazil have recommended the assessment-challenge-support model for engineers to increase leadership capacity. They recommended three ways to enhance engineering leadership as follows.

- Developing leadership skills: In academia, students need to include leadership in most projects such as senior design project. Engineering schools have to encourage team building, communications, and inviting leadership coaches to inspire students as well as encourage faculty to recognize and promote leadership in students.
- Mentorship/on-the-job training: In this phase, management should invest in training young engineers in leadership through activities such as participation in important public or private meetings, development of soft skills and be rewarded for their efforts. Young engineers should also be encouraged to develop personal and professional development plans. Furthermore, management should provide young engineers with feedback to help them sustain their leadership development progress.

- Self-actualization: This phase will help most senior engineers to be great leaders by continuing to improve their leadership skills. Most engineers are successful because they have shown both technical excellence and leadership ability.

Froh (2003) examined how well the undergraduate degree program in the Electrical Engineering and Computer Science Department (EECS) at the Milwaukee School of Engineering (MSOE) prepares engineers for future visionary leadership positions. He found that the course descriptions and syllabi included minimal use of specific words related to visionary leadership. Students surveyed indicated the opposite; students' responses showed an appreciation for the value for visionary leadership.

At the time of the present study, leadership was considered one of the main factors in industry and crucial to any organization's existence. This makes leadership development essential in any industry (Laglera, Collado, & Montes de Oca, 2013). In their 2014 study, Gurdjian et al. surveyed 500 managers, asking them to rank the human resource department's main concerns. Leadership development was ranked the highest and mentioned as a future priority.

Engineering schools have been putting forth strong efforts in teaching students both the technical knowledge and engineering theories required of engineers in the real world. Schuhmann (2010) expressed the belief that these types of skills and their competencies were no longer sufficient for future achievement. Many skills such as communication, project management, and leadership are becoming more important than ever. Schuhmann described an amazing contribution in engineering leadership field which is the academic model of the Engineering Leadership Development Minor (ELDM) at Pennsylvania State University.

To support Penn State's ELDM leadership model, Schuhmann argued that when it comes to developing new products, there is a great demand for the engineers' capability to work and lead groups of people from various backgrounds and cultures. Also it was noted from leaders' experiences in the field that the future opportunity for engineers lies in their ability to exercise their leadership skills in many different areas. These areas include nonprofit and government sectors. This responsibility, however, has more relevance for graduate engineering students (Schuhmann, 2010). Schuhmann also emphasized that it is important that 21st century engineers be better prepared in leadership than their 20th century counterparts.

The demand for jobs has changed, and that puts pressure on the education system to make changes in order to keep up with the market demand. The market demand has been changing due to changes in companies' traditional structure. Companies are no longer operating in one region nor manufacturing their products under one ceiling. Rather, different parts of the product are often designed in different countries by different teams. Assembly of the final product occurs once all parts are shipped to one location in the world. The accounting and financing processes sometimes dictate that companies move their production lines to different countries to reduce labor costs. There is a huge need for leaders in America to be able to overcome many crises in leadership. Numerous researchers have identified a need for curriculum modification for the purpose of producing leaders who can bring effective results to businesses. In order to achieve this goal, changes in education must take place (Kotnour et al., 2014).

One of the interesting studies in engineering leadership conducted by Olude-Afolabi (2011) revealed some facts about engineering leadership definitions compared to those of the industry. Olude-Afolabi (2011) used a system technique that classified different definitions of leadership through the use of text mining by collecting data from industry trade journals and then using fuzzy similarity to classify different expressions used in the description of leadership. Olude-Afolabi (2011) suggested "that the more terms used by journals were classified by engineering academia as having more leadership terms in defining leadership when compared to industry." He used the following leadership terms: communication, motivation, team–building, visionary, coaching & mentoring, time management, listening and innovation. Also this study showed that in the industry, the combined leadership concepts and management concepts was much higher than the combined terms in engineering academia regarding the classification of documents. Olude-Afolabi (2011) suggested that industry understanding of the needed skills and engineering academia should prepare engineering graduates for the workforce by defining leadership as a combined term.

Cox, Cekic, and Adams (2010) findings regarding undergraduate engineering leadership development were based on interviews with 12 engineering faculty at a Midwestern university about ways that leadership might be incorporated into engineering curricula. Their findings suggested integration of leadership topics into current courses and in capstone courses. They also recommended the introduction of real-life experiences, activities, and extracurricular activities in students' leadership development.

Caza and Rosch (2014) examined undergraduate students from all majors who had never had leadership training, investigating their preexisting beliefs about leadership. Their findings can be used effectively to design curricula to meet the students' needs and levels of understanding. The researchers found that students believed that leaders needed to serve their communities, to be open-minded, to honor their values, and to be comfortable with change. Also students' responses were predictive of several leadership outcomes, including leadership self-efficacy, social change behavior, and perspective taking. These findings suggest the value of better understanding students' preexisting beliefs about leadership.

In Laglera et al.'s 2013 study, 301 engineers completed a web survey. The result was a structural equation model that comprehensively showed a significant and positive relationship exists between transformational leadership style and all the factors selected for the present study: specifically, job satisfaction; job performance; organizational commitment; person-organization values congruence; and trust in leadership.

Bayless (2010) described one leadership program, the Robe Leadership Institute (RLI), located at Ohio University's Russ College of Engineering and Technology. The RLI is a 10-week, four-hour course that has been offered in the fall of each academic year. RLI helps engineering students form a base for their leadership styles and helps them understand the various roles involved in being an engineering leader. RLI introduce leadership training to students through the followings activities: selection of students, leadership readings, speaker invitations, seminar structure and learning outcomes, class assignments and activities, guest speakers, and outreach.

In their study, Cox, Cekic, Ahn, and Zhu (2012) conducted interviews to explore the views of engineering experts in industry and academia on leadership, change, and synthesis. The main purpose of their research was to identify constructs that engineers in academia and industry use to describe characteristics they consider important for undergraduate engineering students to possess. They discovered some differences in the views of industry and academic experts. They indicated that due to the fact that academic and industrial tracks for engineering students are serving a common cause, the different views should be studied to enhance education of undergraduate students.

2.3.1 Team-Based Leadership Development for Engineering Students

In their study, Özgen et al. (2013) showed that the engineers of the 21st century need leadership and management skills prior to graduating due to the importance of these skills. In this study, authors stated five reasons which demanded an inclusion of leadership development in engineering curriculum. These reasons are as follows (Özgen et al., 2013).

1. There is a need for leadership skills in engineering field.
2. Leadership is the largest gap in the value of organization.
3. Engineering research consultants regularly seek engineering managers with leadership skills.
4. The National Academy of Engineering (2004) suggested that engineering curricula should provide education that prepares engineering students for leadership positions.
5. Leadership skills cannot be accomplished by adding more subjects to an already full curriculum.

This study, conducted in The Chemical Engineering Department of The Universitat Rovira I Virgili in Tarragona, Spain, was implemented in a Project Management in Practice (PMP) course (an elective for fourth-year engineering students). The following leadership skills were tested to evaluate leaders' performance: (a) client orientation, (b) commitment to learning, (c) drive for excellence, (d) integrity, (e) interpersonal communication, (f) responsiveness to change, and (g) teamwork. The methodology of this study was conducted by the following steps: A total of 11 fourth-year engineering students were selected to participate in a year-long experimental study. Each leader was assigned a team of six first-year engineering students (SD = 1.98). Two data collection strategies were employed: (a) behavioral event interview technique querying participants and PMP course professors about self, team, organization, for an average of 46 minutes (SD = 9.11); and (b) a 360-degree feedback process consisting of a questionnaire about the eight competencies administered to all respondents and leaders. The questionnaire had a Likert-type scale ranging from 1 to 5 where 1= not developed and 5=excellent.

Özgen et al. (2013) discovered that the majority of leaders demonstrated leadership behaviors at the team leadership level more than at the self and organizational levels. In addition, they exhibited leadership competencies in the areas of commitment to learning, interpersonal communication, teamwork, and results orientation. In contrast, they did a poor job in integrity, drive for excellence, responsiveness to change, and client orientation skills. The researchers speculated that the lack of success in these competencies could be attributed, in part to several constraints: (a) the experiment was not a real-world experience; (b) the environment was not client-driven; (c) leaders did not have real responsibility.

Another interesting team-based leadership development study for undergraduate engineering students was conducted by Babuscia, Craig, and Connor (2012). It focused on developing leadership activities to improve the productivity of teams in a short time period (approximately four hours). This experiment consisted of a leadership module to enhance engineering leadership by conducting multiple activities designed to improve students understanding of leadership education. Their experiment was implemented in a Massachusetts Institute of Technology (MIT) satellite development class (Babuscia et al., 2012). Table 3 provides an overview of the leadership module including the duration of activities and the objectives of each of the activities. As can be seen, the Babuscia et al. (2012) leadership model is a normal model used in providing traditional leadership development, (i.e., questionnaire and leadership lectures) in an organized fashion. The results of this experiment indicated that this approach improved the ability of students to interact productively with each other.

Table 3

Overview of the Leadership Module

Activity	Duration	Objectives
Introduction and Initial assessment	20 minutes	To introduce leadership instruction; To investigate students' questions on leadership.
First lecture (interactive leadership discussion)	60 minutes	To summarize concepts on team formation, team roles and responsibilities, meeting planning, team contract, decision making, facilitating communication, project planning; To answer student's questions on leadership; To show students a practical example of distributed leadership model; To show students different leadership styles.
Leadership questionnaire	30 minutes	To understand team leader challenges and accomplishments during the development of the project; To understand team member challenges and accomplishments during the development of the project; To investigate team leaders' abilities of understanding the perception that their team members have of them; To understand team members' perception of their team leaders; To collect feedback on previous leadership activities; To investigate students' interest in future activities.
Peer to peer review	20 minutes	To learn how to evaluate their own work and the work of their peers.
Second lecture (analysis of leadership questionnaire)	80 minutes	To summarize concepts on leadership definitions, engineering leadership, approaches to leadership, distributed leadership, capabilities of effective engineering leaders, leadership styles and situational leadership; To analyze students' perception on team leaders and team members inside their team.
Student's feedback	10 min	Each student logs in the class evaluation website; Each student rates the statements on leadership education.

Source. Adapted from *Teaching Practical Leadership in MIT Satellite Development Class: CASTOR and Exoplanet Projects* by Babuscia et al. (2012).

In a first-year and senior-year engineering design course that consisted entirely of team-based collaborative learning projects, Rosch (2015) examined the effect of team experience when isolated from other structured leadership curricula to determine if it could support student leadership development. This study was designed only to investigate whether undergraduate engineering students' leadership could be enhanced when students engaged in classroom-based team experiences. The findings of this study suggested that only first-year students reported higher scores at the end of the semester and only in regard to their transformational skills and social normative motivation. Senior students made no gains in any leadership-oriented area as related to their team experiences. Rosch concluded that "The results provide an initial indication that simply placing students into teams, in which they possess motivation to succeed and must act interdependently, may not be enough to accelerate the development of their leadership capacity." He also confirmed that "Without a space for intentional practice informed by content knowledge, simply placing students in an environment in which they engage in goal-oriented group behaviors seems insufficient as a catalyst for leadership development." (Rosch, 2015)

Rodríguez Montequín et al. (2013) investigated team-based undergraduate engineering. Their objectives were to study and analyze the effects of the personality traits on team effectiveness. Rodríguez Montequín et al. (2013) used the MBTI to assess the success of engineering teams in project-based learning. The research suggested that the leadership style associated with the MBTI profile of the student playing the role of group coordinator and the members' profile combinations had an influence on the group's success.

Varvel et al. (2004) conducted another study in engineering senior design class using the MBTI and the Team Effectiveness Questionnaire (TEQ). The researchers concluded that there was no statistical correlation between the MBTI and the TEQ. They highlighted the importance of the MBTI for individuals in their training on the type of personality of team members. They determined this could help them improve communication, trust, and interdependence to enhance understanding and tolerance of individuals' behaviors for the purpose of increasing a team's effectiveness.

A research team (Crumpton-Young et al., (2010) from the University of Central Florida (UCF) set out to study leadership skills for both senior engineers who had leadership positions and had worked in the leadership field for many years and for engineering students who were currently enrolled in their undergraduate programs. The purpose of the research was to discover important leadership skills that were needed in industry.

The study revealed that the participants believed that team-building/teamwork, personal development/continual learning, and communication skills were the most useful factors in a leadership position. Furthermore, the surveys helped rank the leadership characteristics the participants felt they possessed. The participants ranked characteristics such as being honorable, credible, and determined as the most useful. Being visionary or networking were ranked as the least useful.

Crumpton-Young et al. (2010) also asserted that it is essential that all universities develop a complete engineering leadership program to enhance skills such as the ability to control a group, critical thinking, how to be a visionary and inspirational, a good communicator, and an effective networker. Finally, the researchers concluded that by gaining the previously mentioned skills, engineers might be able to handle the challenges of future engineering jobs (Crumpton-Young et al., 2010).

The researchers concluded that engineers of 2020 have to be ready to work with diverse teams of engineers and non-engineers, communicate with multiple audiences, and achieve synergy between technical and social systems. Systems-based engineering problems are always associated with an increasing scale of complexity, and typically, engineers need to pursue collaborations with multidisciplinary teams of experts across multiple fields. One of the essential characteristics for these teams is excellence in communication (National Academy of Engineering, 2004). Working effectively with multicultural teams is a future requirement that will surely continue to grow in importance as systems engineering becomes more ubiquitous (National Academy of Engineering, 2004).

Reeve et al. (2015) described a multifaceted leadership learning program that was designed by a collaborative team of researchers with backgrounds in engineering, education, psychology, and industry. The goal of this program was infusing reflective, experiential learning into technical oriented discipline. The program covers four dominions of leadership corresponding to four levels of analysis: self, team, organization, and society. Also the learning experiences include many activities such as elective academic courses, co-curricular workshop programs, and guest lectures in core courses.

Simpson, Evans, and Reeve (2012) described the Engineering Leaders of Tomorrow Program (LOT). LOT recognized academic courses, co-curricular certificate programs, departmental programs, and workshops which emphasize four domains of leadership: self, relational, organizational, and societal leadership.

2.4 Using Simulation in Education

The usage of simulations and games began in the 1950s. Since that time, the use of simulation has increased exponentially in education (Showanasai et al., 2013). Simulation is the representation of the elements of a dynamic system for the purpose of trying to reproduce the behavior of that system. According to Life, Narborough-Hall, and Hamilton (1990), the early knowledge of this behavior enables developers to install the right modifications to the design (Life et al., 1990).

The make-believe environment is a concept reflecting the possibility of emulating the real environment in both structural and dynamic behavior aspects of real settings to create a laboratory equivalent to reality, and this laboratory becomes a learning substitute for the real environment (Pappo, 1998). After that, the simulated environment can be used to learn how to gain and perform skills through practice, acquiring information and using it in stages such as step-by-step learning (Pappo, 1998). In order for the make-believe environment to be useful, the real context of the skill must be provided to resemble both the structural and dynamical reality of the skill and its environment (Pappo, 1998).

Simulation models reflect how one thinks about real environment behavior as well as its dynamics. Building a computer simulation requires relating two functions: modeling and programming. The modeling function contains some concepts such as system analysis and equation settings, and the programming function refers to the process of writing the computer codes (Pappo, 1998). In a computer-based simulation, there is an excellent learning environment because of the multimedia nature which can present very realistic information-loaded settings such as multi-sensory experience for users to be able to practice the targeted skills (Pappo, 1998).

Simulation is an experimental educational process whereby an individual can simulate any situation to mimic the environment or interaction (Putman, 2013). The word simulation is usually applicable for educational purposes. Simulation can be defined as several activities where the best solution for some problem can be found and identified. When it comes to using simulation in research, there are huge benefits. When using simulation, the analytical approach is made simpler in order to answer various research questions in any field of study for the purpose of drawing an accurate conclusion. Without using simulations, researchers might not be able to answer the research questions carefully, accurately, practically, and morally (Cheng et al., 2014).

Showanasai et al. (2013) viewed the purposes of simulation as mainly to handle extremely important tasks (e.g., enhancing complex applied competencies in decision making, enhancing teamwork, fostering skills in higher order thinking and reflection, and learning to use knowledge as a tool for problem solving).

In the current curricula in many universities, students have not had the chance to handle the complexity of real challenges. However, education that includes simulation would introduce real challenges in the environment to students and make them confront those challenges in both individual and team settings. Simulation has the capability to help students share the same experiences and offers opportunities to open discussions. In their study, Siewiorek et al. (2012) investigated whether participation in business simulation gaming sessions could enhance graduate students' leadership, providing them with experiences beneficial for the development of leadership skills. They found that simulation encouraged students to take risks and explore for the sake of learning new ideas and techniques (Siewiorek et al., 2012)).

2.4.1 3D Virtual Simulation

Virtual simulation is a 3D simulation that takes place in a virtual environment which allows users to socialize, connect and create using free voice and text chat. An example of this environment is Second Life (Putman, 2013). Putman investigated the impact of conflict management tactics as well as learning styles on the efficacy of virtual leadership development training. He concluded that virtual simulations can be good experiential learning tools for adult learners to practice the leadership competency of conflict management. Putman used virtual leader (vLeader) in his study. "vLeader is one of the most advanced virtual simulations and was therefore a good choice for this study" (Putman, 2013).

The vLeader simulation is an intelligent-avatar, developed by Simulearn Inc. which was designed to allow participants to practice their relationship building and influencing skills in a realistic gaming environment (Elattar, 2014). In vLeader, students practice and learn skills such as verbal and nonverbal communication, gain and use of influence, team building and collaboration, motivation and persuasion (Sidor, 2007). In this software, "students, given the opportunity to practice different leadership styles in a safe environment, can practice strategies and tactics in the appropriate exercise of power and influence as they maneuver an idea to completion in this virtual world" (Sidor, 2007). The central principle of the vLeader mechanism for leadership interaction in organizations is through business meetings (Sidor, 2007).

The vLeader simulation is comprised of five modules that simulate meetings with different tasks and increasingly complex scenarios to be explored for each module (Putman, 2013). The virtual leader approach for leadership is that "Through these meetings, leaders practice the art of leadership as they attempt to influence characters to produce the right work to further the goals of the organization" (Sidor, 2007). In such meeting settings, participants interact and communicate only with the intelligent avatar (whose name is Oli) not with other real people through avatars. When interacting with Oli, a participant has five options: (a) support/oppose an idea; (b) support/oppose a person; (c) be neutral about an idea or ask a question; (d) do nothing–listen; and (e) switch topics–refocus the conversation.

There is a potential for solutions implementing artificial intelligence and virtual reality to enhance the soft skills such as engineering leadership for both teams and individuals by using either an agent or an avatar. Avatars are controlled by humans to be a virtual representation of them. An agent is an acting entity that includes artificial intelligence making the control by a human unnecessary (von der Pütten et al., 2010). Thus, the difference between an avatar and an agent is that agents are controlled by computer algorithms, and avatars are controlled by humans (Fox et al., 2015).

Fox et al. (2015) concluded in their study that avatars were more influential in that they have been perceived to produce stronger responses than agents when cooperative and/or competitive tasks are required. These researchers also observed that researchers should "acknowledge that the mere perception of humanity in a digital representation can be powerful enough to amplify social responses within virtual environments." When it comes to interaction with humans in the virtual world, avatars have proven to generate a higher response rate than bots and intelligent agents (Hasler et al., 2013). This can be important in particular for leadership education in team-based environments which are ubiquitous in engineering.

Callaghan, McCusker, Lopez Losada, Harkin, and Wilson (2009) investigated how virtual worlds can be integrated to create learner-centered experiential-based learning experiences in the area of engineering education. They also demonstrated the tracking and subsequent recording processes of user interactions in the virtual world. Their conclusion was that it is possible to integrate the relative strengths of virtual learning environments and the immersive/highly interactive nature of virtual worlds to produce great learning experiences for students. Also it is relatively easy to track, record, and evaluate users' interactions and movements inside virtual worlds.

von der Pütten et al. (2010) identified two main studies (the Ethopoeia concept and the Threshold Model of Social Influence concept) in which the role of behavioral realism in explaining the social influence of virtual characters was discussed. Both studies compared avatars and agents (agent-avatar paradigm).

The Ethopoeia concept is a phenomenon that permits individuals to naturally and unconsciously respond to computers in the same way they do to other people (von der Pütten et al., 2010). The human brain developed a long time ago when only real human and real places existed. In that time, human beings were able to show social behavior in a real environment. In dealing with daily life, the human brain creates automatic responses. Therefore, humans still automatically accept both people and places as real. This automation of response takes place socially and naturally because the characteristics of media or the situations remain real in this process. Thus, by the absence of a significant warning, the human brain continues to accept media as real people and places (von der Pütten et al., 2010).

The Threshold Model of Social Influence concept relies on a function called social verification. This function contains two factors: behavioral realism and agency. These factors are considered to be continuous factors fluctuating from low-to-high in both agent behavioral realism and avatar behavioral realism. The Threshold of Social Influence concept is only possible when the level of social verification is sufficiently high.

When the factor agency is high (i.e., when the user knows that the virtual character is a representation of a human being), then the factor behavioral realism does not have to be high in order for social verification to take place and for social effects to occur. (von der Pütten et al., 2010)

von der Pütten et al. (2010) engaged in empirical research to compare the two concepts and to determine which was more accurate in explaining the effect on the human behavior component in dealing with the virtual world. They concluded that "the Ethopoeia concept by Nass and Colleagues is more suitable as an approach to explain the social effects we found than the Threshold Model of Social Influences by Blascovich and colleagues" (von der Pütten et al., 2010).

In 2014, Lin and Wang explored the effects of the human behavior component, people's behavioral patterns, and their major motivations for avatar creation in the virtual world. They found that (a) 73% of users had multiple (1 to 16) avatars; (b) 35.6% of the participants reported making their avatars look like another species or non-organic creatures; and (c) 93.4% of the users had a main avatar interact with others in the virtual world, at least sometimes, if not most of the time. Lin and Wang (2014) identified four major motivations for users to create their avatars in the virtual world: virtual exploration, social navigation, contextual adaptation, and identity representation. Figure 3 illustrates the ability of avatars to take on an almost real human appearance.

Figure 3. An example of an avatar appearance in the virtual world

Leaders have recognized the importance of virtual simulations in education. They have found that it helps in reducing the cost and time in preparing future leaders with little complexity. Conine (2014) noted that numerous researchers have recommended simulation-based education as an effective method of enhancing students' educational experiences. Education that includes virtual simulation can introduce students to real challenges in the virtual environment, allowing them to confront those challenges in both individual and team settings. Virtual simulations can also imitate the actual operations of a business and require workers to interact with their leaders using remote communication. Companies such as Microsoft, Dell, and General Electric have recognized the usefulness of these practices. Examples were the joint effort of Microsoft and TRI Corporation to create experiential learning by developing their first virtual business simulations. They recognize the benefits in helping meet the companies' goals (*Virtual Leader Leadership Styles Workbook*).

Due to the educational benefits that can be derived, virtual simulations have been used as a method of teaching in many occupational settings, such as medicine, rehabilitation, baseball, and firefighting (Williams-Bell et al., 2015). Virtual world simulation is used in aviation training, software engineering, military and nuclear power systems training, and healthcare (Williams-Bell et al., 2015). Some virtual world platforms used are Second Life, OpenSimulator, Active Worlds, and Onverse (Lemheney et al., 2016). Virtual world simulation uses the virtual world such as Second Life or OpenSimulator to simulate the real life scenario and allow trainees to practice in live, virtual and interactive settings using avatars to represent the real people.

Virtual reality is the presentation of the computer-generated data in a way that those who use it perceive the presentation as having similar characteristics of a recognized world (Lemheney et al., 2016). Due to the important role of virtual simulation in education, Lemheney et al. (2016) have used 3D virtual simulation in their study as a novel way to recreate high-risk medical scenarios targeted for office-based emergencies.

Showanasai et al. (2013) defined the virtual world as the "simulated environments with digital resemblance of animated actors and their physical surroundings where they can engage in interactive activities through computer-generated tools." Virtual simulation has the capability to provide students with shared, simultaneous experiences and offers opportunities to initiate discussions that might otherwise not occur. Virtual simulation encourages students to take more risks and explore while learning new ideas and techniques (Sequeira & Morgado, 2013a). The virtual world is a form of simulation where via the internet the real world can be simulated in a three-dimensional, computer-based, immersive environment such as the 3D virtual world of Second Life (Siewiorek et al., 2012). The simulated 3D virtual world environment provides opportunities for a user's interaction with the 3D simulated environment and with other users simultaneously in the environment via a user's avatar (their virtual alter ego) along with other features such as text-based chats, voice-based chats or movement between different simulated geographical areas. This allows users to express themselves very differently than they might in the physical world (Hudson, Taylor, Kozachik, Shaefer, & Wilson, 2015). Simulations developed in 3D virtual worlds, sometimes called virtual world simulations or virtual reality simulations, offer trainees many advantages in their learning process such as being able to safely make and identify their mistakes. Providing them with the same experience in a live real-world situation would be difficult due to cost, time constraints, and ethical considerations (Cruz-Benito, Therón, García-Peñalvo, & Pizarro Lucas, 2015). In their study, Cruz-Benito et al. (2015) introduced serious games and virtual simulation applications that may be utilized for training in the fire service.

In 3D virtual world simulated environments, users participate and interact using avatars (Williams-Bell et al., 2015). "The avatar is a digital representation through which the user interacts with and relates to others in the virtual environment" (Lin & Wang, 2014). Hooi and Cho (2014) tested a research model, exploring the effect of perceived avatar-self similarity on self-disclosure via different theoretical constructs such as self-awareness, self-presence, and identifiability. Results indicated that avatar similarity can impact self-disclosure, but the effect is mediated by variables of identifiability, self-awareness, and self-presence.

In their research, Kahai, Jestire, and Huang (2013) examined the effects of interventions, transactional and transformational leadership on cognitive effort and outcomes during collaborative learning within a virtual world. Their found that transformational leadership increased cognitive effort, and transactional leadership reduced it.

Once researchers were able to design an accurate computer simulation, it became possible to create a form of virtual reality (Chorafas & Steinmann, 1995). Thereafter, only well-designed simulation software would be needed to imitate any real-case scenario.

The real-world perception can be obtained by combining sophisticated 3D graphics with virtual reality (Siewiorek et al., 2012). Chorafas and Steinmann (1995) discussed the ways in which virtual solutions can enhance concurrent business and engineering processes. They elaborated on the importance of the interaction between simulated and real facts and the combined positive impact of a 3D visualization, a real time response, and interaction in 3D in bringing real-world experience to a laboratory setting for improved learning.

The development of virtual world environments began with the use of computer gaming. The use of such software has since shifted toward online social networking sites (Chorafas & Steinmann, 1995). Even though there is still not enough research-based knowledge to show the impact of games on leadership training, the current studies have shown that simulation games can enhance learning related to complex problem-solving as well as provide outcomes and feedback in real time (Lesko & Hollingsworth, 2013). “Simulation game is a simplified simulated experiential environment that contains enough verisimilitude, or illusion of reality, to include real-world-like responses by those participating in the exercise.” (Siewiorek, Gegenfurtner, Lainema, Saarinen, & Lehtinen, 2013). Also, simulation gaming can be used widely in the training of leadership and other professional skills that require working environments (Showanasai et al., 2013).

Virtual worlds have been effectively used as tools for educational, simulation and training purposes (Siewiorek et al., 2013).

> Virtual worlds are synthetic, computer-generated simulated environments where user interaction is usually made through avatars, that is, an element of the simulated environment which embodies the human user. These may normally assume a textual or graphical form, including full three-dimensional (3D) representation. (Sequeira & Morgado, 2013a)

In this project, OpenSimulator (OpenSim) was used to simulate undergraduate engineering students' leadership environments. It is similar to Second Life (2013). OpenSim and Second Life are both 3D graphical settings where users' access is through the web in a form of graphical representation of an avatar that can walk, fly, drive a vehicle, and teleport to simulated environments to engage in all kinds of activities (OpenSimulator, 2014). Communication is not only synchronous and asynchronous. The virtual environment can also be dynamically changed by all users to build within it (Alrayes & Sutcliffe, 2011). Avatars can interact with each other freely as well as join other groups; they can buy land, build homes, and sell their products to other users of the program (Alrayes & Sutcliffe, 2011).

OpenSim is an open source that was developed by and a group of enthusiastic volunteers. By using Linden Lab's released code of their client application, the communication protocol was reverse engineered, and that contributed to the creation of OpenSim which is a simulator that mimics the working in Second Life Grid and allows Linden Lab's own 3D viewer to be used to create and visualize content in a similar way to Linden Lab's grid (Lesko & Hollingsworth, 2013). Linden Lab created and maintained many virtual worlds such as Second Life (Sequeira & Morgado, 2013b).

OpenSim is a platform used to operate a virtual world environment. It supports multiple independent virtual regions that are connected to a single centralized grid, and it can be used to create a private grid that remains accessible only within a finite network infrastructure (Alrayes & Sutcliffe, 2011). The advantage of OpenSim is that it can be run by Windows and Linux-based operating environments as well as and it supports both MySQL and MSSQL database technologies. The Primary coding for OpenSim is developed using C# with a .Net framework (Lesko & Hollingsworth, 2013).

Linden Scripting Language (LSL) is a simple language, similar to Java, which allows users to attach behaviors to an object. The programming code is compiled into an executable file. This file is then run within a virtual machine inside the simulator. (Sequeira & Morgado, 2013b).

OpenSim can be deployed on any computer able to run Microsoft and the content can be saved and restored using an XML-based file format known as Open Archive (OAR). OpenSim is mostly used by researcher to build stand-alone projects which are often inaccessible by the general audience. (Brashears, Meadows, Ondrejka, & Soo). Both Second Life and OpenSim use the exact same viewers and present the same 3D contents. The only major differences are that OpenSim is a free and open source server-side application which can be installed on any computer to run a personal virtual world. OpenSimulator-based grids are run by independent commercial operators and are not interconnected with the Second Life Grid (Sequeira & Morgado, 2013b).

The working space or region in OpenSim is the visible, virtual working space where the avatars interact. It is a square piece of virtual landscape that can be further developed to contain such topologies as deserts, mountains, roads, houses, lecture halls, oceans, and other virtual space (Sequeira & Morgado, 2013b). Multiple regions then construct what is typically referred to as a grid. The advantage of the grid is the provision of organizational structure to the many regions by managing the relative position of each region within the virtual world and also managing such services as permissions, inventory and user access (Lesko & Hollingsworth, 2013). The virtual environment, sometimes called the region layer, “is the environment where all virtual activity occurs and may contain a flat piece of land, an island, mountains, a plain, buildings, a combination of all of these, or simply be a vast ocean space.” (Lesko & Hollingsworth, 2013).

A virtual setting is different than the traditional setting that take places in a tangible facility such as a classroom or a workplace where the interaction happens face-to-face. It is the setting that happens in an indefinite space of the internet and face-to-face interactions are absent (Lesko & Hollingsworth, 2013). In virtual settings, organizations use virtual teams due to the substantial opportunities gained by teaming, and workers are connected virtually. An obvious example of this is that companies are literally working around the globe and also around the clock. The secret ingredient behind the tremendous benefits of virtual worlds is simplicity, accuracy, and availability of virtual technology. “Virtual teams depend on technology” (Lueke, 2004). Technology provides the linkage of participants’ ideas and information as well as the environment in which participants coordinate activities and build bond of trust (Lueke, 2004).

Virtual teams mainly use the technology to communicate with each other. They use digital media to communicate and manage their work. In virtual teams, at least one of the team members should be located in a different place or in a different time zone (Lueke, 2004). Virtual teams in a global business simulation are small groups who manage their work with electronic communication (Krumm, Terwiel, & Hertel, 2013). Virtual teams are individuals or groups who work remotely using a mixture of communications and technologies to perform their tasks (Conine, 2014). Team members interact and manage their tasks using the technology without the need of meeting face-to-face as in traditional settings.

Some engineers consider a virtual team as a great option in dealing with day-to-day work activities due to the fact that working from home is a relief from choosing clothes, finding parking spaces, being exposed to air pollution and facing daily traffic. Others who found the virtual team not to their liking complained about loneliness, being disconcerted, and a lack of project visibility (Phillip & Johanna, 2008).

The virtual team must be built based upon understanding the limitations of the virtual team and technology. By embracing this understanding, the team will be able to ignore the disadvantages of the method of communication and focus on the team's goals (Phillip & Johanna, 2008). Kimble (2014) suggested that virtual leaders and teams should use their skills, behaviors, and habits to bridge what he called the "virtual gap" and try to eliminate the impact of being separated by enhancing collaboration and communication. In addition, he offered some recommendations to close the "virtual gap." During the start of the team formation, team members should meet face-to-face to build relationships and learn about team members' capabilities. Also, the members should share electronics and internet websites in order to enhance team cooperation and openness. He suggested choosing communication technologies that are suitable for and agreeable to all team members and rotating the time of virtual meetings in order for each member to have a good meeting times and bad meeting times (Lepsinger, 2012). “As virtual simulations continue to evolve, many of their challenges--from leadership issues to communication limitations--will be resolved through advances in technology and as younger generations grow into leadership roles” (Lepsinger, 2012).

2.5 Research Gaps

The literature and research reviewed in this chapter was associated with engineering leadership development. Relevant topics were research efforts in engineering leadership development, team-based leadership development for engineering students, 4-D leadership system and other classification schemes, and the use of simulation (especially 3D virtual world simulation) in education and training. A major gap was identified in the literature in that there was no comprehensive study of engineering leadership preparation for undergraduate students with real industry cases that could be used and implemented in team-based classroom settings.

Due to the great importance of teams, most, if not all, organizations use some form of team-oriented work; and more than 90% of higher-level managers ranked teamwork to be central to organizational success (Morgeson, DeRue, & Karam). The first gap in this area was that team-based leadership development for undergraduate engineering students was lacking in traditional leadership development programs in that there was a lack of real life examples to allow engineering students to experience real life leadership challenges.

Traditional leadership development has not been found to be an effective way of developing leadership. Özgen et al. (2013) identified weaknesses in his competency-based educational model for leadership development in a team-based leadership development setting. He attributed his lack of success in fostering development to factors such as a lack of reality, a non client-driven environment, and that leaders had no real responsibility. His model was conducted in the classroom, and real clients were absent from the classroom environment. To address this problem, the real client expectations could be enhanced by transforming current integrated design projects into real industry settings (Özgen et al., 2013). In the present research, the framework was based on well-designed 3D virtual world simulation environment and the industry and customer-orientation settings were intended to resolve the problems identified in Özgen et al.'s research.

Rosch (2015) examined the effect of team experience without introducing any structured leadership curricula. He concluded that, "The results provide an initial indication that simply placing students into teams, in which they possess motivation to succeed and must act interdependently, may not be enough to accelerate the development of their leadership capacity." He also confirmed that "Without a space for intentional practice informed by content knowledge, simply placing students in an environment in which they engage in goal-oriented group behaviors seems insufficient as a catalyst for leadership development." This means that team activities that occur in a traditional curriculum typically have a minimum impact on leadership enhancement for undergraduate engineering students.

Babuscia et al. (2012)'s leadership model using a questionnaire and leadership lectures was based on traditional leadership development. In addressing the first gap (i.e., a lack of team-based engineering leadership development for undergraduate engineering), there has been no demonstrated way to teach it (with the respective consequences). The second gap is that the 3D virtual world simulation provides a potentially comprehensive environment that has not yet been exploited in a systematic manner to enhance the leadership development for undergraduate engineering students Also, having the virtual environment designed based on industrial case studies so as to represent real industry, thereby allowing engineering students to visualize, interact and lead based on a simulated virtual industry environment was not yet explored in the literature.

The third gap was identified in comparing the various classification schemes. The most complete system was found to be the 4-D leadership system. The 4-D system was originally designed to detect the leadership failures in engineering and technological teams along with the unique classification of leadership styles that always appear in engineering projects. As per Pellerin (2009), engineers can be classified using four categories of leaders: (a)visionary; (b) directing; (c) including; and (d) cultivating. Pellerin demonstrated that leaders can act differently due to their previous leadership styles and that having a leader with a different leadership style than appropriate for a project. He stated that the 4-D coordinate system "simplifies the key components of high-performance teams and effective leaders." The 4-D system and MBTI were derived from Jung's classification of personality types. 4-D leadership system classify leadership to four leadership styles that can be easily evaluated. In contrast, MBTI classifies leadership and personality to 16 styles which was inconvenient to measure progress in this study. Another important consideration regarding choice of leadership system is its ability to accurately assess the engineering and technological leadership of teams. The system should have the ability to select the best leader for any engineering project team. According to Pellerin, a former vice president and general manager of the Raytheon Corporation, stated:

> The 4-D assessment methodology, honed through 15 years of teambuilding with NASA project, engineering, and management teams, has the potential to improve team performance in almost any enterprise. This book emphasizes the importance of

understanding cultural norms and social behaviors which are often overlooked in technical projects, and yet can play a critical role in their success.

Thus, not using the 4-D system in the undergraduate engineering leadership development was a second identified gap. 4-D systems classification has been used in the engineering and technological with great success and have, according to Pellerin (2009), an accuracy rate of almost 90% in predicting the leadership style of a leader. It also has the ability to classify the strength of the leadership style from 4-D able to 1-D able to show the possible range of improvement for each leader's leadership style. The 4-D system can easily identify effective leaders in a practical and meaningful way. The leaders who are 4-D able, meaning they can lead with four leadership styles (i.e., visionary, directive, cultivating and including), are considered effective leaders. The classification allows one to easily and accurately identify weak leadership styles and improve them based on the 3D virtual leadership simulation scenarios.

The fourth gap was identified based on confirmation in the literature review that there was no established and validated framework that could assist undergraduate engineering students in improving their leadership skills. The literature of engineering leadership was revealing in that the contributions to this important field were rare and limited. The efforts of prior researchers can be classified as either contributions that merely highlighted the importance of leadership development in the engineering curriculum or suggested improving existing engineering skills. An example of that was Özgen et al.'s (2013) suggestion that stronger engineering leadership skills are needed in the workplace compared to those required in prior years. Other research efforts indicated the need for leadership in general but did not present specific solutions based on tested and validated frameworks. For instance, the work of

Crumpton-Young et al. (2010) presented the model of the Engineering Leadership Development Minor (ELDM) at Pennsylvania State University. Due to the lack of prior specific methodology and frameworks that might guide engineers in developing their leadership engineering skills, the framework put forth in the present research will fill a gap in this area of research and literature.

Table 4 shows some of the primary research articles studied as part of the review of literature and research. As reflected in the table and summarized in this review, there are great benefits in using virtual simulation to educate and train professionals and students, but no studies have been conducted utilizing virtual simulations to enhance undergraduate engineering students' leadership development. The researcher aimed to develop a framework and provide a fresh approach to enhance and elevate engineering leadership development for undergraduate engineering students. Figure 4 shows the research gaps that were addressed and the contribution to engineering leadership training that was made in the present research. Using the 4-D leadership system, the 3D virtual world simulation in team-based engineering leadership development made this dissertation's framework unique in its approach to improving the preparation of undergraduate engineering students.

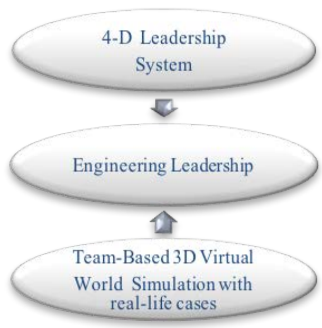


Figure 4. Study framework: Addressing research gaps in engineering leadership

Table 4

Engineering Leadership Literature Gaps

Researchers	Technological Leadership Classification Systems	Virtual Simulation			Engineering Leadership Development for Undergraduate Students		
		Avatar	Agent	Other	Team	Individuals	Others
Study Research Framework	4-D	√			√	√	
Schuhmann, 2010						√	
C. Pellerin, 2009	4-D						
Hartmann & Jahren, 2015					√	√	√
Farr and Brazil, 2009							√
Froh, 2003							√
Özgen et al., 2013					√		
Kotnour, Hoekstra, Reilly, Knight, & Selter, 2014							√
Crumpton-Young et al., 2010					√	√	√
Olude-Afolabi, 2011							√
Babuscia, Craig, and Connor, 2012					√		
Cox et al., 2010							√
Caza and Rosch, 2014						√	
Varvel, Adams, Pridie, and Ruiz Ulloa, 2004	MTBI					√	√
Elattar, 2014			√			√	
Rosch, 2015					√		
Rodríguez Montequín et al., 2013	MTBI				√		
National Academy of, 2004					√	√	
Laglera et al., 2013							√
M. Anderw Life, 1990				√			
Pappo, 1998				√			
Bayless, 2010							√
Cox, Cekic, Ahn, and Zhu, 2012							√
Putman, 2013			√				
Showanasai et al., 2013				√			
von der Pütten et al., 2010		√	√				
Fox et al., 2015		√	√				
Hasler et al., 2013		√	√				
Lin & Wang, 2014		√					
Conine, 2014				√			
Sequeira & Morgado, 2013		√					
Hudson et al., 2015		√					
Cruz-Benito et al., 2015		√					
Williams-Bell et al., 2015		√	√				
Hooi & Cho, 2014		√					
Lemheney et al., 2016		√					
Chorafas & Steinmann, 1995				√			
Siewiorek et al., 2012				√			

Researchers	Technological Leadership Classification Systems	Virtual Simulation			Engineering Leadership Development for Undergraduate Students		
		Avatar	Agent	Other	Team	Individuals	Others
Lesko & Hollingsworth, 2013		√					
OpenSimulator, 2014		√					
Kahai, Jestire, & Huang, 2013		√					
Callaghan, McCusker, Lopez Losada, Harkin, and Wilson, 2009		√					
Alrayes & Sutcliffe		√					

CHAPTER 3: METHODOLOGY

3.1 Introduction

In this chapter, the research methodology is presented to convey the building blocks used in the development of this research. All of the research design procedures ranging from the initial general research idea to the detailed methods of data collection, analysis, and validation are presented to illustrate the research flow that has been utilized in this study. A clear methodology is expected to achieve the goals and the objectives of this contribution to the engineering leadership development field of study.

3.2 Research Methodology

The research originated from a concern about the failure of engineering leadership development to achieve its goals. This concern brought forth more concerns such as using the best technological and engineering leadership classification scheme for quantifying engineering leadership development efforts. This idea evolved into more noteworthy methods during the researcher's review of the literature and related research. Due to a mere handful of peer reviewed articles and several books concerning engineering leadership and the lack of a solid solution for the current engineering leadership development failure, the problem is likely to remain, and more money will be wasted on ineffective traditional leadership development. The next step in the research methodology, the literature review, revealed an obvious gap. In this step, it was identified that engineering leadership development lacks a tangible leadership development method that depends on an innovative and practical solution. The research methodology shows that this research is the first of its kind in the engineering leadership body of knowledge and it can be applied to any real-life industrial case study to enhance the leadership of undergraduate engineering students in a practical and nontraditional way of training. Figure 5 displays the process used to transform the initial general research idea into logical steps to tackle the research problem.

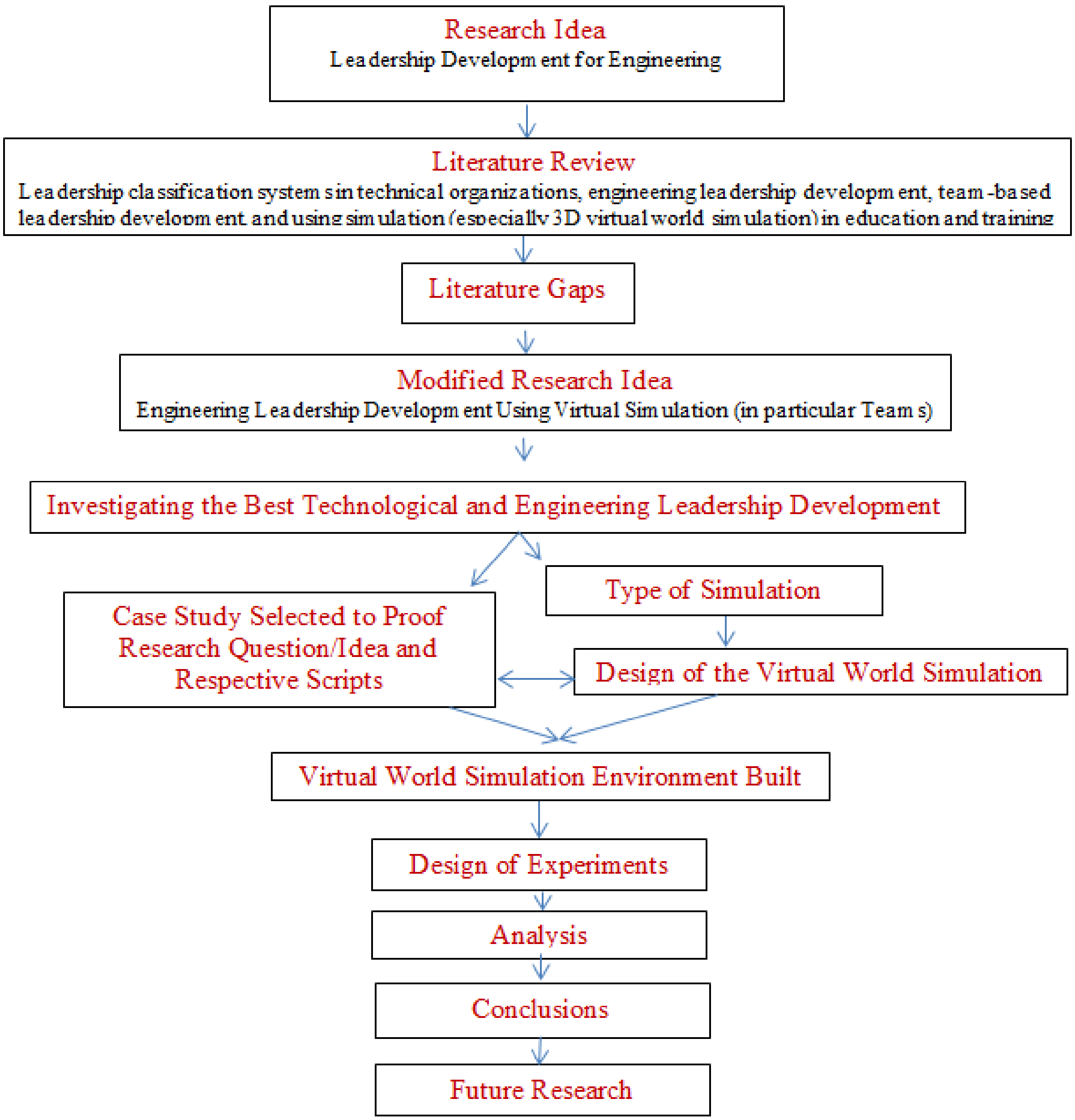


Figure 5. Research design diagram

3.3 Research Idea

The original research challenge was to find solutions for the engineering leadership failures presented by Gurdjian, Halbeisen, and Lane (2014). These researchers found that for some time, organizations have spent approximately $14 billion annually on leadership development. Gurdjian et al. surveyed 500 managers, requesting that they rank their most important human resource in the future. Leadership development was ranked one of the highest (Gurdjian et al., 2014). Gurdjian et al. (2014) identified the following four reasons for leadership development failure:

1. There was no match between specific leadership skills and traits to the context at hand;
2. The leadership development was not embedded in real work;
3. There was a fear of questioning the leaders' mind-sets; and
4. There was no way of monitoring the impact of improvements over time.

3.4 Literature Review

Engineering leadership development efforts have not been as well served as have other leadership development initiatives. Though there have been efforts to develop leaders in traditional leadership areas, there has been a lack of attention to engineering leadership. In the literature review, I focused on three main areas directly related to this dissertation: (a) leadership classification systems in technical organizations; (b)engineering leadership development; and (c) team-based leadership development, using simulation (especially 3D virtual world simulation) in education and training. By presenting the literature review in these areas, the research gaps have been identified. Furthermore, literature review proved that this contribution is not only the first of its kind in this area of knowledge but also highly needed to solve the current engineering leadership development problems.

<u>3.5 Research Gaps</u>

After analyzing and reviewing the literature, four major gaps in the literature and related research were found. The first gap was that there were very few reports of team-based leadership development for undergraduate engineering students, and those identified lacked real life examples to allow engineering students to experience real life leadership challenges. In this dissertation, a team-based approach has been utilized to ensure that students exercise their leadership by creating a company in the virtual world with mission, vision, and goals.

The second gap was identified through a comparison of classification schemes. The most complete system is the 4-D leadership system. The 4-D leadership system was originally designed to detect the leadership failures in engineering and technological teams but also to address the unique classification of leadership styles that always appear in engineering projects. Engineers, according to Pellerin (2009), can be classified using four types of leadership: (a) visionary; (b) directing; (c) including; and (d) cultivating; and leaders can act differently due to their previous leadership style. The 4-D system has been used, with almost 90% accuracy, in predicting the leadership style of leaders of engineering and technological. It also has the ability to classify the strength of the leadership style from 4-D able to 1-D able to show the potential range of improvement that could occur in leaders' styles. The 4-D system can be used to easily identify effective leaders in a practical and meaningful way. The leaders who are 4-D able, (i.e., they can lead with four leadership styles--visionary, directive, cultivating and including), are considered to be effective leaders. The classification allows one to easily and accurately identify a weak leadership style and improve it based on the 3D virtual leadership simulation scenarios.

The third gap was discovered in the literature review. No studies were found concerning the utilization of 3D virtual world simulations for enhancing the undergraduate engineering students' leadership development, in particular, team-based development. The literature review also revealed that there are great benefits in using virtual simulation to educate and train professionals and students.

The fourth gap identified was in the lack of a framework other than the traditional teaching format, (i.e., regular lectures and reading assignments). Alternative frameworks have not been tested or validated.

3.6 Modified Research Idea

Though there is an abundance of literature related to leadership, in a general sense, the researcher learned through the literature review process that engineering leadership has not been explored by other researchers. Engineers have contributed countless extraordinary contributions to society. 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" (Crumpton-Young et al., 2010). Leading teams of inventors to accomplish certain goals is not easy and cannot be taken for granted. Extensive, specialized and focused leadership training must be provided in order to enhance the preparation of engineering students to include leadership skills and attributes.

Specifically, in conducting the literature review, the researcher determined that the engineering leadership body of knowledge lacks a clear and practical methodology compared to other types of leadership. Generally, engineering leadership development has not been served well in academia, as there is no innovative and validated framework that is dedicated to training engineers to improve their leadership skills based on real industry cases and in teams. Simulation can provide the backbone to build this new framework.

Engineering leadership is crucial and highly needed to be able to be effective in dealing with customer relations, making decisions, and working as members of a team (Crumpton-Young et al., 2010). One of the critical success factors for team members and team leaders is having a balanced set of personal, management, and leadership skills (Wysocki, 2002). Therefore, the key is balanced leadership and also team-based development.

3.7 Investigating the Best Technological and Engineering Leadership Development

There are several leadership classification assessment schemes that can be used to discover and measure the leadership style. The main objectives of obtaining the leadership styles for engineering students are to understand their leadership background and be able to scale their current leadership style. Four leadership classification schemes were investigated in the literature review:

- 4-D Leadership System
- The Myers-Briggs Type Indicator (MBTI)
- Big Five Personality Traits
- Bass Classification of Leadership

3.8 Types of Simulation

Simulation was used in this project as a tool to enhance preparation in engineering leadership. Simulation is an experimental educational process where an individual can simulate any situation to mimic the environment or interaction and a great tool for education and training (Putman, 2013). Cheng et al. (2014) expressed the belief that without using simulations, researchers might not be able to answer research questions carefully, accurately, practically, and morally. Showanasai et al. (2013) recommended simulations as extremely important to enhancing (a) complex applied competencies in decision making and (b) teamwork.

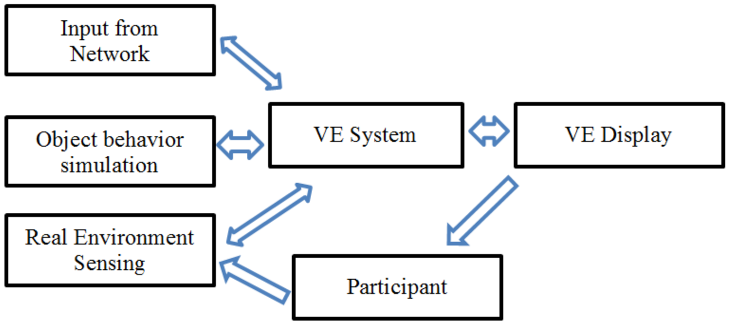
There are different types of simulations such as discrete event simulation, agent based simulation, system dynamic simulation and virtual world simulation. For the present study, it was important to have teams working together to achieve certain engineering goals. Thus, the virtual environment that mimics real life using avatars as virtual representations was found to be the best type of simulation to be used in developing engineering leadership in undergraduate engineers.

Virtual world is a form of simulation where, via the internet, the real world can be simulated in a three-dimensional, computer-based, immersive environment such as the 3D virtual world of Second Life (Hudson et al., (2015). There are many names are being used interchangeably with virtual reality such as virtual environment, artificial reality, and virtual worlds (Bamodu & Ye, 2013) and multi-user virtual environment (MUVE); massively-multiplayer online game (MMOG); immersive virtual world (Girvan, 2013).

The simulated 3D virtual world environment provides opportunities for a user's interaction with the 3D simulated environment and with other users simultaneously in the environment via a user's avatar (a virtual alter ego) along with other features such as text-based chats, voice-based chats, or movement between different simulated geographical areas. This allows users to express themselves very differently than they might in the physical world (Cruz-Benito et al., 2015).

Virtual world simulation was selected for use in this research due to its having been successfully employed as tools for educational, simulation and training use (Sequeira & Morgado, 2013a). Virtual simulation has the capability to provide students with shared, simultaneous experiences and offer opportunities to open discussions, and it also encourages students to take more risks and explore while learning new ideas and techniques (Siewiorek et al., 2012). 3D virtual worlds offer trainees many advantages in their learning process. They are able to safely make and identify their mistakes in simulated settings, gaining the same experiences as they would in a live real-world situation without the difficulties due to cost, time constraints, and ethical considerations (Williams-Bell et al., 2015).

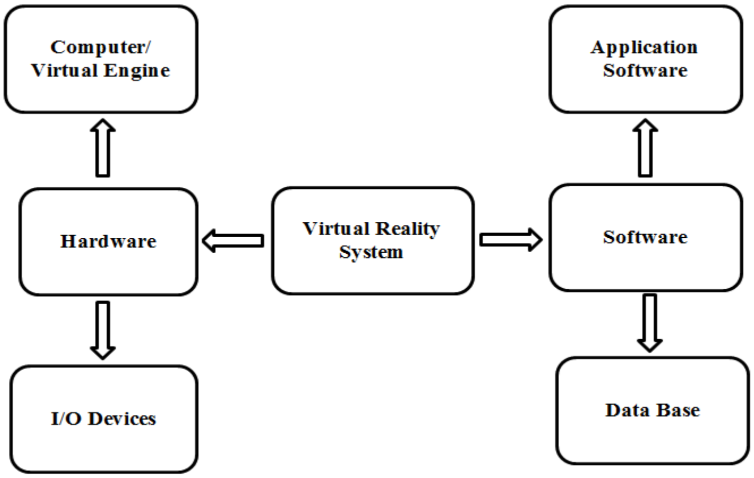
Virtual environment is the synthetic sensory experience that communicates abstract components to a participant, and it is the intersection of three environments: visual environment, auditory environment and haptic/kinaesthetic environment (Tolga, Capin, Magnenat-Thalmann, & Thalmann, 1999). The system where multiple geographically distant users are interacting in common virtual environment is called Networked Virtual Environment [NVE] (Tolga et al., 1999). Figure 6 presents a graphic display describing the integrated NVE where NVE provides an input and receives output from a participant. The participant is a real person who is participating in NVE with an avatar (Tolga et al., 1999).



Source. Adapted from Tolga et al. (1999).

Figure 6. Integrated networked virtual environment (NVE).

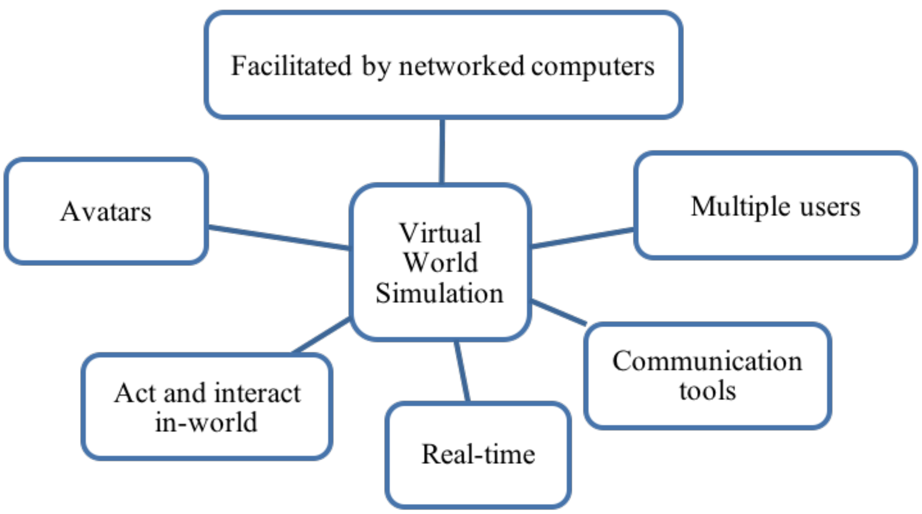
Figure 7 provides a graphic representation of a virtual reality system. The hardware components include the computer virtual reality engine and I/O devices; the software consists of the application software and database (Bamodu & Ye, 2013). The input devices provide the means by which users interact with the virtual world. The output devices extract feedback from the virtual reality engine and pass it on to the users to stimulate the senses. A virtual reality engine is a computer system that has to be selected according to the graphic display and image generation, user, I/O devices, and level of immersion (Bamodu & Ye, 2013).



Source. Adapted from Bamodu & Ye (2013).

Figure 7. Components of virtual reality systems

Virtual reality system software is a set of tools and software that used to design, develop and maintain virtual environments and the database (Bamodu & Ye, 2013). The features and characteristics of the virtual world simulation are displayed in Figure 8.



Source. Adapted from Girvan (2013).

Figure 8. Virtual world simulation features and characteristics

Virtual world architectural solution contains four key components: (a) a simulated environment; (b) an end-user client; (c) a collection of collaborative resources available from within the virtual world environment; and (d) a network infrastructure to captures and supports the virtual world solution (Lesko & Hollingsworth, 2013). The main differences between 3D graphics and virtual world are shown in Table 5 (Chorafas, 1995) .

Table 5

Comparison of 3D Graphics and Virtual World Features

Components	3D Graphics Features	Virtual World Features
Agents	Agents are passive and nonexistent	Agents are active and participating
User Participation	User is a spectator	Presence and role playing can be immersive or not immersive
Multimedia	Mainly graphics with text	Full multimedia such as sound and other stimuli
Data Feed	Still images (online or batch)	Online real space with wide bandwidth and live images
Networking	Deferred or online	Networked solution with no time delay with wide bandwidth and gig stream desk area networks (DAN)

Source. Adapted from Chorafas (1995)

There is a potential for solutions implementing artificial intelligence and virtual reality to enhance the soft skills such as engineering leadership for both teams and individuals by using either agents or avatars. Unlike Virtual Leader, an intelligent-avatar developed by SimuLearn for leadership environment (Elattar, 2014), the 3D virtual world is a simulation where the real world can be simulated in a three-dimensional, computer-based, immersive environment such as Second Life (Hudson et al., 2015). Virtual world is a simulated 3D virtual world environment which provides opportunities for a user's interaction with the 3D simulated environment and with other users simultaneously in the environment. This occurs via a user's avatar along with other features such as text-based chats, voice-based chats or movement between different simulated geographical areas, allowing users to express themselves very differently than they might in the physical world (Cruz-Benito et al., 2015). In the 3D virtual world simulation, users access the game through the web in a form of graphical representation of an avatar that can walk, fly, drive a vehicle, and teleport to simulated environments to engage in all kinds of activities. Due to these characteristics of the 3D virtual simulation, the virtual environment must be designed according to the simulation objectives.

3.9 Case Study Selected to Proof Research Question/Idea and Respective Scripts

Using a case scenario approach to building the virtual leadership environment makes an experiment a powerful tool to mimic the real business world and affords students a logical, enjoyable and meaningful leadership activity time. The selected industrial case study was required to have the following features:

1. Technological- and engineering-based
2. Can be conducted in team-based setting
3. Covers multi-engineering disciplines concepts
4. Logical, simple and appealing to meet the students' educational level

5. Customer-based case study that represents a future demand by the current customers
6. Has room for innovation and creativity

3.10 Design of the Virtual World Simulation

After successfully obtaining the scripts based on the case study selection and analysis, and identifying the best simulation type as well as the best leadership classification scheme for engineering students, the design of the virtual world simulation took place using a series of steps which are described in the following section. To achieve the researcher's main objective, to enhance the engineering leadership development, the design of the simulation needed to be carefully implemented to reflect both the case study characteristics and the needed leadership style.

3.11 Building the Virtual World Simulation Environment

In this step, the 3D virtual world simulation software was selected that would be used to implement the case study scenarios. Using this software enables virtual simulation environment scenarios to be built not only to mimic the real-life example but also to match a logical and step-by-step leadership approach to allow students who finish their leadership simulation activities to achieve certain leadership goals. The virtual world leadership simulation selected for this research was validated by three engineering management professors, a psychology professor, a virtual world design artist, and the team leaders to ensure that the virtual world simulation activity was effective as a virtual means of developing engineering leadership in undergraduate engineering students.

3.12 Design of Experiments

In order to examine the effectiveness of the 3D virtual world simulation in enhancing engineering leadership development, the design of experiment, both experimental and control group are carefully selected through a randomization process. In this experiment, the experimental group's leadership style was tested. After that, it was subjected to the experimental treatment (the 3D virtual world simulation) and then observed again. The control group's leadership style was also tested, and the group was isolated from any influence of the treatment. Instead, the control group received instruction using traditional engineering leadership development methods (i.e., lectures, reports, and presentations). Students in the control group worked in teams, preparing and presenting a leadership industrial case study. This type of design is very accurate in detecting the effects of the treatment and also enables researcher to avoid two issues associated with experimental design: (a) determining whether a change has taken place after the treatment and (b) eliminating confounding variables.

3.13 Analysis

Validating the effectiveness of the researcher's approach to enhancing engineering leadership can be achieved by checking and testing the research hypothesis (i.e., to examine if the 3D virtual world simulation is able to create a 3D virtual industrial environment that permits engineers to practice leadership, communication, and decision-making virtually). In this study, the participants' leadership capability may well be enhanced. The effect of the simulation was measured using the chosen leadership classification scheme. Statistical analysis tests were used to examine the null hypothesis to evaluate the differences between scores of the experimental and control groups and also between the teams within each group.

3.14 Conclusions

After completing all the experiment steps and procedures and having students conducting the 3D virtual world leadership activity, conclusions were drawn based on the results of the virtual world leadership experiment. The results were further discussed to confirm the feasibility of the 3D virtual world simulation in enhancing the engineering leadership development for undergraduate engineering students and also provide suggestions for future research.

3.15 Future Research

Because of this study, subsequent researchers should have a clearer vision in expanding the development of engineers as leaders, using improved techniques and efficient approaches. This experiment has, however, been limited by time constraints and resources available. There is always room for enhancement; research is always evolving, and many new ideas may generate greater results.

3.16 IRB Approval

Prior to initiating this research (i.e., pretest leadership assessment), the proposal for the research was reviewed and approved by the Institutional Review Board (IRB) of the University of Central Florida (Appendix A). An informed consent was distributed to all participants to further familiarize them with the study, its objectives, methodology, risks, location, and the duration of the experiment. All participants were assured that confidentiality and anonymity would be maintained throughout the research.

CHAPTER 4: DEVELOPMENT OF FRAMEWORK

4.1 Introduction

This chapter contains a discussion of the methodology used to construct the framework and investigate its components. Initially, the researcher identified a failure of current methods used to develop engineering leadership in undergraduate engineering students. The methods did not incorporate real-life industry examples or relevant contexts. Literature review and relevant research were then reviewed to identify gaps. After the gaps were analyzed, the research idea was further modified to include simulation to be used in the leadership development. This chapter details the methods and procedures related to: (a) revision of the framework, (b) investigation of the best technological and engineering leadership classification scheme, (c) advantages of using the 3D virtual world simulation matched to a specific development environment, and (d) details of the framework.

4.2 Revising the Framework

Based on the literature gaps, it was determined that a holistic framework was needed in order to develop leaders in engineering. It was clear that the framework must include three characteristics:

1. The classification scheme must be appropriate for engineering that provides for assessment and support in the development of education/training materials.
2. The classification scheme must support team and individual development.
3. The classification scheme must enable the creation of an appropriate environment for leadership development. Though experiential learning in a real-world setting is the

first choice for the development of engineering leadership, in its absence, simulation is a very strong alternative.

4.3 Investigating the Best Technological and Engineering Leadership Classification Scheme

Several classification schemes have been used to understand and scale leadership style and identify innate personality and leadership traits. These classification schemes reveal tremendous information about leaders' personality and leadership styles. "Perhaps one reason that personality has been used as a framework for understanding leadership is because behavior is a function of personality--what people do is a function of who they are" (Strang & Kuhnert, 2009). Also "another reason for the employment of personality theories in leadership studies is because personality has a trait-like nature: personality is consistent across adulthood and has longitudinal predictive power" (Strang & Kuhnert, 2009)

The most well-known schemes discussed in the literature review were (a) the 4-D Leadership System, (b) the Myers-Briggs Type Indicator (MBTI), (c) Big Five Personality Traits, and (d) Bass Classification of Leadership

The leadership style classification scheme selected for use in the present study was based on the following criteria: (a) the ability to classify engineering leadership using leadership classification styles that tie closely to actual industrial and technical project approaches, (b) the ability to evaluate engineering leadership styles for engineering-based project phases, (c) the ability to identify the effects of leadership types on engineering and technological teams and projects, and (d) the ability to discover the technological leadership context and recommend the appropriate leadership styles in that situation.

Based on the identified selection criteria, the 4-D leadership system was selected for use in this research. The 4-D leadership system reflects engineering-based project phases from early stages of brainstorming and design, to the development of a prototype and the sale of an actual product, including its maintenance and modification. The 4-D leadership system's unique methodology of classifying the information perspective and deciding prospective is unmatched in tracing the nature of engineering thinking and decision making. Pellerin (2009) indicated that some technical projects need a certain type of leadership and that if a leader's style is incompatible, the team and the project will fail. Pellerin further explained, illustrating the advantage of each leadership style of the technical teams, stating:

> What do Greens and Yellows provide to technical project teams? Their deep values and relational skills help people work together. They offer important diversity in thinking that improves decisions. . . . Orange people excel in tasks that require management abilities as in plan, organize, direct, and control. . . . Visioning leaders excel in tasks where concept mastery and creativity matter most.

Pellerin (2009) specifically classified the best leadership within the same engineering project design and implementation, providing the following example:

> Imagine building a house or adding a room to your house. You would want a free-ranging Blue innovative architect during the planning phase. Of course, you would have your Orange manager/builder review your design to confirm efficient and doable construction. Once the design is complete, you would turn the job over to your Orange manager for the construction phase.

The 4-D leadership system was originally designed to classify technological and engineering projects and help choose the best leader for a given project. In his book focused on NASA's teambuilding skills, Pellerin (2009) created the 4-D leadership system to avoid engineering leadership failure. Pellerin had been a manager at NASA when the Hubble telescope failed in its first mission. He attributed the failure of the Hubble to leadership rather than a technical issue, arguing that the harsh and forceful leadership style required to meet the schedule and stay within the budget caused the contractor to move relentlessly forward. His book was aimed at technical audiences, because technical thinking developed the processes it describes.

The 4-D leadership system has a clear, accurate and easy approach in evaluating leadership. Pellerin (2009) stated that the 4-D coordinate system "simplifies the key components of high-performance teams and effective leaders." Both the 4-D system and MBTI were derived from Jung's classification of personality types. The 4-D leadership system classifies leadership using four leadership styles that can be easily evaluated. In contrast, the MBTI uses a more complex system of 16 styles to classify leadership and personality that is not convenient to measure progress.

Another important consideration in selecting an assessment system is its ability to accurately assess the engineering and technological leadership for teams and projects. 4-D has the ability to select the best leader for any engineering project team. Dr. Anthony J. Calio, former vice president and general manager of the Raytheon Corporation, observed: "The 4-D assessment methodology, honed through 15 years of teambuilding with NASA project, engineering, and management teams, has the potential to improve team performance in almost any enterprise." Pellerin (2009) emphasized the importance of understanding cultural norms and social behaviors which are often overlooked in technical projects, and yet can play a critical role in their success. Also, Pellerin reported that the 4-D system has been used for more than 2,000 workshops and it had a record of more than 90% accuracy in predicting leadership styles.

The 4-D Leadership System is not a new classification tool in leadership; it is quite similar in structure to other protocols such as the Myers-Briggs Type Indicator (MBTI) that are presently on the market for use in personality/temperament and individual/group compatibility training (D. Hollister, personal communication, December 23, 2015). Both the 4-D Leadership System and the MBTI are based on Jung's archetypes. The 4-D test has been administered on numerous occasions by government and private agencies and, according to Pellerin (2009), has led to increased productivity for managers/supervisors/employees. The 4-D is a process and tool that provides a useful framework to introduce leadership skills training to students in an undergraduate engineering program.

4.3.1 4-D Engineering Leadership Pilot Study

After arriving at what was thought to be a suitable leadership classification scheme for engineering students, the researcher conducted a pilot study in two engineering programs in the central Florida area of the United States. The purpose of the pilot study was to become well acquainted with the 4-D leadership system. A total of 488 undergraduate engineering/technical students took the 4-D leadership test and the results are illustrated in Figures 9 and 10.

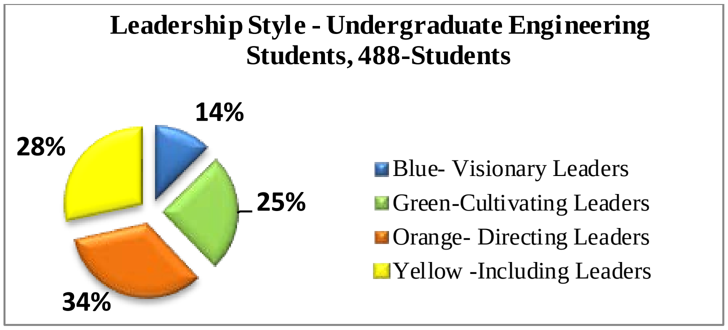


Figure 9. Pilot study: Leadership style of undergraduate engineering students

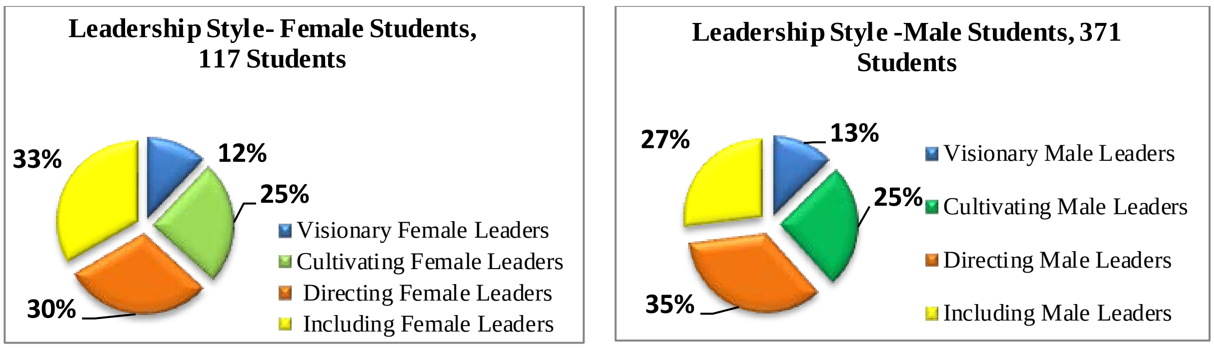


Figure 10. Pilot study: Leadership styles of female and male engineering students

The results of this pilot study showed less tendency for visionary leadership for undergraduate students compared to the other three leadership types. Figure 10 shows that male students had a higher tendency than female students toward directive leadership style by almost 5%. In contrast, female students tended to use including more than male students by 5%. In general, in the respective area studied in this pilot study, undergraduate engineering students had a tendency to be more systematic (directive) in their approach to problem solving. This indicated the need for development to create effective leaders.

4.3.2 Effective 4-D leadership Style and the Phases of a Technological Project

Engineers work in teams. Therefore, team leaders must be effective. Pellerin (2009) stated clearly that teams must be well-rounded (to be effective) in order to perform well in complex engineering projects. He stated that "early phase" project teams should be mostly blue. These creative idea builders perform trade studies to compare alternatives with out-of-the-box thinking. He also indicated that "Great scientists and engineers are usually logical deciders." He expressed the belief that innovation, creativity, critical thinking and seeing the whole picture are visionary leadership skills; and that without developing these skills, engineers would use only technical skills in the decision making and strategy-creation processes. Pellerin's (2009) classification of leadership styles is shown in Table 6.

Pellerin also observed that directive (Orange) leadership style is important in "taking action--organizing and directing others." Directive leaders have the ability to move the performance ahead quickly with discipline, process, and certainty of outcomes. The importance of including (Yellow) leaders comes when the relationship and teamwork matter the most. He stated, "I believe including leaders are the best leaders of the largest and most complex project teams. . . . The Green, cultivating personality performs best in jobs where caring about people matters most. They frequently provide training and coaching" (Pellerin, 2009). Being able to achieve all the leadership styles in a team or on an individual basis in a balanced manner is considered the best and effective leadership.

Table 6

Pellerin's (2009) Classification of Leadership Styles

Leadership Style	Leadership Dimensions	Technological Leadership Strength and Capabilities of Team and Individuals
Visionary style (BLUE)	Information: Intuition → Deciding: Logical	Leaders have the intellectual, thinking about the potential future, forward looking capabilities. They are good at invention, design, patent, creativity and invention.
Cultivating style (GREEN)	Information: Intuition → Deciding: Emotional	Encouraging, appreciating, inspiring engineering teams and individuals to create a better world, and sincere concern for humanity.
Directing style (ORANGE)	Information: Sensing → Deciding: Logical	Encouraging taking actions and directing others. Managing, planning, organizing, directing, and controlling. They are very productive, and efficient leaders.
Including style (YELLOW)	Information: Sensing → Deciding: Emotional	Engineering teams benefit from this style by strengthens the relationship between team members to focus their efforts on achieving the ultimate engineering goals. Fostering the communications and relationships with others. Conflict intolerant.

4.4 Use of 3D Virtual World Simulation for Engineering Leadership Development

In order for engineers to transfer the complexity of real-life scenarios to manageable techniques, they may use simulations. With the advanced science and technology in the human-computer interface (HCI) field, and computer-aided design (CAD) tools, physical world elements become easy to reproduce in a computer-generated or virtual environment (VE) or virtual world. The latest communication services and multi-media embedded in virtual world platforms enable engineers to visualize the real physical environment in enhanced and advanced ways that permit them to accelerate their research and design.

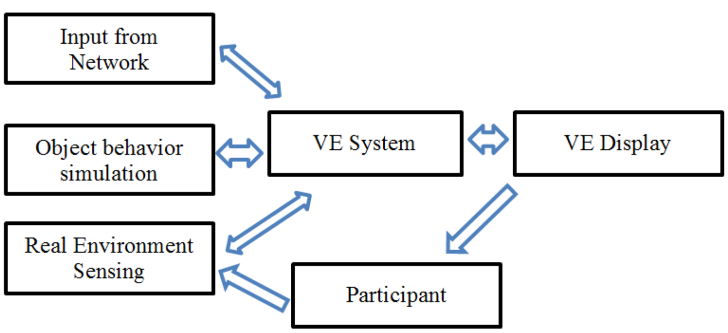
Experiential learning is the best method of training and development. In the absence of real-life experiential learning, simulation provides a viable alternative and is superior to the traditional classroom/textbook/lecture styles in use in many colleges and universities. Virtual environment simulation based education not only complements traditional ways of teaching and supports information exchange. It also bridges the gap between content knowledge and experiential learning, and it can engage users by creating a sense of being present in a particular environment (Bhide, 2015).

Engineers can easily access virtual worlds through the internet to either design and construct or communicate and socialize with others. 3D Virtual world simulation is a specific form of simulation where via the internet the real world can be simulated in a three-dimensional, computer-based, immersive environment such as the 3D virtual world of Second Life. Virtual world simulation take place in a virtual environment that allows users to socialize, connect, and create using free voice and text chat. These convenient design and communication tools support engineers in enhancing their technical design and production skills as well as their social and communication skills.

Virtual reality is the presentation of the computer-generated data in a way that those who use it perceive the presentation as having similar characteristics of a recognized world (Lemheney et al., 2016). These advantages of having computer-generated data that closely replicate the real world permit engineers to simulate the complexity of real-life scenarios with almost no cost to expedite their research and findings. Instead of testing their theories in real-life settings where it is risky and costly, virtual worlds give engineers opportunities to test and validate their engineering assumptions. Showanasai et al. (2013) defined the virtual world as "simulated environments with digital resemblance of animated actors and their physical surroundings where they can engage in interactive activities through computer-generated tools."

"Virtual worlds are synthetic, computer-generated simulated environments where user interaction is usually made through avatars that is, an element of the simulated environment which embodies the human user. These may normally assume a textual or graphical form, including full three-dimensional (3D) representation." (Sequeira & Morgado, 2013a).

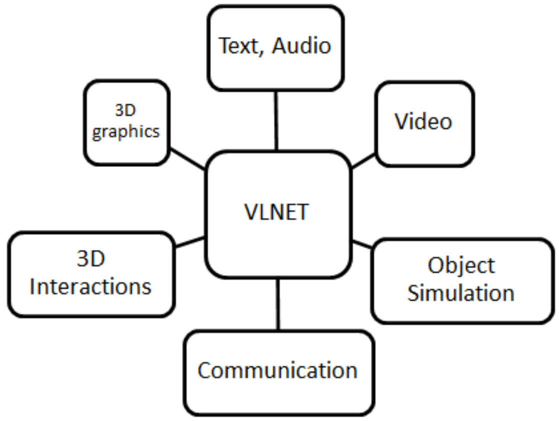
Using avatars as a human representation to move, interact, and discover other people, places, and virtual projects and technology allows engineers to utilize the full benefits of virtual world experience. Avatars are the only elements that can participate in the Networked Virtual Environment (NVE). (NVE) is a system where multiple geographically distant users interact in a common virtual environment (Tolga et al., 1999). Figure 11 describe the integrated NVE where NVE provides input and receives output from the participant who is a real person participating in NVE via an avatar (Tolga et al., 1999).



Source. Adapted from Tolga et al. (1999).

Figure 11. Integrated Networked Virtual Environment (NVE)

NVE is a single environment shared by multiple participants connected from different hosts and where each host stores subsets of scenes. Avatars allow participants to move around in all the NVE scenes (Tolga et al., 1999). Engineers can develop NVE using two main approaches: toolkit-based and integrated software (Tolga et al., 1999). Examples of a toolkit-based approach are WorldToolkit (WTK) developed by Sense8 Corporation and Minimal Reality (MR) developed by researcher at University of Alberta. Examples of integrated software approach include DIVE (Distributed Integrative Virtual Environment), developed by the Swedish Institute of Computer Science and VLNET (Virtual Life Network) developed at Computer Graphics Lab, EPFL, MIRALAB and University of Geneva (Tolga et al., 1999). VLNET combines both artificial life techniques and virtual reality techniques to create a true virtual reality environment that is shared by real people and autonomous virtual humans. VLNET supports a networked shared virtual environment in real time to be accessed by multiple users, 3D virtual human actors. As shown in Figure 12, VLNET can benefit engineers by incorporating different media, 3D models, facial interactions, gestures, and real-time movies. These rich virtual world communication features enable engineers to utilize the full capabilities of enhance their engineering applications effectively and efficiently.



Source. Adapted from Tolga et al. (1999).

Figure 12. Virtual Life Network (VLNET) media features

Researchers use different names (e.g., virtual reality, virtual environment, artificial reality) for virtual worlds (Bamodu & Ye, 2013); multi-user virtual environment (MUVE); massively-multiplayer online game (MMOG); immersive virtual world (Girvan, 2013). According to Martia-Isabel (2005), virtual world technology is drawn from virtual reality. Virtual world has three unique features that make it special and more accurate in simulating real life environment and scenarios and make the virtual world a great place for engineering communication, collaboration, and interactions. First, virtual worlds provide for a homogeneous simulation environment rather than have a large of diversity of heterogeneous resources. For example, users can access all their computing resources, websites, models, and others. Second, avatars move, communicate, interact with users and also change the virtual environment itself. Third, virtual worlds, like virtual reality, are organized in spatial metaphor. Figure 13 shows three major concepts from which the virtual world simulation has been developed (Martia-Isabel, 2005).

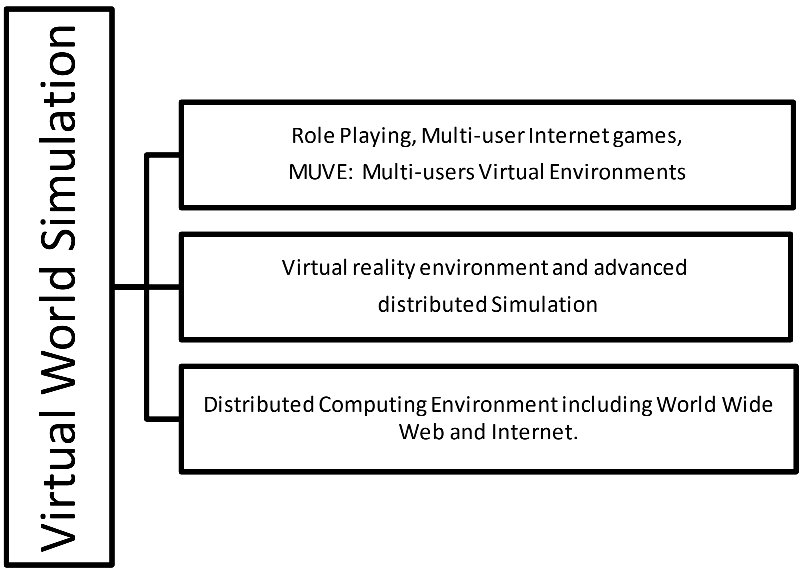


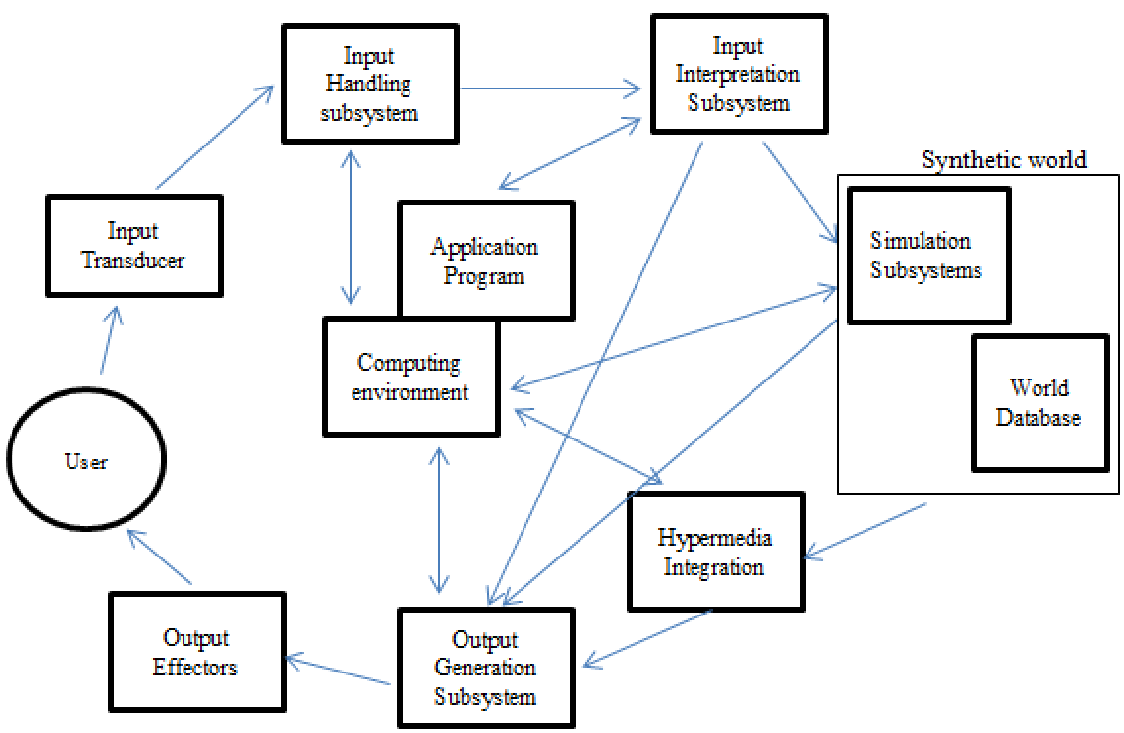
Figure 13. Original concepts behind the development of virtual world

Table 7 and Figure 14 contain a description and a graphic display of the virtual world as an integrated system in which users meet, interact, and socialize in a common virtual platform. Understanding these components can be helpful in understanding the utilization of teams. In the decoupled simulation model, virtual environment consists of four components: computation, interaction, geometric model and presentation (Stuart, 1996).

Table 7

Description of Virtual Environment Application Components

Application Components	Description
Computation model	Evaluating and updating the state of the computational model to send data to the geometric model.
Interaction component	Managing user inputs and coordinating output to the users.
Geometric model	It receives input from both computation model and interaction model and convert them to a suitable data for display.
Presentation component	Rendering images, synthesizing audio, generating display.



Source. Stuart (1996)

Figure 14. The virtual world as an integrated system

In another interesting description, Maxwell (2014) described virtual world as scenes and actors. Scenes are data structures that store and manage entities (objects and avatars) and their properties. Actors are sets of simulation engines operating on the scene, and each simulation engine is called an actor as shown in Figure 15. Physics actors or engines simulate an object's behaviors. Script actors or engines execute scripts to drive an object's behaviors. Client management updates the scene as indicated by user inputs and send updates to users to refresh their views (Maxwell, 2014). This concept of scene and actors appear to have potential for use in the development of engineering leadership.

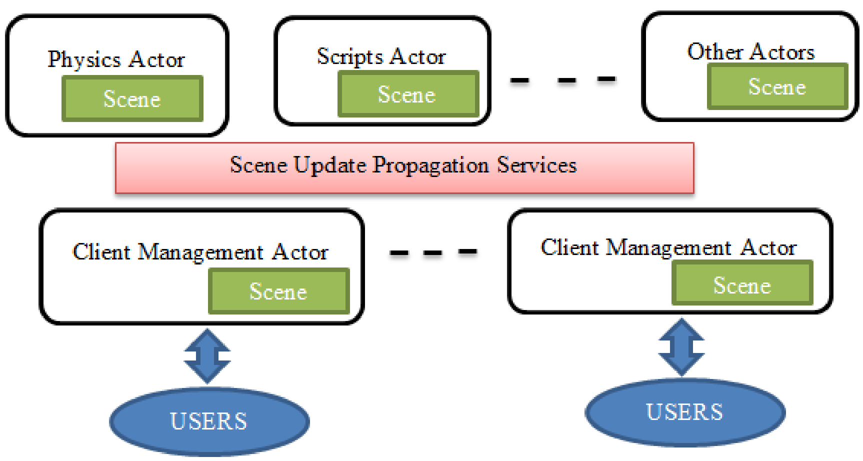
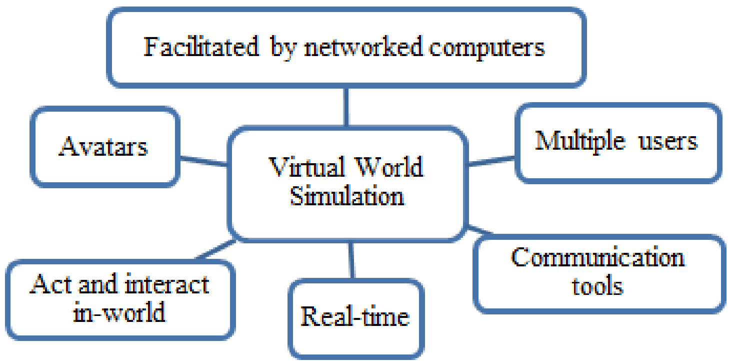


Figure 15. Virtual world simulation: Scenes and actors

Figure 16 displays the characteristics of virtual world simulation (Girvan, 2013). These characteristics totally support using the virtual world simulations to be used in enhancing the engineering leadership in team-based settings. Being able to connect multiple users on real-time and provide them with all communication tools in a virtual industrial environment make the engineering leadership development as almost as close to the real-life industry settings.



Source. Adapted from Girvan (2013)

Figure 16. Features and characteristics of virtual world simulation

The virtual world architectural solution contains four key components: (a) a simulated environment, (b) an end-user client, (c) a collection of collaborative resources available from within the virtual world environment, and (d) a network infrastructure to capture and support the virtual world solution (Lesko & Hollingsworth, 2013). Because of these components, this type of simulation is very practical for use in engineering leadership development. It should also be noted that virtual world simulations differ from 3D graphics. Major differences are displayed in Table 8 and are related to types of agents, user participation, multimedia, data feed, and networking

Table 8

A Comparison of 3D Graphics and Virtual World

Elements	3D Graphics	Virtual World
Agents	Agents are passive and nonexistent	Agents are active and participating
User Participation	User is a spectator	Presence and role playing can be immersive or not immersive
Multimedia	Mainly graphics with text	Full multimedia such as sound and other stimuli
Data Feed	Still images (online or Batch)	Online real space with wide bandwidth and live images
Networking	Deferred or Online	Networked solution with no time delay with wide bandwidth and gig stream desk area networks (DAN)

Source. Adapted from Chorafas (1995).

4.4.1 Virtual World Simulation Applications and Advantages

The main objective of this dissertation was to enhance the engineering 4-D leadership to an effective and balanced level whereby all students would enhance all four leadership styles to be able to manage, lead, and communicate effectively in all types of engineering and technological tasks. The researcher used virtual world simulation in this experiment because of the following advantages:

1. It affords opportunities for humans' interaction within the 3D simulated environment, providing students with shared, simultaneous experiences and offering opportunities for open discussions.

2. Virtual world simulation encourages taking more risks and exploring while learning new ideas, skills and techniques. This advantage allows engineering students to exercise their decision making without any actual consequences.
3. Virtual world simulation provides engineering students with active learning rather than passive learning experiences.
4. Unlike Virtual Leader (an intelligent-avatar), virtual worlds are simulations where the real world can be simulated in a fully immersive environment to allow students to utilize their graphical representation, an avatar, to walk, fly, and drive a vehicle. They can teleport to different engineering simulated environments to engage in all kinds of activities with other teammates, coworkers, and other virtual world participants. Prior researchers have established that avatars are more influential and have been perceived to produce stronger responses than agents when cooperative and/or competitive tasks are required. This fact is essential, particularly in leadership education, in team-based environments which are ubiquitous in engineering.
5. It has the ability to visualize the real-world perception by integrating and combining sophisticated 3D graphics with virtual reality to create learner-centered experiential-based learning. This advantage permits engineering leadership trainees to participate and learn while conducting their virtual engineering leadership activities.
6. Due to the great advantages of virtual world simulation, it has been used in the training of the most sophisticated aviation technology, software engineering, military and nuclear power systems training, and healthcare.

7. Human avatars can interact with any object in the simulation without prior setup by a scenario designer. Also, scripted behaviors can be added to the environment to increase the fidelity and to create complex interactions.
8. Because the virtual world training environment can achieve the highest levels of operational accuracy, virtual world simulation has an excellent constructive learning environment and can support collaborative learning with a large number of participants.
9. Virtual solutions can enhance concurrent business and engineering processes by elaborating on the importance of the interaction between simulated and real facts and the combined positive impact of a 3D visualization, a real time response, and interaction in 3D in bringing real-world experience to a laboratory setting for improved learning (Chorafas & Steinmann, 1995).

4.4.2 The Importance of Case Studies in Virtual Worlds

Building a virtual world leadership environment with a diversity of case scenarios approach will make the framework robust. Therefore, the framework calls for a library of cases which are designed according to the leadership scheme and implemented/played by teams using Virtual World. The case studies implemented in virtual worlds are not only a powerful tool to mimic the real industry world. They also have the potential to give students a logical, enjoyable and meaningful leadership activity time.

4.4.3 Design of the Virtual World Simulation

Based on the dissertation objective which was to enhance the development of engineering leadership to be effective and well-rounded, the virtual world simulation was based on the criteria shown in Figure 17. It is a logical way to use the selected leadership classification scheme. In this dissertation, the goal was to enhance all four leadership styles (cultivating engineering leadership, directing engineering leadership, visionary engineering leadership, and including engineering leadership) to a balanced level with close percentages in both teams and individuals.

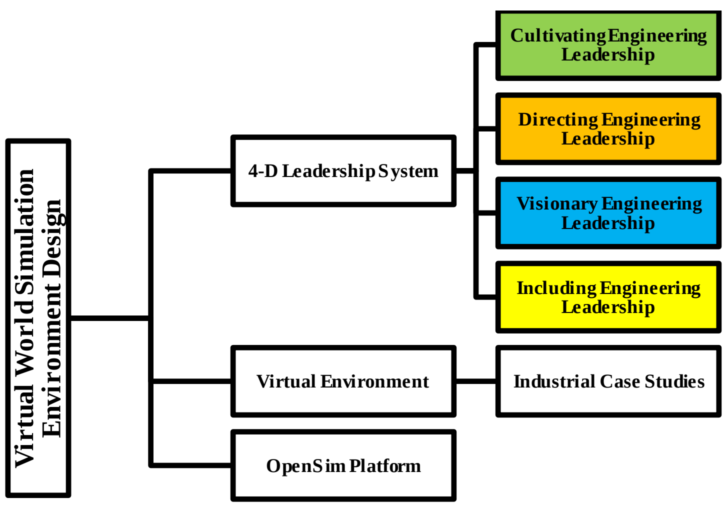


Figure 17. Virtual world simulation environment design

4.4.4 Virtual World Leadership Simulation Activity: Preparation and Experiment

Because the expected end result of this research was enhancing engineering leadership, an appropriate way to measure the effectiveness of this framework was by conducting a single case study. The purpose of the process was to measure the change in leadership skills based on the classification scheme selected. In this experiment, both groups (experiment and control) were given the exact same pretest. After the pretest, the experimental group was subjected to the experimental treatment, which was a 3D virtual leadership simulation.

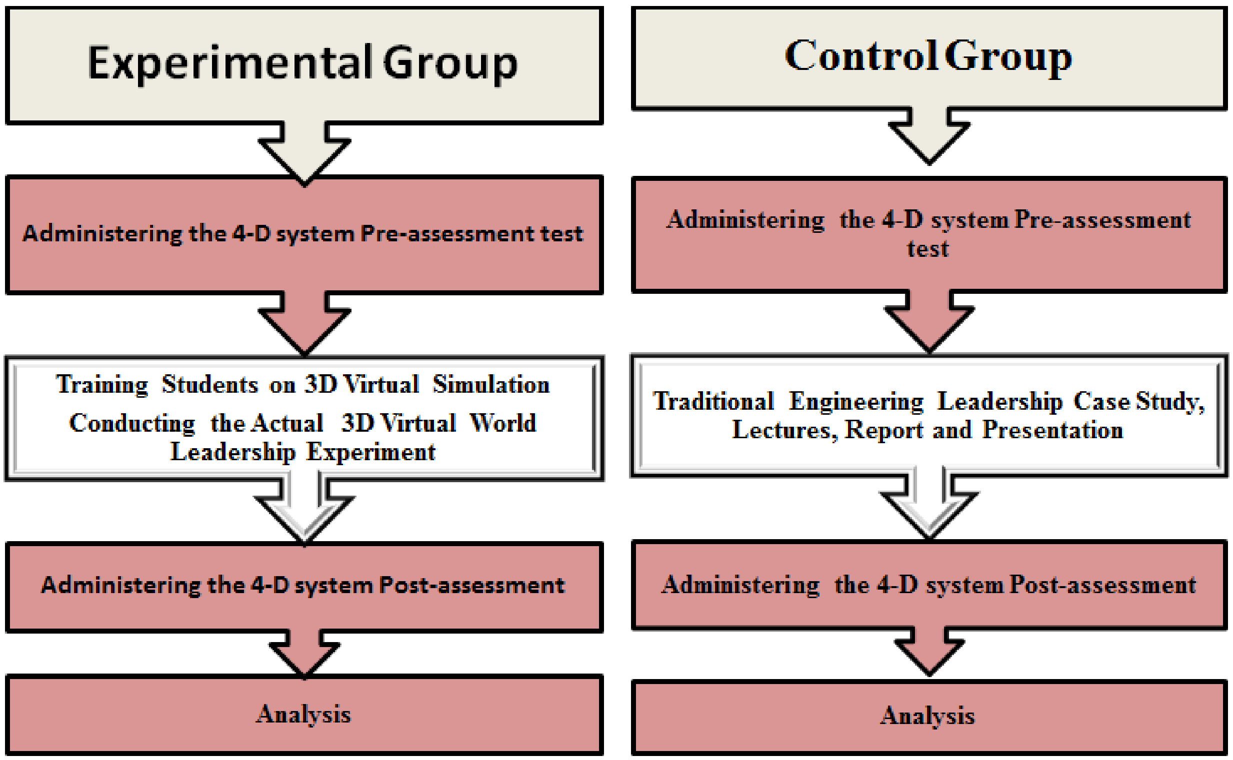


Figure 18. Activities of experimental and control groups

4.5 Summary

The proposed framework that utilized a well-recognized methodology and was designed to provide more effective leadership development for undergraduate engineering students was presented in this chapter. The 4-D leadership system selected to be used to classify the engineering leadership over other leadership classification schemes was discussed. The results of the 4-D leadership system pilot study that was conducted to check the capabilities of this scheme to assess and evaluate the leadership styles for undergraduate engineering students was also shared. Finally, the applications of the virtual world simulation that have been successfully used as a means of education and training were identified.

It was clear that the framework must include the following components as shown in Figure 19:

1. A classification scheme appropriate for engineering to provide assessments and help the development of the education/training material. The 4-D leadership system was determined to be most suitable for engineering leadership development.
2. The classification scheme must support team and individual development, and the 4-D leadership system was found to be appropriate in this regard.
3. The classification scheme must create an environment that supports leadership development. In the absence of experiential learning, utilization of virtual world simulation, which incorporates a set of industrial case studies, is most appropriate.

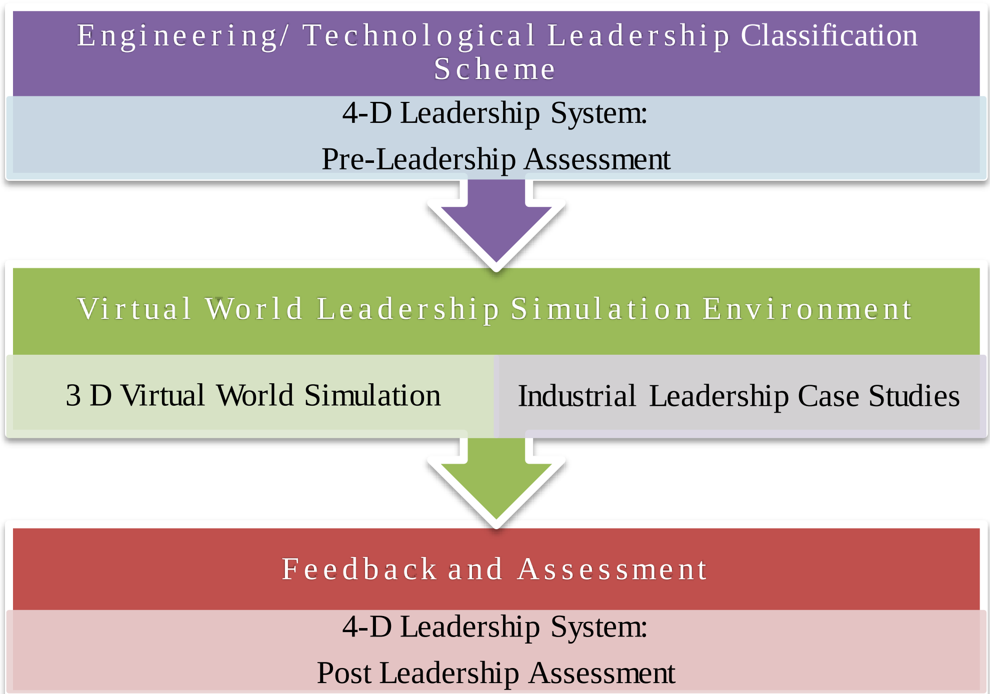


Figure 19. A holistic framework for effective engineering leadership development

CHAPTER 5: FRAMEWORK VALIDATION AND FINDINGS

5.1 Introduction

The framework of this dissertation uses a classification scheme that is suitable for engineering to provide assessments and help the development of education/training materials to support team and individual engineering leadership development. The 4-D Leadership System can serve engineering leadership effectively. Also, the framework establishes a way to create an environment for engineering leadership development that can be a good substitution for experiential learning. The closest technique to experiential learning is the utilization of simulation. Virtual world simulation has been found to be the most appropriate technique, particularly when used with a set of industrial case studies. To validate this framework, an experiment incorporating an industrial case study will be conducted in order to validate and measure the potential of this framework.

5.2 4-D Leadership System: Effective Leadership Indicator (ELI).

In this project, the leadership style for engineering students was evaluated before and after the experiment. To be able to assess the effective leadership style for teams and individuals, the 4-D Leadership System will be used before the experiment to understand the current students' leadership styles. After conducting the virtual world leadership experiment, the leadership style was examined again to assess the impact of the experiment. As shown in Figure 20, the 4-D Leadership System consists of two main dimensions which are Y-axis, innate information preference (sensed information and intuition information) and X-axis, innate deciding preference (emotional decider and logical decider).

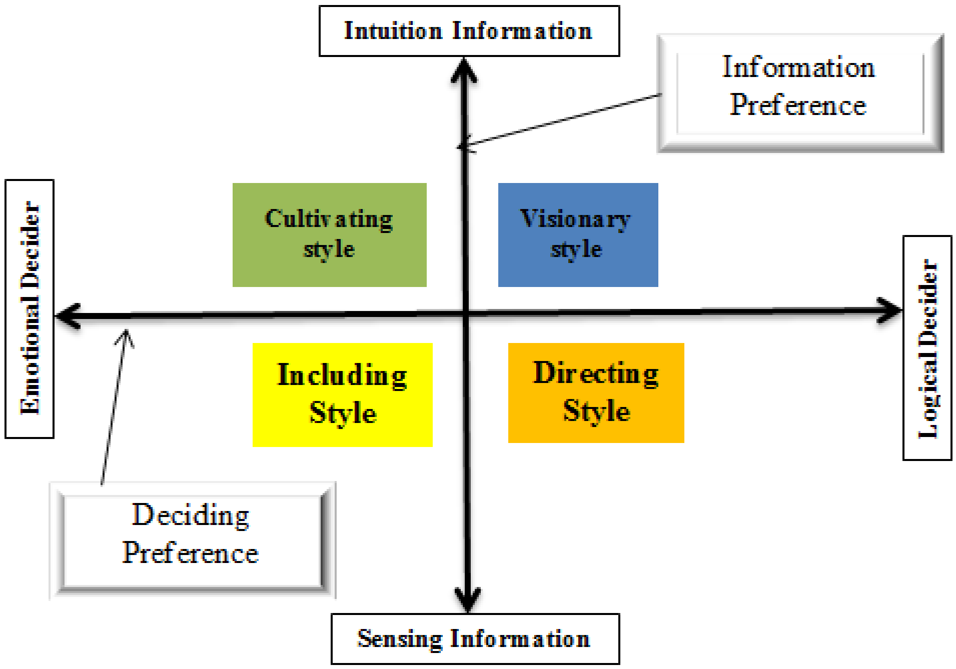


Figure 20. 4-D Leadership System

The percentage of each dimension was calculated for each team member. After that the average of all team members' leadership percentages were calculated before and after the experiment. The smaller the deviation between the 4-D Leadership System, the closer the leadership to be effective and well-rounded, because all leadership styles are closer to the average score. Thus, the standard deviation is the indicator for team and individuals to have effective and well-rounded engineering. In this study, it is termed effective leadership Indicator (ELI)

5.3 Using Industrial Case Study to design the 3D Virtual World Simulation

As discussed in Chapter 4, the framework relies on conducting an industrial case study incorporated in the virtual world simulation. For the industry case selection, there are some general conditions to make the virtual leadership activity more beneficial for engineering students. The selection of the case study was based on the following features:

1. It is a technological and engineering case based-study.
2. It can be conducted in team-based settings.
3. It covers multi-engineering disciplines concepts.
4. It is logical, simple and appealing to meet the students' educational level.
5. There is a room for innovation and creativity .

After investigating the students' background, education, leadership style (based on the 4-D Leadership System pilot study) and the virtual world and gaming capabilities, it was found that the use of home development and sustainability with a smart home capabilities case study would be a great approach for undergraduate engineering students in the introductory engineering class. Smart home development and construction is a multi-discipline engineering application. Furthermore, the industrial case study complexity was carefully assessed to allow for the following criteria for participating students. They (a) were either freshmen or sophomores, (b) represented most of the engineering disciplines, and (c) had no prior experience with virtual world gaming and simulation.

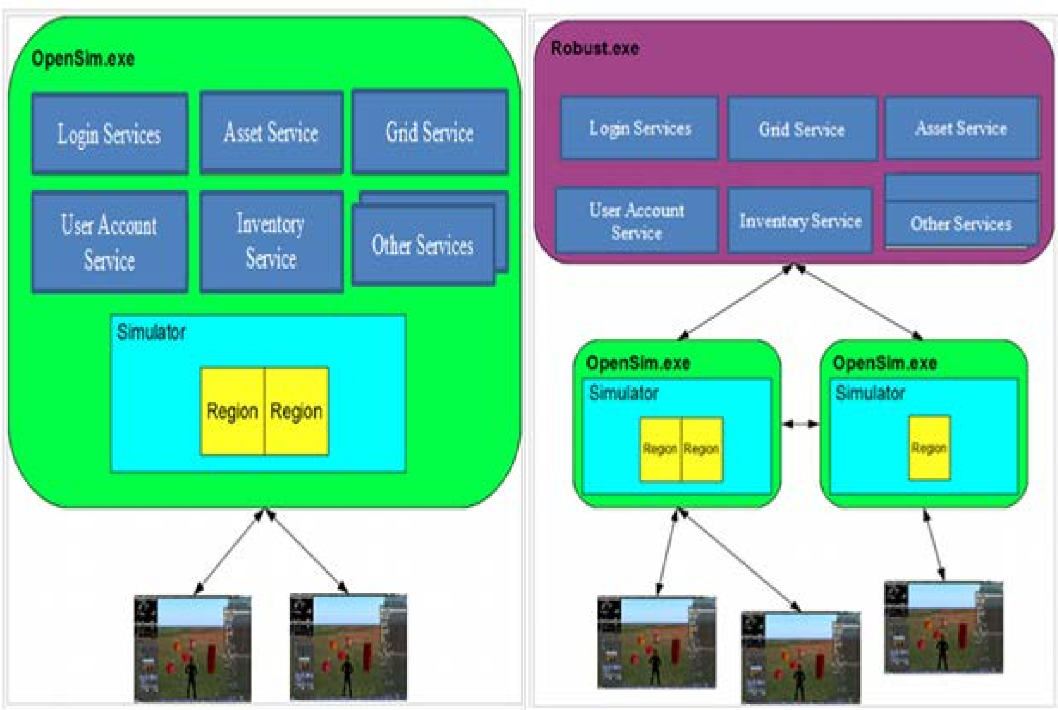
Due to these facts about the undergraduate students, the virtual simulation activity was designed to be simple, thorough, and comprehensive. The comprehensive concept of this project enables all students from various majors to participate in the activity. For example, civil and construction engineers will be concerned about the design of the house, insulation, and green house. Electrical engineers will be consultants in the lighting, and electricity selections. Computer engineers will advise teams to choose the right smart home technologies, and industrial engineers will be concerned about quality vs. budget. In general, all the project aspects are important for all engineers regardless of their majors because they are in the introductory phase of their education journeys, and additional knowledge is useful to them in enhancing their teamwork leadership skills and strengthening their general engineering problem-solving skills.

Smart Homes are homes that adapt intelligent control technologies (Miller, 2015). Also, according to Harper (2003), it has been defined as a residence equipped with computing and information technology to fulfil the need of occupants to promote their comfort, security and entertainment. The use of the phrase, smart house, was originated by the American Association of Homebuilders in 1984 (Miller, 2015). Smart homes features range from basic communications capacities to very advanced automating tasks as follows: (a) basic communications such as landline phone, mobile phone and internet connectivity; (b) simple commands such as voice command, motion sensor to turn on the light and alarm security sounds; (c) basic automating that has basic functions such as a room controlling temperature; (d) tracking and taking action, (e) track the residents' data and use these data for predicting the residents' life style; (f) promoting activates and answering questions capabilities; (g) automating tasks to act automatically without prior permission based on data collected from the family members.

Because "every team needs a leader" (Harvard Business School Press, 2004), each team was asked to create a smart home development company where the team leader is the CEO and the rest of the team members comprise the management team.

5.4 Virtual World Simulation Platform: OpenSimulator

OpenSimulator (OpenSim) was chosen to be the virtual world platform that allows engineering students to build the virtual leadership environment that was specifically designed for this research. The environment created using this platform simulates the industrial real life scenario to allow engineering leadership trainees practice in live, virtual, and interactive settings using their avatars as a digital representation of themselves. Figure 21 displays OpenSim regions (mini grids) and the full OpenSim grids architecture.



Source. Adapted from *OpenSim Architecture* (2016).

Figure 21. OpenSim regions (mini grids) and full OpenSim Grids Architecture.

Even though there are many similarities between OpenSim and other platforms such as to Second Life and Military OpenSimulator Enterprise Strategy grid (MOSES), OpenSim was chosen over the rest due to the following advantages:

1. OpenSimulator provides its users all the controls and features in two ways, a standalone application or robust grid mode. In this research project, a standalone OpenSim region has been used. The difference between standalone OpenSim regions (mini grids) and full OpenSim grids is that an OpenSim configuration consists of regions (run by region simulators) and backend data services (such as user, assets and inventory management). Standalone mode runs both the region simulator and all the data services in a single process. When one runs OpenSim.exe, many regions can be run in a single machine. In the grid situation, the data services are not included in the server, but they are run executable called Robust.exe to allow all services to be run on entirely separate machines. In the grid settings, the OpenSim.exe acts as the region server; and multiple OpenSim.exe region simulators can be run on different machines as shown in Figure 20.
2. OpenSim is an open-source server platform that grants users full control of the server, and Second Life is a proprietary software platform (private server control feature).
3. OpenSim has been used and adapted by technological and engineering companies such as NASA and Intel" (Hebbel Seeger, Reiners, & Schäffer, 2013).
4. OpenSim can be deployed on any computer able to run Microsoft and the content can be saved and restored using an XML-based file format known as Open Archive (OAR).

5. OpenSim is editable and flexible but Second Life is only accessible.
6. OpenSim has the feature of back-up and security.
7. OpenSim gives more freedom to control the implementation environment, but there are some restrictions in Second Life. Also OpenSim is mostly used by researchers to build stand-alone projects which are often inaccessible by the general audience. (Brashears et al., 2003).
8. Its servers can be set up in any secure situation (Hebbel Seeger et al., 2013).

In this dissertation, OpenSim platform has been used through Dream Land Metaverse, a leading OpenSim hosting service to make sure that the engineering leadership simulation not only has the latest technological features but also enables engineers to practice their leadership with a complete, advanced and fully functional platform. In this project, the construction was done in 256 x 256 meters and it has an area of 65,535 square meters as shown in Figure 22.

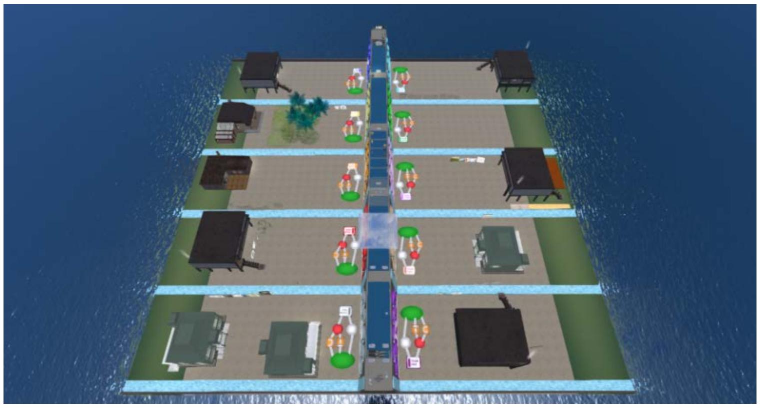


Figure 22. Top view of the virtual simulation area

This region is a complete virtual world running on a single process. This includes user registry, user inventory, assets, and messaging, as well as simulating the 3D spaces of this virtual world. It is similar to any other existing virtual world where users can travel to other OpenSim grids using hyper grid capabilities. The process has 1,024 MB memory which allows almost 48,000 prims. This mini grid is hosted as a fully managed service (software-as-a-service) on a high-performance, dedicated, multi-core server that is optimized for OpenSim.

This virtual region is integrated into Dreamland Metaverse service management platform that provides the following features:

9. This platform also provides additional features, like the web based control panel, that allow for controlling additional aspects of OpenSim services.
10. The service uses a high speed internet connection, a huge amount of memory and high performance processors to ensure that the server is never near to performance limits to allow nearly real time responses. This is important for a lag free in-world experience.
11. All viewers communicate with a single OpenSim process that offers all services and interfaces needed for mini grid.
12. 3D Meshes: It can be uploaded by using Colada format and use them as objects or avatars
13. Groups are mainly used to distribute information to certain teams to control permissions for parcels of land or of objects. Groups have great advantages for privacy where closed groups do not allow other users to add themselves in the group.

14. HyperGrid: This technology allows teleport between different OpenSim grids and standalone regions.
15. OpenSim regions support in-world scripting using XEngine script engine and the LSL scripting language.
16. Backup and storage: There is an automatically daily database backup to reduce the risk of data loss to minimal level using redundant data storage (RAID)
17. Offline Messages are fully supported. Instant messages to users that are offline are stored along with the user login and the message delivered to allow engineering leadership trainees always to be connected during the experiment.
18. To allow teams with their leaders discuss any issues that related either to the engineering virtual leadership project or to the team issues using the web, OpenSim provide a feature called web-on-prim to display web contents inside the virtual world. In this feature, they access any website to be displayed in the virtual world for further team discussions.

5.5 Experiment Settings

A total of 160 undergraduate engineering students were randomly invited: 80 in the experimental group and 80 in the control group. Only 84 students voluntarily responded to participate in this project: 42 in the experimental and 42 in the control group. All the members in both groups were randomly selected. In this experiment, both groups (experimental and control) will be given the exact same pretest. After the pretest, the experimental group will be subjected to the experimental treatment which is a 3D virtual leadership simulation. In contrast, the control group is isolated totally from the 3D virtual world simulation treatment and will receive traditional engineering leadership development using the typical method of conducting engineering leadership case study as a team: case study analysis lectures, report, and leadership solution presentations. As shown in Figure 23, both groups were subjected to the same 4-D post assessment to assess the change in the leadership as result of the particular treatment.

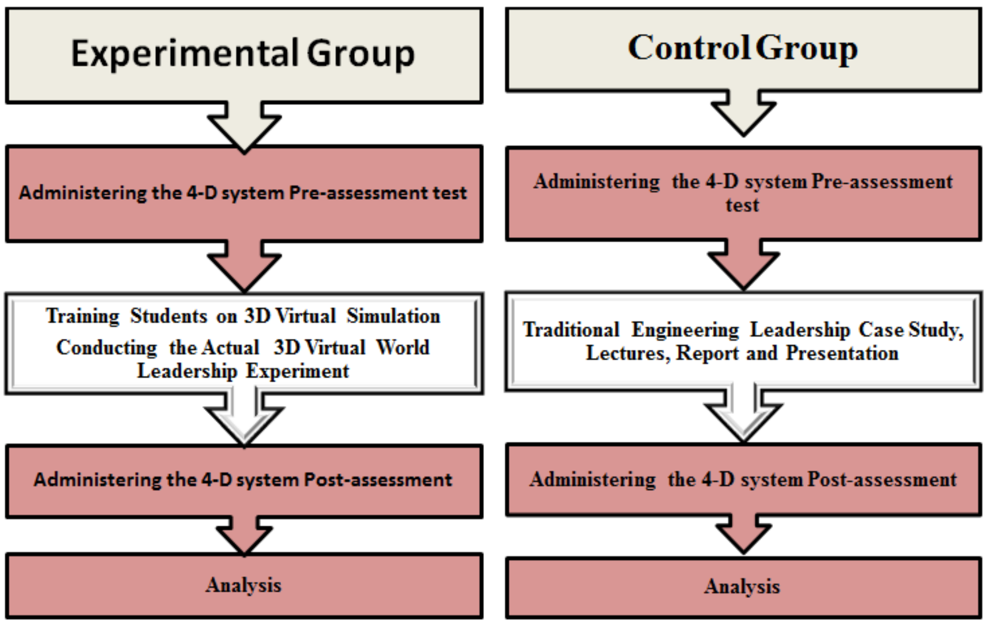


Figure 23. Experimental and control group activities

Both groups were divided randomly into 10 teams. The demographic characteristics of the two are shown in Table 9.

Table 9

Demographics of the Research Groups

Characteristics	Total (n=84)	Experimental (n=42)	Control (n=42)
Number of Teams	20	10	10
o Team Members Mean	4.2	4.2	4.2
o Team Members (SD)	1.1	1.3	0.79
Age			
o Mean	20.1	20.5	19.6
o SD	4.6	4.7	4.4
Gender			
o Male	67	30	37
o Female	17	12	5
Ethnicity			
o Hispanic	33	13	20
o White	28	15	13
o African American	11	7	4
o Asian	8	4	4
o Prefer Not To mention	5	3	1
Credit hours Completed			
o Mean		41.94	37.5
o SD		23.83	15.91
Years of Experience			
o No Work Experience	19	10	9
o Less than a year	11	7	4
o 1-2 Year	28	12	15
o 2-4 Year	16	8	8
o More than 4	11	5	6

5.6 3D Virtual World Simulation Training

In this activity, students were not expected to have any knowledge of either virtual simulation or the virtual viewer software, Firestorm Viewer. The training started immediately after the 4-D Leadership System pre-assessment. The training duration was two weeks. In the first week, students completed an orientation training on how to work in the 3D virtual environment of OpenSim with their avatars using the Firestorm viewer. Also, students were given videos as a homework assignment to familiarize themselves with the 3D virtual world and viewer controls. During the second week, each student spent a minimum of three hours in a dedicated computer laboratory to complete orientation exercises in the virtual simulated training environment, using their avatars within the 3D virtual world. As shown in Figure 24, all students customized their own avatars based on the skin color and physical appearance.

Figure 24. Avatar selection and customization based on gender and skin color

After customizing their avatars, students bought hats and shirts that were based on the color assigned to their respective teams. The team selections are displayed in Figure 25.

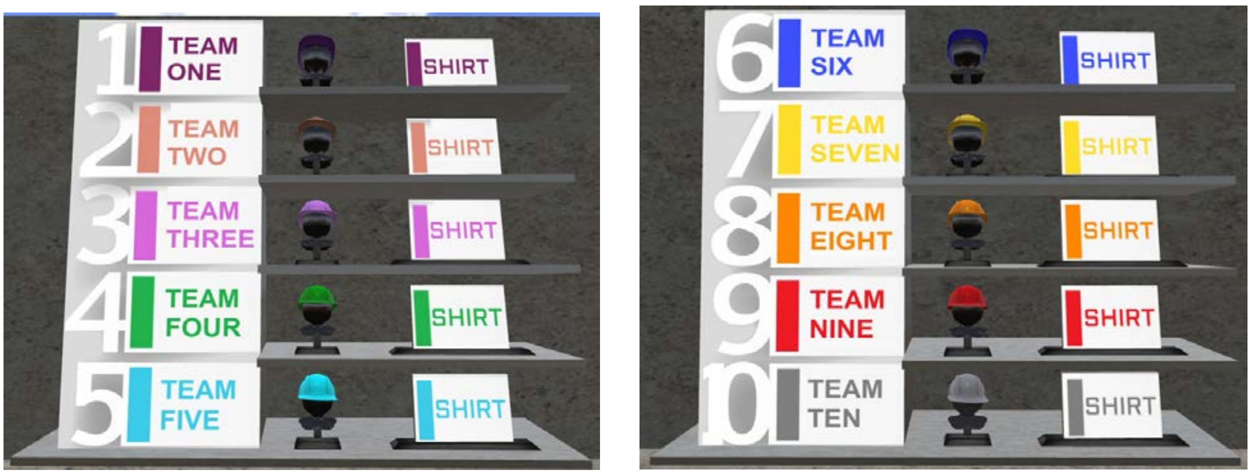


Figure 25. Team hat and t-shirt selections

Next, students learned to use the virtual simulation to know how to communicate and move around in the virtual environment. Two virtual workshop stations were dedicated to training students to use this software. As depicted in Figure 26, all the steps were presented in a logical sequence to allow students repeat them until they mastered them.

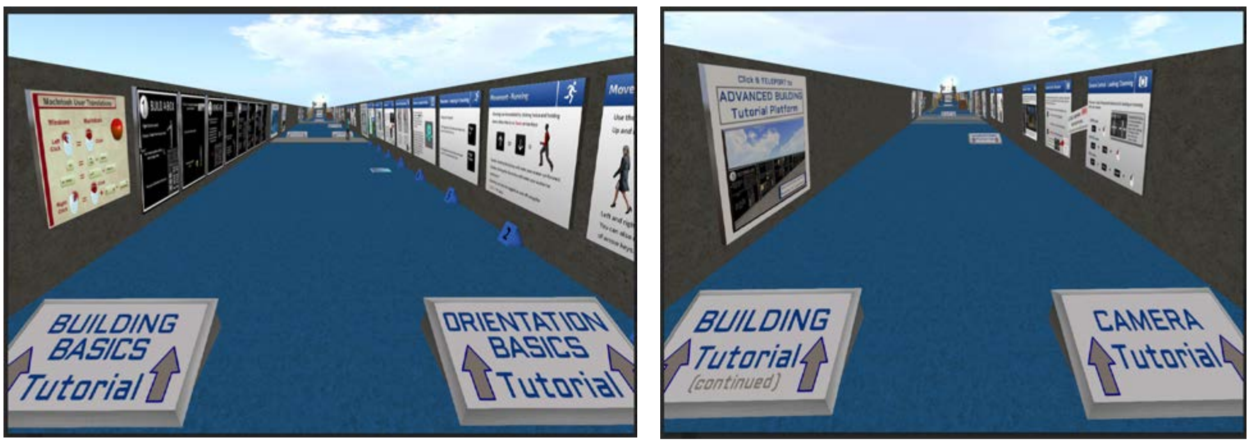


Figure 26. Virtual world tutorial and training

In this training activity, students learned how to communicate with teammates, how to buy virtual objects, how to access objects in their inventories, and how to arrange objects in the simulated environment and other features of the 3D virtual world. During this second week training period, students also completed mock exercises in how to conduct the actual virtual leadership training activities in teams. The laboratory computers had the virtual world viewer pre-installed as shown in Figure 27. Each team member was given a user name and password for extra training in his/her own time.

Figure 27. Virtual simulation training session in dedicated computer laboratory

5.7 The Virtual Leadership Activity

Because " every team needs a leader" (Harvard Business School Press, 2004), each team was asked to create a smart home company where the team leader is the CEO and the rest of the team members are part of the management team. When anyone would like to work in a team, a significant consideration is whether there exists a clear and meaningful purpose (Overfield, 2016). This is why the first task in the simulated virtual leadership training activity is that the teams select one vision, one mission and three specific goals for their respective companies, using the decision negotiation circle activity tool. In their book on leadership, Morrison and Ericsson (2003) discussed that all leaders should translate their organization's vision/mission into strategic objectives for the purpose of converting these objectives to a profit as shown in Figure 28. His theory confirms the concept that in order to gain a profit, vision and mission must be the first step in the business process. This concept not only will give the management team a clear direction of the business plan but also will make all stakeholders' efforts concentrated on accomplishing one purpose. The consolidation of the efforts can be achieved by having a clear and focused vision and mission statement.

Source. Adapted from Morrison & Ericsson (2003).

Figure 28. The importance of the mission creation in enhancing the profit

Team members in the successful teams not only share a clear understanding of their teams' goals; they are also committed to those goals (Harvard Business School Press, 2004). In this virtual leadership activity, each team has a region where all team members actively negotiate with their leader (CEO of the smart home company) to choose the best vision, mission and goals for their future company. Each of the possible four visions, four missions, and eight goals are reviewed during the selection process. To begin the decision negotiation circle activity, all members of the team stand on their team's name square and start by considering the Vision #1 statement. The team repeats the following process to choose the team's vision, mission, and three goals. Team members go to the red circle if they disagree completely with a vision, mission or goal, to the yellow circle if they have some hesitation, and to the green circle if they support it completely. Once everyone is standing on the color representing their initial opinion decision, the negotiation process starts between team members, under direct supervision of the CEO.

It is the CEO's responsibility to clearly explain each vision, mission and goal statement to the team members. They mediate any conflicts, and ensure all team members are in agreement on the final decision for the team's vision, mission and goals, thus ensuring they will later contribute fully to achieving the team goals (Harvard Business School Press, 2004). During the negotiations team members can move to different decision circles as their opinions change as shown in Figure 29 and 30.

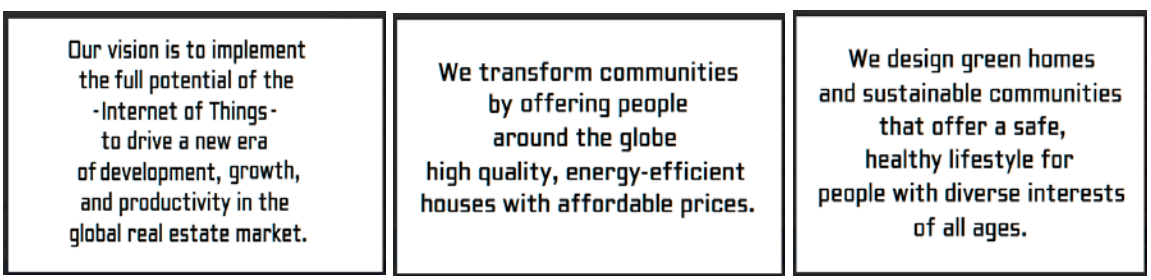


Figure 29. Sample of vision statements used in the virtual simulation activity

If all members cannot agree on a vision, mission, or goal, it is rejected; and the next one is considered. Because this is a timed experiment, once there is unanimous agreement on a vision, mission, or goal, it is adopted. Figure 30 presents a visual of the process used to select the vision, mission, and three goals in the decision negotiation circle activity.

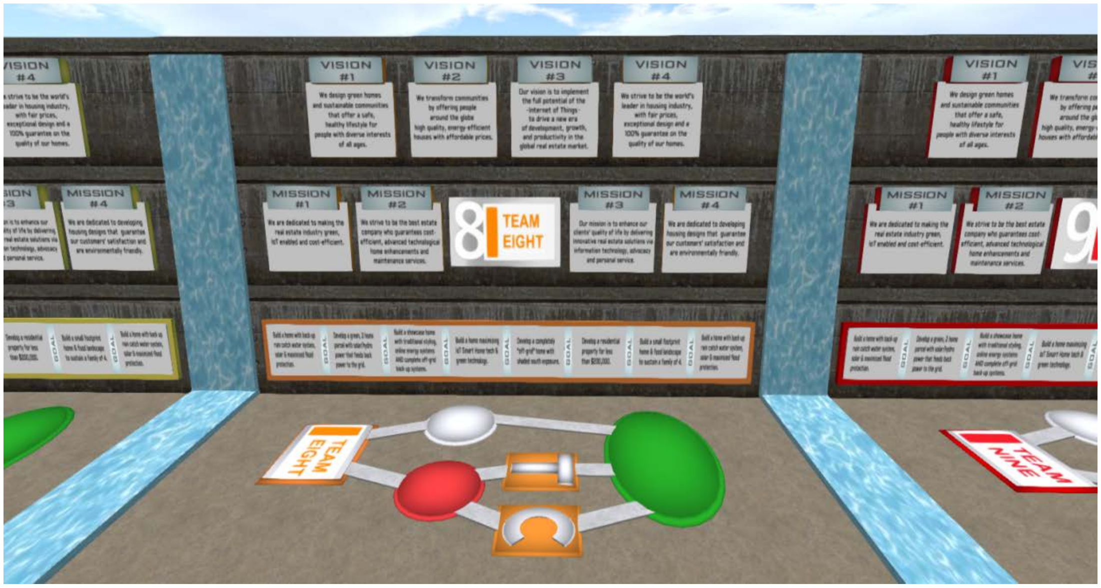


Figure 30. Selecting vision, mission and three goals based on decision negotiation circle activity

After successfully negotiating and choosing their vision, mission and goals, the team will go to the Shopping Showroom, as shown in Figure 31, to select a house, its smart home technology, energy, water systems, and its landscaping features, which when combined in a smart residential development, will best fulfill their team's vision, mission, and goals. Figure 32 contains a graphic depicting Team 9 virtually shopping for a house based on their vision, mission and goals.

Figure 31. Shopping showroom with variety of virtual houses at different prices available to teams

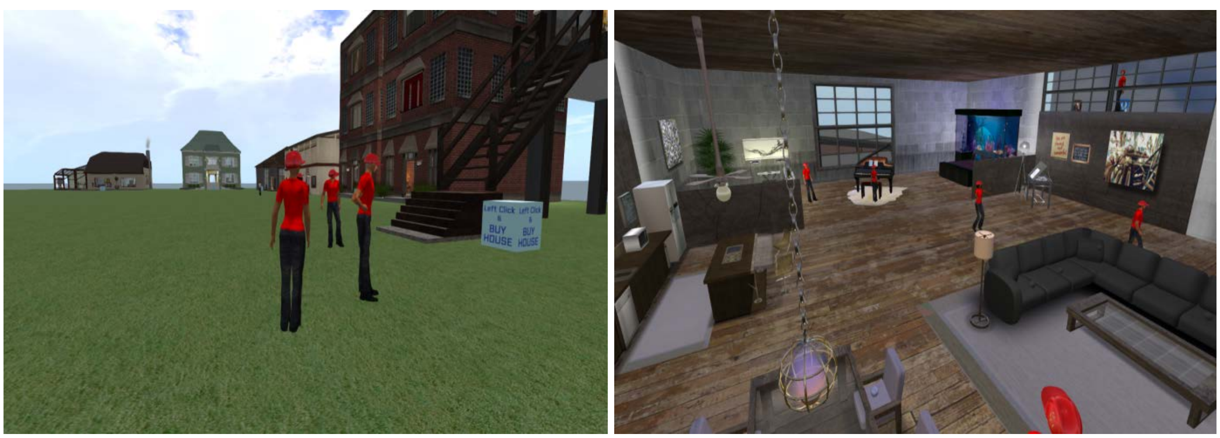


Figure 32. Team 9 virtually shopping for a house based on their vision, mission and goals

After selecting the best house based on their engineering background and assumptions, all team members will select the smart home technology, energy, water systems and landscaping features to complete the development of the residential property.

These selection decisions are designed to make team members consider future customers' demands and exercise their engineering skills in the selection process so as to be able to use their engineering knowledge and engineering leadership to design homes fully equipped with smart home technologies to attract the future customers. Examples of these choices are shown in Figures 33 and 34. They include smart home systems which allow connectivity of the house to the internet (Internet of Things, IoT), as well as the different types of energy, water systems, and a variety of green houses.

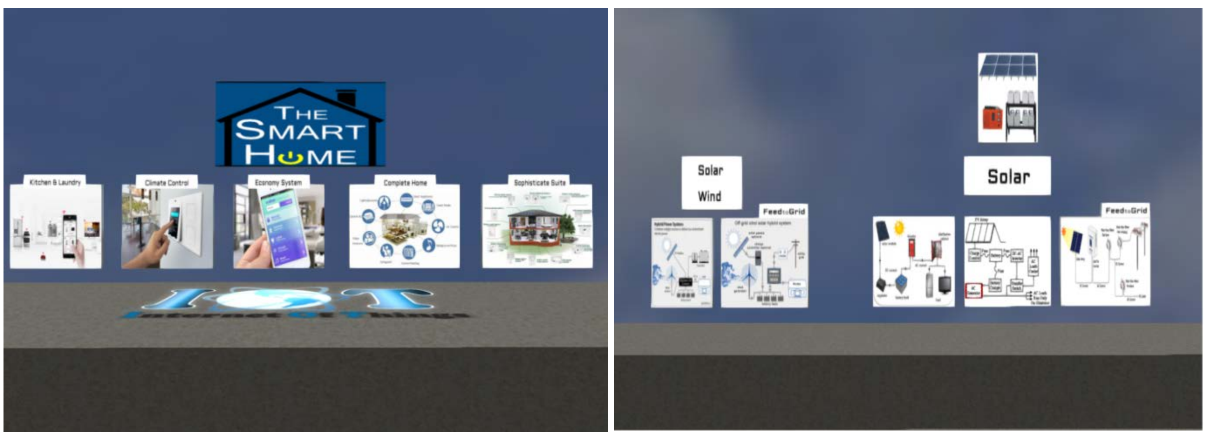


Figure 33. Technology system and energy system options for a team's virtual residential development

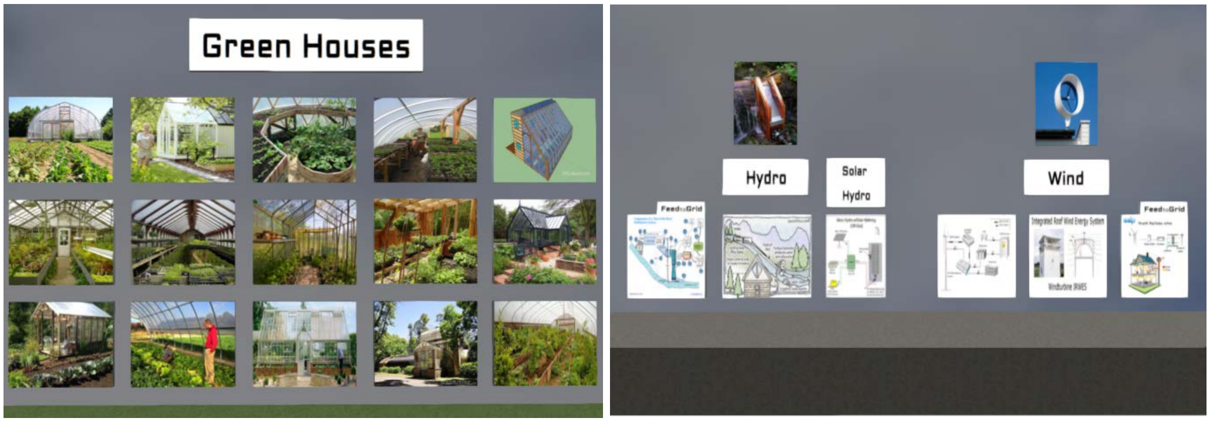


Figure 34. Green house and energy system options for a team's virtual residential development

All the houses, energy and water systems, and landscaping features have different prices. Thus, the opinions of industrial engineers as to the quality vs the cost is very important. Each team was given $400,000 in virtual money to make purchase choices to develop a smart residential property that would fulfill their company's vision, mission, and goals, while satisfying anticipated future customer demand at a reasonable sales price. Figure 35 shows the several team developments and individual members placing a house and a water system in their team regions after buying them. After placing the house, with its systems and features in their team's region, team members have accomplished their virtual leadership activity, and all team members will take the posttest. A video describing the entire 3D virtual world simulation activity can be accessed at https://youtu.be/sMEmjfyMHUw. It provides an overview of the entire activity including all steps in the process.

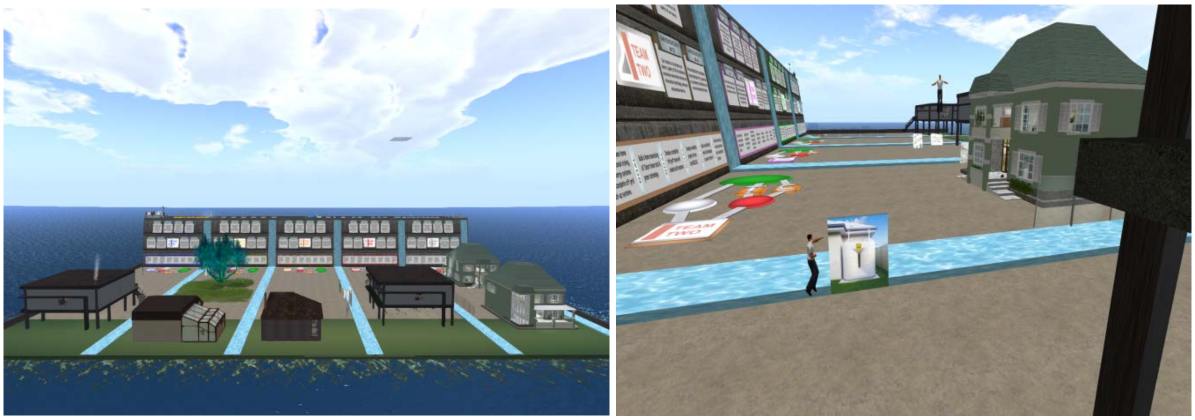


Figure 35. Experiment's final activity showing several team's developed regions and team members placing their residential development components in their team's region

5.8 Results and Findings: Leadership Skills

The null hypothesis and the research hypothesis for teams/individuals are as follows:

For the paired t-test, the null hypothesis and the research hypothesis for team/individual are as follows:

Null Hypothesis: H_0 : 3D virtual simulation will not enhance the leadership to become more effective.

Research Hypothesis: H_1 : 3D virtual simulation will enhance the leadership to be more effective.

Hint, Effective Leadership Indicator (ELI) is the standard deviation between the leadership styles; and the smaller the ELI the more effective the leadership is.

$$H_0 : \mu_{(ELI)after} - \mu_{(ELI)before} = 0$$

$$H_1 : \mu_{(ELI)after} - \mu_{(ELI)before} < 0$$

Where $\mu_{(ELI)after}$ denotes to the mean of ELIs posttest results team/individual. $\mu_{(ELI)before}$ is the mean of ELIs of the pretest results team/individual.

By the above test, the researcher was trying to determine if virtual leadership simulation enhanced leadership. The paired t-test was used to test the null hypothesis within the same group.

The independent t-test was used to evaluate the score difference between the experimental and control groups.

$$H_0 : \mu_{(ELI)after} - \mu_{(ELI)before} = 0$$

$$H_1 : \mu_{(ELI)after} - \mu_{(ELI)before} \neq 0$$

The effect of the 3D virtual world simulation to both team and individuals' leadership examined. Also, the effect of the 3D virtual simulation on the traditional leadership development represented by the control group is examined. The statistical analysis determines the significance of each method in enhancing the engineering leadership development. Figure 36 illustrates the statistical analysis steps that were conducted to test the research hypothesis.

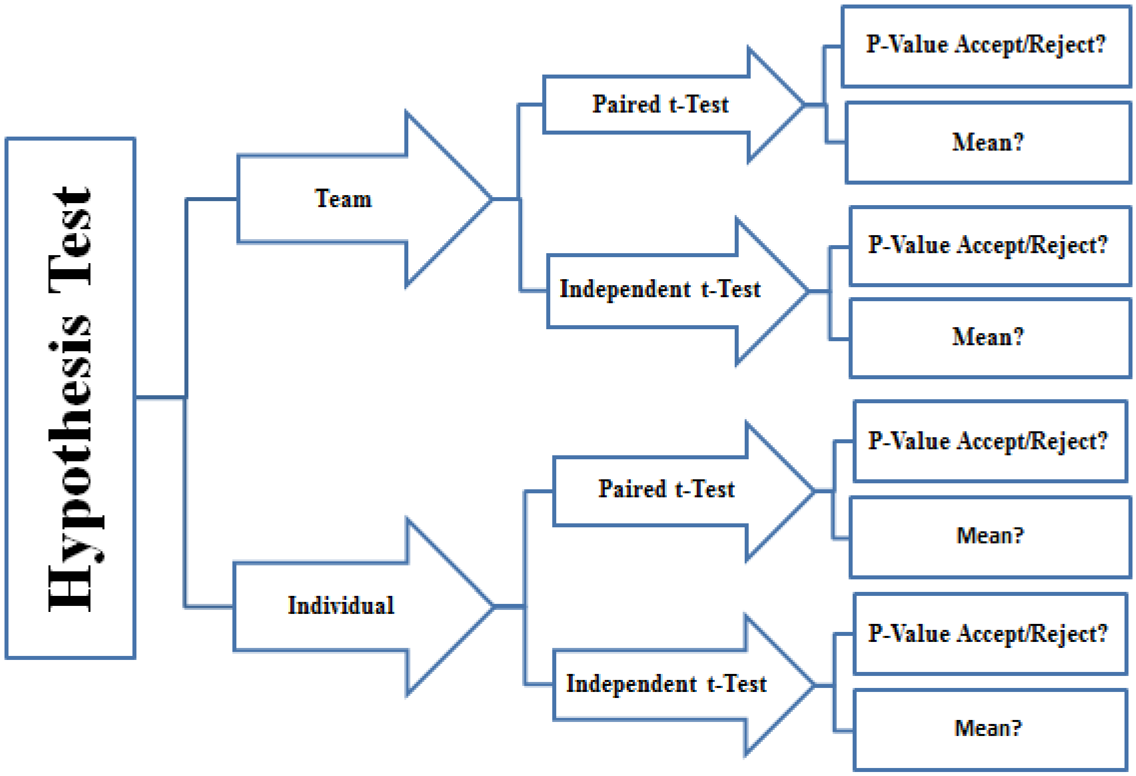


Figure 36. The research hypothesis test steps

In order to validate and measure the potential of the framework, an experiment incorporating an industrial case study was conducted. Undergraduate engineering students were participants in the study conducted to examine the effects of this framework as well as its capabilities on enhancing the engineering leadership in both teams, and individuals for both groups, experimental and control

5.8.1 Team: Average Leadership Skills

As shown in Table 10, there was significant statistical evidence that the null hypothesis must be rejected for the experimental group because the p-value (.010) was less than the significance level (.05). Regarding the control group, no significant change occurred between the pretest and posttest. These analyses prove that the 3D virtual leadership simulation was more effective in enhancing engineering leadership. Also, the results indicated that the traditional leadership development did not enhance engineering leadership in becoming balanced, effective, and well-rounded. As shown in Table 11, the same finding was determined to be true between the control and the experimental group when using an independent t-test.

Table 10

Analysis of the Average Team Leadership Skills: 4-D Leadership System - Paired t-test

	Experiment Group		**Control Group**	
Paired t-test To assess the before and after within the same group	**Pretest** Mean (SD)	0.1418 (0.0578)	**Pretest** Mean (SD)	0.1200 (0.0656)
	Post-test Mean (SD	0.0885 (0.0675)	**Post-test** Mean (SD	0.1525 (0.0607)
	Difference Mean (SD)	-0.0533 (0.0594)	**Difference** Mean (SD)	0.0325 (0.0622)
	Significance, P-Value	T-Value = -2.84 P-Value = 0.010	**Significance, P-Value**	T-Value = 1.65 P-Value = 0.933

Table 11

Analysis of the Average Team Leadership Skills: 4-D Leadership System - Independent t-test

Independent t-test to evaluate the score difference between the Experiment and control		**Experiment Group Mean (SD)**	**Control Group Mean (SD)**	**Significance, P-Value**
	Pretest	0.1418 (0.0578)	0.1200 (0.0656)	T-Value = 0.79 P-Value = 0.441
	Post-test	0.0885 (0.0675)	0.1525 (0.0607)	T-Value = -2.23 P-Value = 0.039

5.8.2 Teams: The Balanced Effect of the 3D Virtual World Leadership Simulation

Figure 37 provides an example of the balanced effect of the 3D virtual world leadership simulation based on the framework. It can be noticed that the experimental group has better balanced leadership skills after the experiment. In the control group, no clear trend in leadership balance is observable.

This balancing effect relocates the leadership skills to the center of the 4-D Leadership graph where the effective leadership skills are mainly located. In the control group charts, there is no indication that the posttest effect is balancing the skills toward the center. This example shows that the administration of the 3D virtual world simulation is a very effective approach to be used in obtaining well-rounded and effective team leadership. Of the 10 teams, nine showed a similar result. All of the remaining team graphs are available for review in Appendix B.

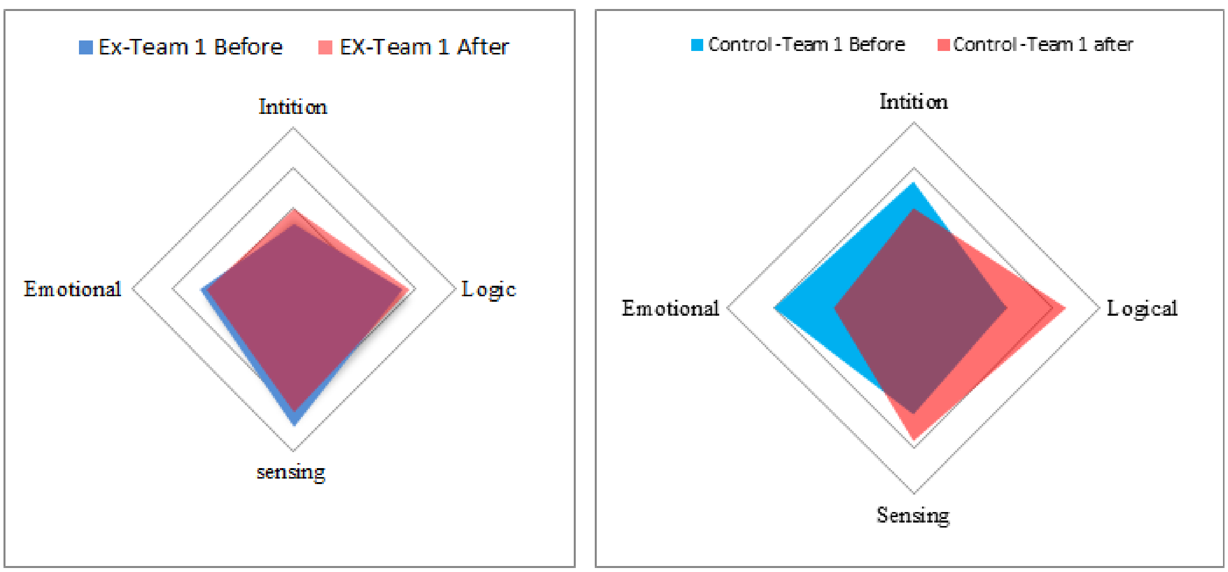


Figure 37. Example of the balanced effect of the 3D virtual world leadership

5.8.3 Individual: Average Leadership Skills

As reflected in Table 12, the 4-D Leadership test results did not show significant statistical evidence for the average individual's engineering leadership in either the experimental or control groups. Therefore, the null hypothesis must be not rejected. However, there was a clear, significant reduction in the ELI's mean of the experimental group compared to the reduction the control group. This reduction in the mean indicate a slight change in the average individual's engineering leadership to be more effective.

Table 12

Analysis of Individuals' Leadership Skills: 4-D Leadership System - Paired t-test

	Experiment (n=42)		Control (n=42)	
Paired t-test To assess the before and after within the	**Pretest** Mean (SD)	0.2099 0.1108	**Pretest** Mean (SD)	0.2545 0.1276
	Post-test Mean (SD	0.1987 0.1110	**Post-test** Mean (SD	0.2551 0.1153
	Difference Mean (SD)	-0.0112 0.1172	**Difference** Mean (SD)	0.0006 0.1074
	Significance, P-Value	T-Value = -0.62 P-Value = 0.269	**Significance, P-Value**	T-Value = 0.04 P-Value = 0.515

However, as shown in Table 13, when evaluating the effective leadership indicator (ELI) means between the experimental and control groups, there was significant statistical evidence indicating that the null hypothesis must be rejected because p-value (.025) was less than the significant level (.05), enabling 95% confidence level that both groups have the same ELI means in the pretest and not the same in the posttest. By having ELI means reduced in the posttest for only the experimental group, it can be concluded that there is a noticeable effect for the 3D virtual world leadership simulation in enhancing the leadership to be more effective in the individual case as well as the team. The results show that the 3D virtual world simulation had more significant impact on enhancing individuals' leadership than did the traditional engineering leadership development method.

Table 13

Analysis of Individuals' Leadership Skills: 4-D Leadership System - Independent t-test

Independent t-test to evaluate the score difference between the Experiment and control		Experiment Group Mean (SD)	Control Group Mean (SD)	Significance, P-Value
	Pretest	0.210 (0.111)	0.255 (0.128)	T-Value = -1.71 P-Value = 0.091
	Post-test	0.199 (0.111)	0.255 (0.115)	T-Value = -2.28 P-Value = 0.025

Figure 38 presents a summary of the results of the statistical analysis of both average teams' leadership skills and the average individuals' leadership skills. There was significant statistical evidence that the 3D virtual world simulation had a positive impact on enhancing the leadership for engineering students to be more effective for engineering teams. Also, the result shows that the effect of the 3D virtual world simulation was not statistically significant when considered on an individual basis. However, there is a slight improvement observed based on the reduction in the ELI means for the individual's leadership in the experimental group. The independent t-test also supports this conclusion that the administration of the 3D virtual world leadership simulation was more impactful on the individual's average leadership than was traditional leadership development.

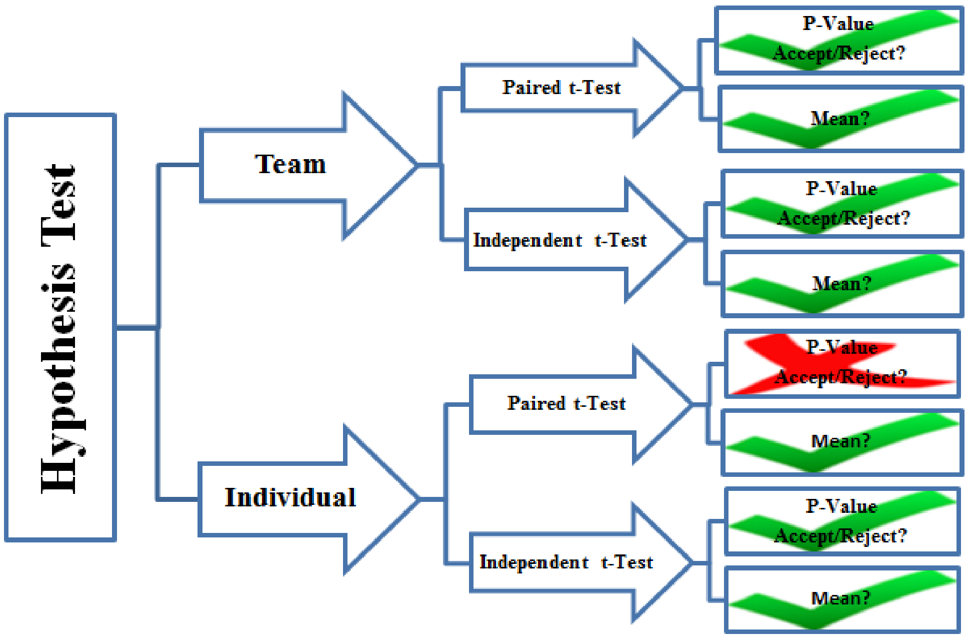


Figure 38. Hypothesis test steps completed

5.9 Effects of 3D Virtual World Simulation on Team and Individual Leadership Skills Based on the 4-D Leadership System

In this section, the effects of 3D virtual world simulation will be examined for the following skills as per the students' responses to the pre and posttest. In the following 10 figures, the percentages of change will be shown to highlight the effect of 3D virtual world simulation represented by the experimental group and traditional engineering leadership development represented by the control group: (a) team conflict; (b) considering people vs. the task; (c) considering future or current thinking; (d) relying on creativity vs. common sense; (e) harmonious relationships vs. being right; (f) logic vs. feeling; (g) inner thinking vs. observation; (h) decide through consensus vs. own thinking; (i) big ideas vs. established reality; and (j) details vs. a holistic approach.

5.9.1 Effects of 3D Virtual World Simulation on Team Conflict

Figure 39 shows that team conflict tolerance among the team members increased by almost 5% for the experimental group while there was no change in the control group. This result indicates that the 3D virtual world leadership simulation enhanced the team's stability and performance as well as encouraged creative and diverse ideas by encouraging more discussions and being able to tolerate the conflict and disagreement between team members. This is evidence that the 3D virtual leadership simulation can enhance the blue and orange leadership style.

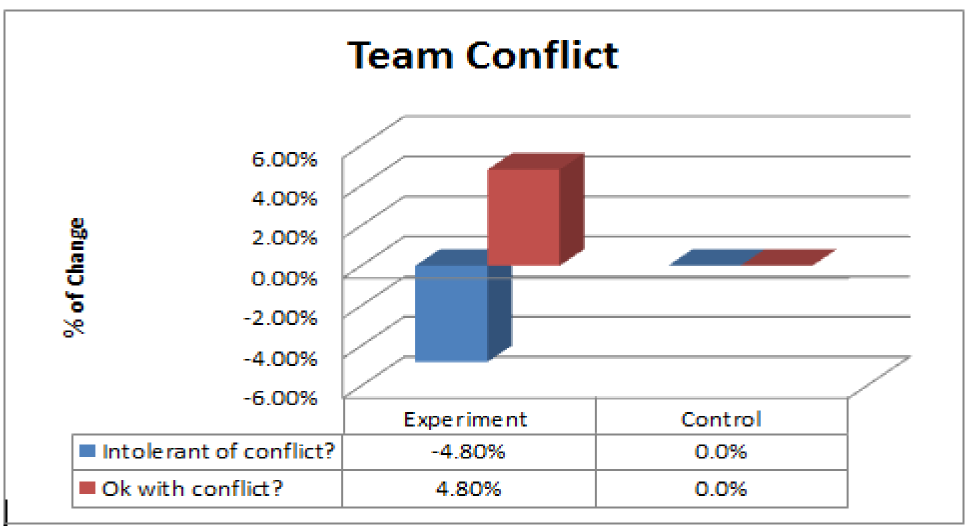


Figure 39. Percentage of change in team conflict

5.9.2 Effects of 3D Virtual World Simulation on Considering People or Task in the Leadership Decision Making Process

As shown in Figure 40, while working in teams, the experimental group participants' perspective toward either considering people or tasks first, was shifted toward task by 2.4% for the experimental group and 9.5% for the control group participants. This indicates that the 3D virtual world simulation participants were considering the importance of people and tasks in an almost equal manner, demonstrating a balanced approach between the cultivating and including leadership styles on one side and directing and visionary leadership style on the other side. The result for the experimental group also shows balance between the emotional and logical sides.

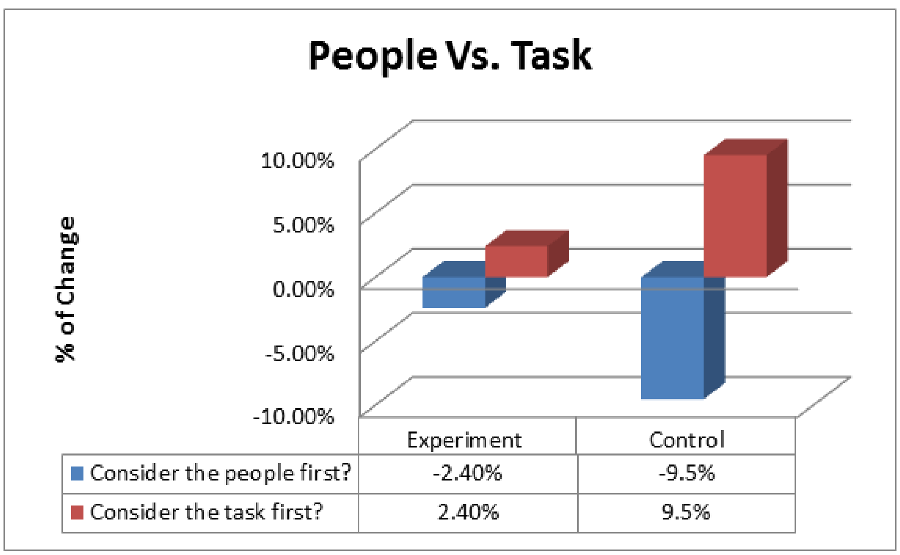


Figure 40. Considering the people or the task first

5.9.3 Effects of 3D Virtual World Simulation on Considering Visionary Leadership Solutions

As shown in Figure 41, 3D virtual world simulation’s participants preferred considering a futuristic thinking approach over a status-quo or current situation thinking approach by almost 14.3%. In contrast, the control group participants shifted by almost 12% toward thinking about the current situation of the organization. This is another indication that the 3D virtual simulation helps undergraduate engineering students to develop into more visionary leaders.

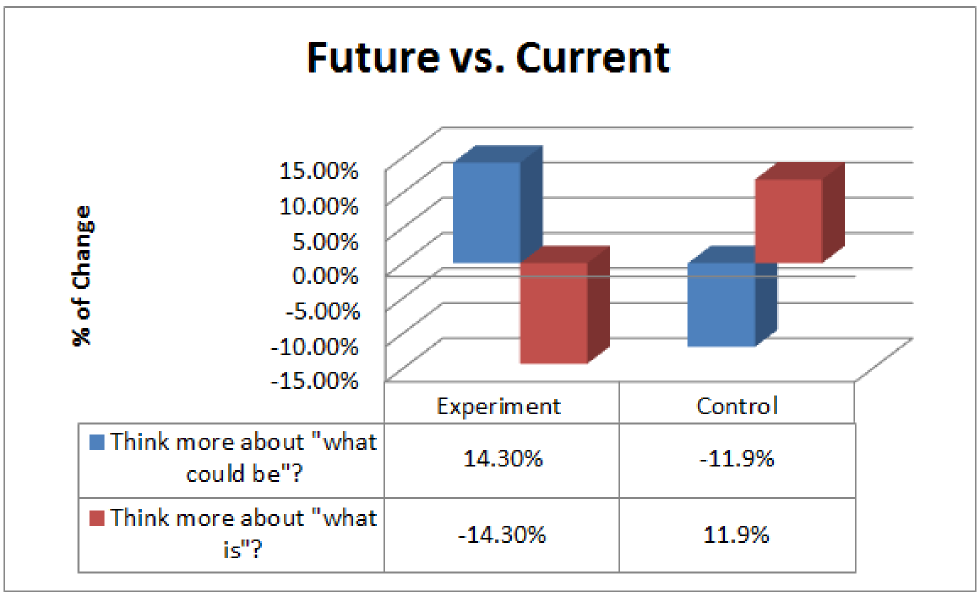


Figure 41. Thinking about the future or current matters

5.9.4 Effects of 3D Virtual World Simulation on Considering Creativity or Common Sense

Figure 42 indicates there was no change in the creativity and common sense preference of participants as a result of the 3D leadership virtual simulation. On the other hand, there was almost a 7% change toward preferring creativity over common sense in the control group. This indicates that the 3D virtual world simulation had no effect on choosing either creativity over common sense or vice versa.

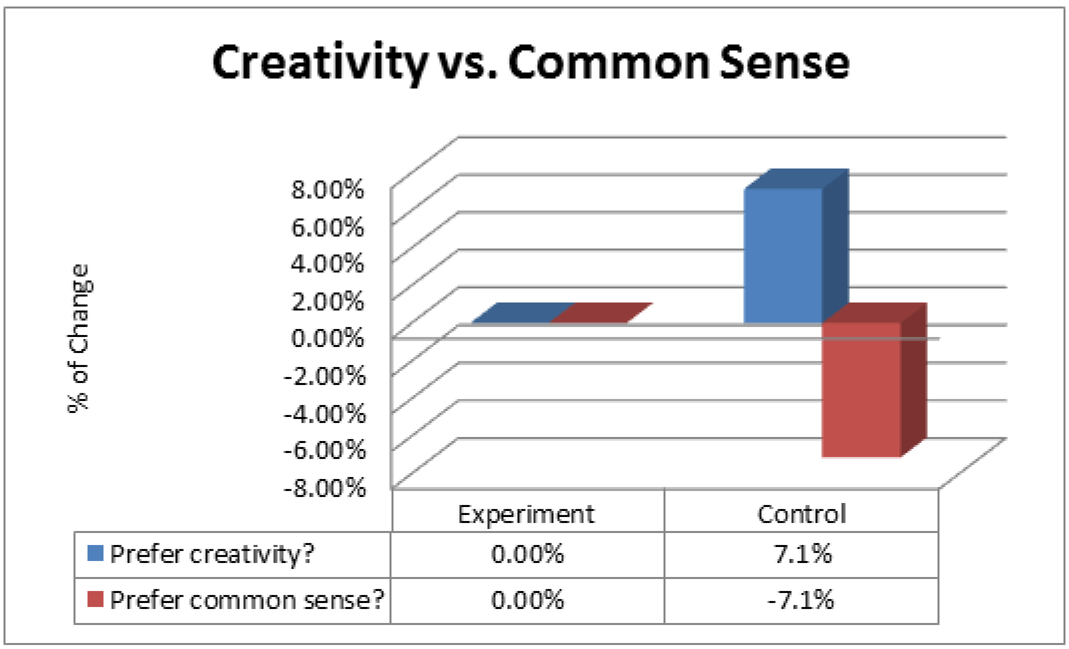


Figure 42. Preferring creativity or common sense

5.9.5 Effects of 3D Virtual World Simulation Enhancing Team Member Relationships

Figure 43 reveals that there was almost a 21% change in the experimental group between pre- and post-test toward choosing the harmonious relationship over being right and only a 9.5% change in the control group. This is one of the great advantages of the 3D virtual world leadership simulation in preparing undergraduate engineering students to be great team members. As stated in Chapter 2, engineering curricula usually focus on the technical and engineering issues and ignore the development of communication and personal and leadership development. In this study, the 3D virtual world leadership simulation based on the undergraduate engineering student's leadership development framework enhanced the including and cultivating leadership skills almost twice as much as did the traditional engineering leadership development.

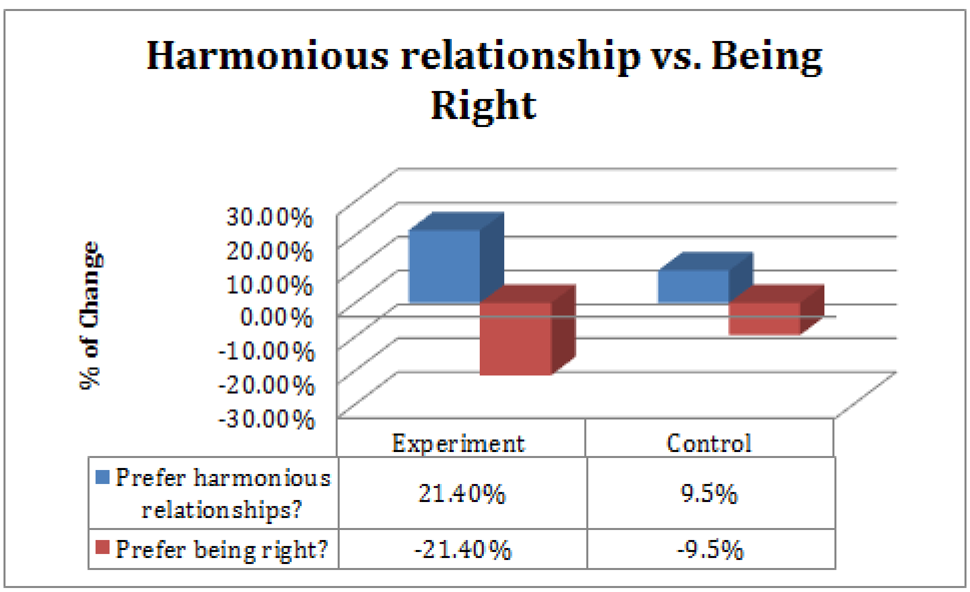


Figure 43. Harmonious relationship vs. being right

5.9.6 Effects of 3D Virtual World Simulation on the Logical Leadership Skills

Figure 44 shows that the 3D virtual world leadership simulation enhanced the logical thinking approach by almost 7% more than did the traditional leadership method represented in the control group. This result supports the fact that in the present study, the 3D virtual simulation enhanced the visionary and directing leadership styles more than did the traditional method.

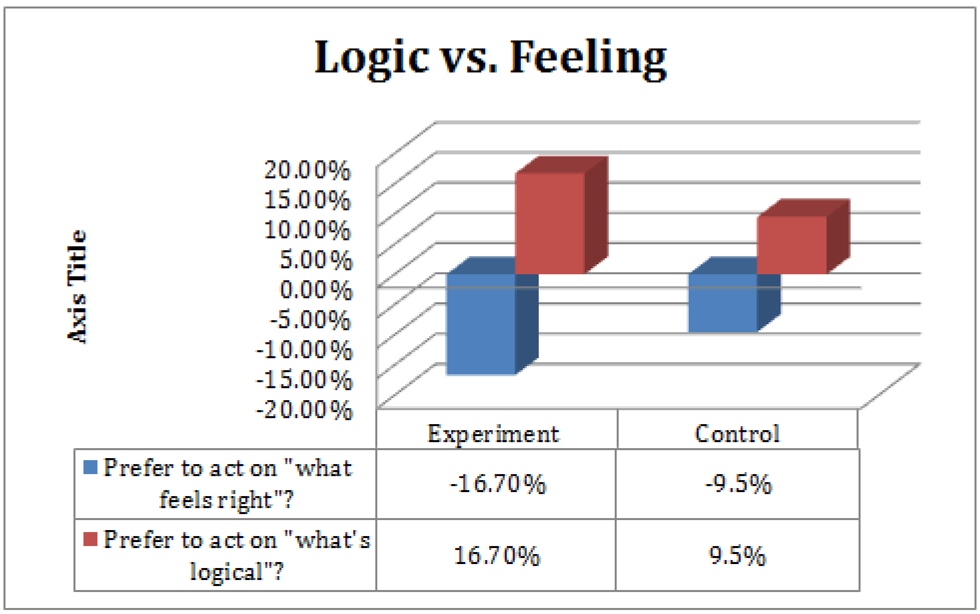


Figure 44. Logic vs. feeling

5.9.7 Effects of 3D Virtual World Simulation on Considering Intuition and Inner Thinking

Figure 45 shows that there was an increase in the use of intuitive skills in the experiment group as a result of the 3D virtual world leadership simulation, but that there was a reduction in the use of intuition by the same amount for participants in the traditional method of engineering leadership development. This result supports that the 3D virtual simulation has, to a certain extent, more potential than traditional methods to affect the intuition abilities of undergraduate engineering students .

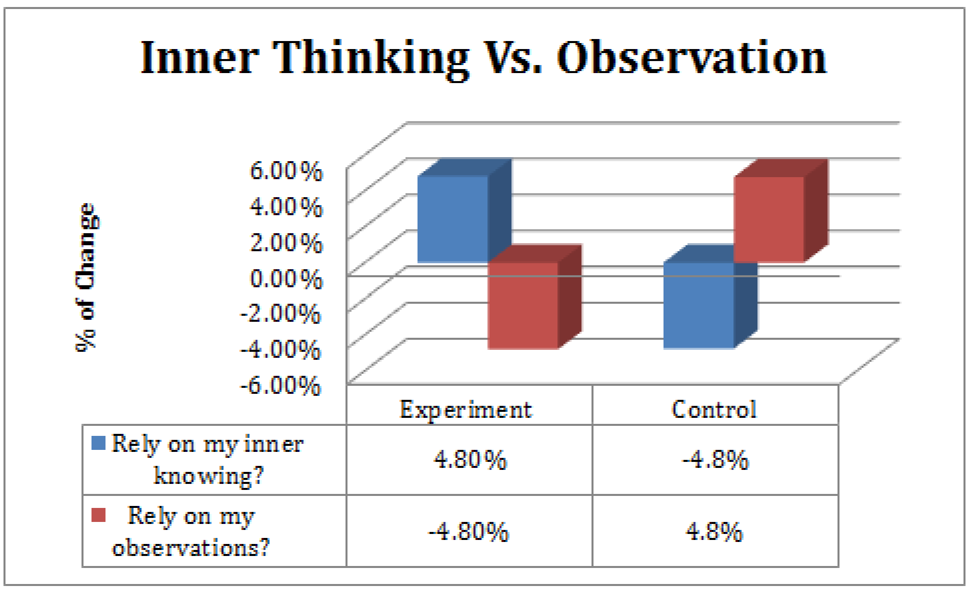
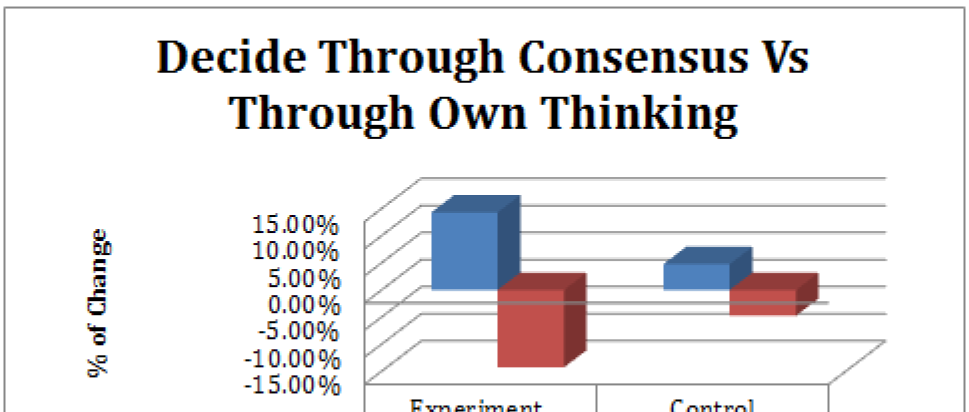


Figure 45. Inner thinking vs. observation

5.9.8 Effects of 3D Virtual World Simulation on Considering Consensus in Decision Making

Figure 46 displays a magnificent result, revealing that the effect of the 3D virtual world leadership simulation in team building in this study was unmatched and extraordinary. There was a shift of 14.5% in the experimental group in preferring to seek consensus while there was only a 4.8% shift in the control group as result of the traditional method. This result supports that the 3D virtual simulation can affect the collaboration abilities of students to work effectively in teams.

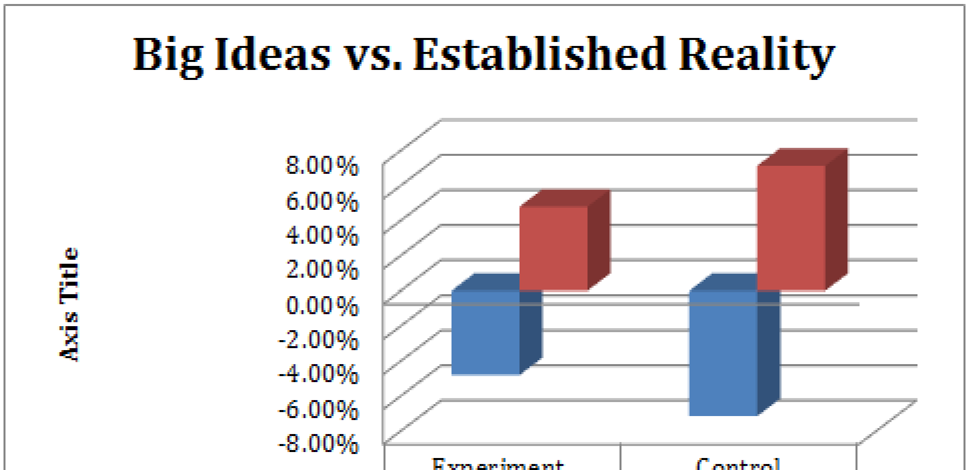


	Experiment	Control
Decide through consensus?	14.30%	4.8%
Decide with my own thinking?	-14.30%	-4.8%

Figure 46. Decide through consensus vs. own thinking

5.9.9 Effects of 3D Virtual World Simulation on Considering Creative and Innovative Approaches

Given the nature of engineering thinking, students used their sensing and observation approach to reach judgments. In Figure 47, one can notice an interesting phenomenon. Participants of the 3D virtual world leadership simulation were almost 3% better than traditional engineering method participants in their shift toward established reality. This means that the 3D virtual world simulation encouraged engineering students to be creative and visionary by considering new and big ideas.



	Experiment	Control
Love big ideas?	-4.80%	-7.1%
Love established reality?	4.80%	7.1%

Figure 47. Big ideas vs. established reality

5.9.10 Effects of 3D Virtual World Simulation

on Considering Visionary and Holistic Approaches

Similar to the prior example (i.e., creative and innovative approaches), Figure 48 shows that the 3D virtual world leadership simulation was 5% more successful in reducing the preference for detailed thinking than the traditional method represented in the control group. Engineering students used their sensing and observation approach to reach judgments. Being able to consider a holistic approach is a great visionary engineering leadership approach.

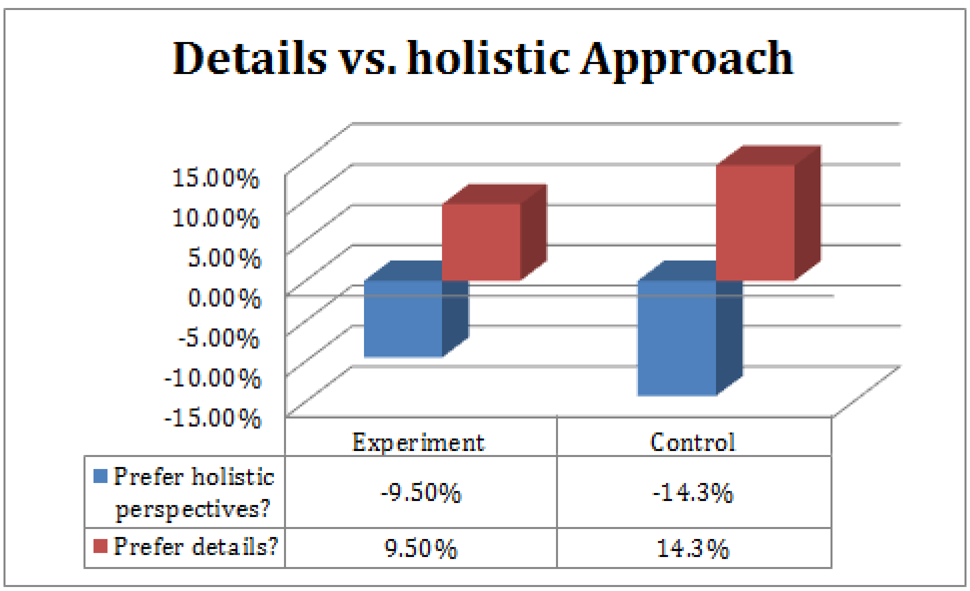


Figure 48. Details vs. holistic approach

5.10 Conclusion

In this chapter, the researcher has illustrated the implementation of an experiment using an industrial leadership case study in a virtual world simulation. The experimental design steps have been presented followed by the results and findings that were obtained from the 4-D

Leadership classification scheme results for both teams and individual to test the research null hypotheses. Finally, the effects of the 3D virtual world simulation on various important leadership skills were reported based on the 4-D leadership responses from students' pre and post-leadership tests.

The results indicate that this framework is a potential method for enhancing engineering leadership development in teams and on an individual basis:

1. There is statistical evidence that the administration of the virtual world simulation incorporating an industrial leadership case study enhanced engineering teams' leadership. In contrast, there was no statistical evidence to support the impact of the traditional leadership method on engineering teams' leadership.
2. There was a noticeable enhancement in individuals' engineering leadership as a result of administering the virtual world simulation. No enhancement was noticed as a result of the traditional engineering leadership method (e.g., lectures, power point).
3. Detailed analysis of participants' responses revealed that the framework, using virtual world simulation and incorporating an industrial case study, had a greater impact on achieving effective engineering leadership than did traditional engineering leadership development in both team and individual cases.

CHAPTER 6: CONCLUSIONS, CONTRIBUTIONS, AND FURTHER RESEARCH

6.1 Introduction

Due to numerous effects of leadership styles on the decision making process, there is a great demand for engineering leadership development. Organizations cannot achieve their ultimate goals without having effective leadership. Researchers have shown that engineering programs are lacking in training their students in leadership and management skills (Kotnour et al., 2014; Özgen et al., 2013). Also many researchers have recommended that engineering curricula should be modified for the purpose of producing leaders who can be effective leaders. Also, researchers have found that due to the absence of experiential learning in engineering programs, engineering leadership development was not being as successful as it could for undergraduate engineering students. This framework incorporating virtual world simulation based on an industrial case study for undergraduate students engineering teams tested a solution for this current engineering leadership failure (Gurdjian et al., 2014). In order for future engineers to be fully prepared to be great leaders, the current traditional engineering leadership development must include a holistic engineering leadership approach.

In this dissertation, the researcher introduced an innovative framework of leadership development based on a comprehensive and well proven leadership classification scheme integrated with virtual world simulation utilizing industrial leadership case studies. Figure 49 provides a visual explanation of the undergraduate engineering leadership development framework which guided this study.

6.2 Undergraduate Engineering Leadership Development Framework

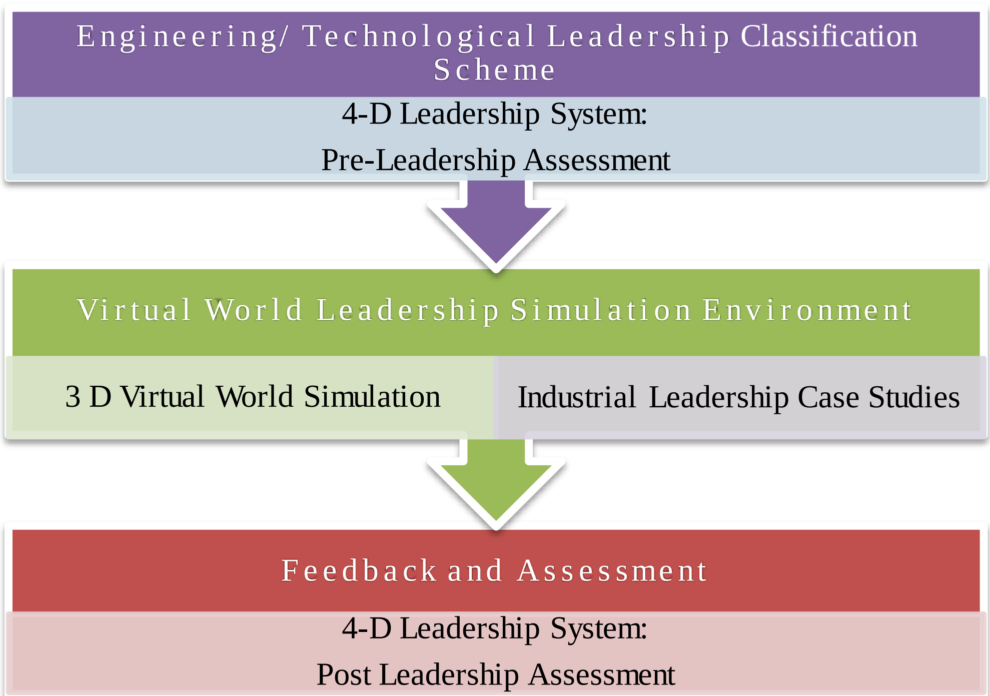


Figure 49. A holistic framework for effective engineering leadership development

Literature gaps revealed that a holistic engineering leadership framework was needed in order to develop leaders in engineering. Also, the gaps indicated the weakness of current traditional leadership development. It was clear that the framework needed to include the following components:

1. A technological and engineering leadership classification scheme appropriate for engineering to provide assessments and help in the development of education/training materials; thus, the 4-D Leadership System was selected.

2. Due to the great results that have been generated from the use of simulation in education and training, simulation was selected to provide students with hands-on experience through real life industry leadership scenarios. Simulation can mimic the real environment and allow participants practice, interact, and receive feedback in real time (Bhide, 2015).
3. Industry case studies were incorporated with the 3D virtual world environment to facilitate leadership development for undergraduate engineering students.
4. The framework steps were used in designing the 3D virtual world leadership simulation so as to derive maximum benefits for undergraduate engineering students in their leadership development training.
5. The 4-D Leadership post assessment was used to assess the effects of the framework in enhancing engineering leadership development and validating the effectiveness of the framework as a potential solution for current engineering leadership failures.

6.3 Summary and Conclusion

Engineers have an essential role as leaders of teams and technical personnel tasked with creating, designing, and implementing engineering tasks effectively and efficiently. This research was focused on ways to enhance the quality of engineering leadership development programs for undergraduate engineering students in order that they are better prepared as they assume their places in the profession. In this study, the researcher proposed an engineering leadership development framework using an industrial case study approach that incorporated in 3D virtual world simulation. Using this framework, the 3D virtual world environment was carefully designed, based on unique planning processes that incorporate industrial case studies and an engineering leadership classification scheme. Significant insights about engineering leadership development gained through the literature review and the gaps identified in the literature were useful in settling on essential components of the framework.

There are several classification schemes which have been used to understand and scale leadership styles and identify innate personality and leadership traits. The researcher focused on technological and engineering leadership classification schemes that might best serve undergraduate engineers in their preparation for leadership positions. Guided by criteria related to the specific nature of engineering technological leadership requirements, the 4-D Leadership System was selected for use in this research due to the advantages in identifying engineering and technical teams' behaviors and projects phases, in assessing engineering leadership, and in the development of education/training materials.

Also investigated in this research were the advantages of using 3D virtual world simulation in education and training. 3D virtual world simulation supports communication, team discussion and negotiations and also bridges the gap between experiential learning and traditional methods of education and training. It can engage users by creating a sense of being present in an environment; it encourages risk-taking and exploring while learning new ideas, skills, and techniques. Due to these advantages and others, 3D virtual world simulation was used to design the virtual engineering leadership activity based on selected industrial leadership case studies to allow students to gain maximum benefits from their leadership training.

The leadership development framework was validated to ensure the effectiveness and ability of such a framework to enhance the leadership development of undergraduate students. This framework was examined and validated by a randomized pretest-posttest control group design. A paired t-test showed a statistical significance of the development in the average team leadership skills in the experimental group; however, no significant change occurred in the control group teams. The same results were observed in a two-sample t-test when both experimental and control groups were evaluated. There was a reduction in the mean of individuals' tests. This indicated that there was a small enhancement in individuals' leadership skills but that the change was small and statistically insignificant.

Based on the detailed analysis of participants' responses, it can be concluded that this framework, using virtual world simulation and incorporating an industrial case study, had a greater positive impact on engineering leadership development than did the traditional engineering leadership development in both team and individual cases. The research has resulted in insights that should be useful in assisting engineering programs to improve curricula and strengthen engineering leadership preparation undergraduate engineering students to meet industry demands.

Fostering 3D virtual leadership and incorporating industrial case studies in the curricula of undergraduate engineering students has great potential in further developing undergraduate engineering students' leadership skills. It can enhance their communication, teambuilding, and business skills through the use of practical scenarios and provide a viable alternative to more costly experiential real-world preparation.

6.4 Contributions

In this study, the main objective was to contribute innovative ways to address the existing leadership failures within the field of engineering leadership development. This researcher sought to identify and test innovative techniques to help engineering programs in improving leadership development for undergraduate engineering students. The contributions of this dissertation are as follows:

1. This is the first framework for engineering leadership development that integrates industrial case studies with the design of a 3D virtual world simulation environment along with a 4-D Leadership System classification scheme. The purpose of the framework was to implement practical, customized and innovative engineering leadership development to help engineering schools, organizations, and leadership development institutions more effectively develop true and capable engineering leaders. This framework is the first framework that provides for a comprehensive, holistic, and practical virtual leadership development training activity after carefully selecting the right leadership scenario and the right virtual environment.
2. The framework enabled the establishment of innovative team leadership development for undergraduate engineering students that targeted the team as a unit rather than individual team members. This was accomplished by training individuals while they were actually carrying out their assigned responsibilities as team members.
3. According to Wysocki (2002), there are four critical team success factors: (a) a balanced problem-solving capability; (b) a balanced decision-making capability; (c) a balanced conflict management capability; and (d) a balanced skill profile (i.e., diversity). In this dissertation, the researcher successfully created, developed and implemented a balanced 4-D leadership approach to enhance all four engineering leadership styles (engineering visionary leadership style, engineering cultivating leadership style, engineering including leadership style and directive engineering

leadership style) to a balanced level to allow teams and individuals be able to lead different teams and projects effectively.

6.5 Future Research

There was a noticeable reduction in the mean score of individual posttest results compared to the pretest, but there was no statistical significance in the individual case. This reduction indicated that the leadership of students on an individual basis was becoming well-rounded along the same lines as the average team leadership skills. One possible explanation is that the duration of the 3D virtual leadership simulation was not enough to reflect the enhancement on the individual as it does in the team case. In the future, a researcher might replicate the study over a longer period of time to further explore the effect of the leadership development on individuals.

This study was designed, using the 3D virtual world leadership simulation activity based on a case study that targeted multi-engineering disciplines. It would be appropriate to further explore more specialized industrial case studies, focusing on specific engineering majors such as Civil Engineering, Industrial Engineering and Electrical Engineering.

Participants in this study were undergraduate engineering students. Future research might be focused on graduate students to determine their leadership preparation needs and whether similar simulation activities might be beneficial to them.

This study was quantitative in nature and did not take into account the perceptions of the participants regarding the simulation experience. A qualitative study using interview techniques would be a logical follow-up to this study to determine what strengths or weaknesses in the program participants would identify.

It is important to develop a methodology using system engineering principles to select and organize the case studies. The objective would be to have many case studies in order to create a better environment for leadership development.

APPENDIX A: INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Hamed M. Almalki**

Date: **November 09, 2015**

Dear Researcher:

On 11/09/2015, the IRB approved the following human participant research until 11/08/2016 inclusive:

Type of Review: UCF Initial Review Submission Form
Project Title: Engineering Leadership Development Framework using 3D Virtual Simulation and Culture Foundation
Investigator: Hamed M Almalki
IRB Number: SBE-15-11713
Funding Agency:
Grant Title:
Research ID: N/A.

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 11/08/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

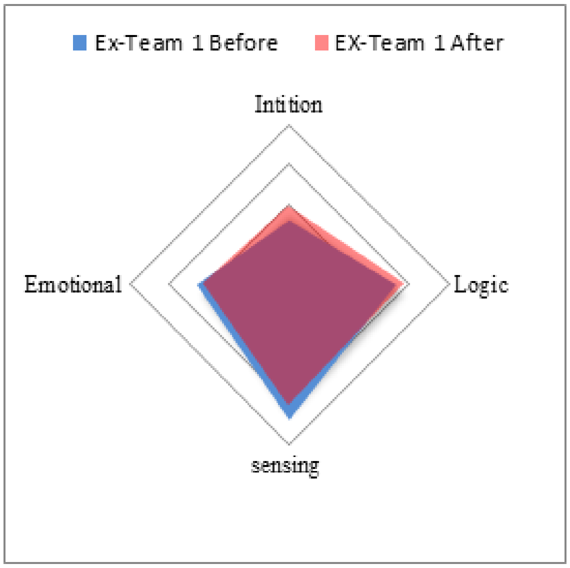
Signature applied by Joanne Muratori on 11/09/2015 03:27:57 PM EST

IRB Manager

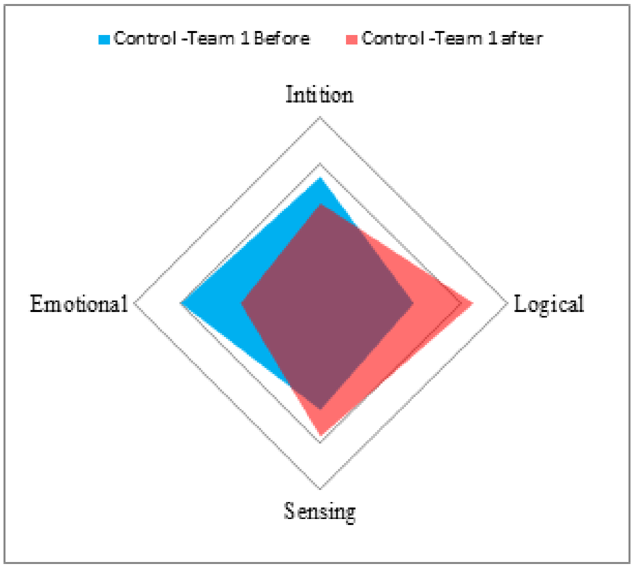
APPENDIX B: RADAR CHARTS

Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 1

Experimenral Group

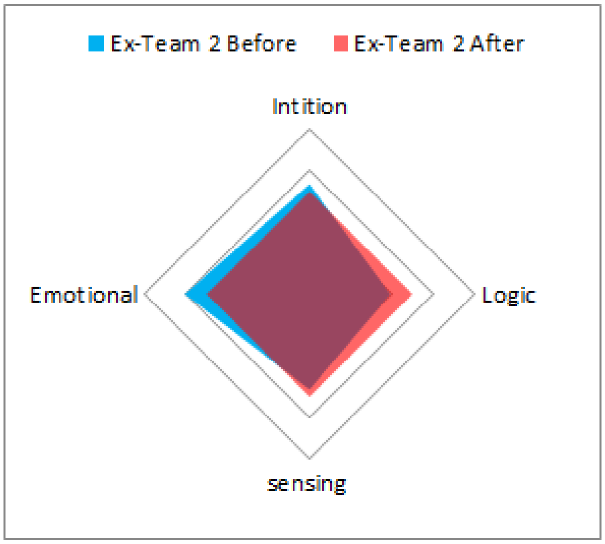


Control Group



Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 2

Experimenral Group



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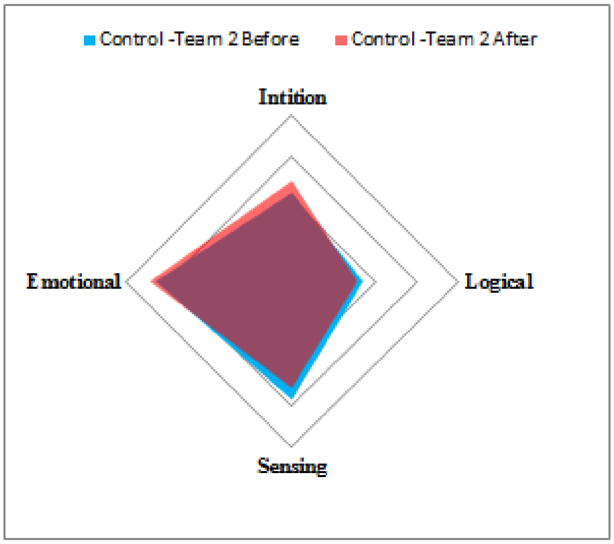
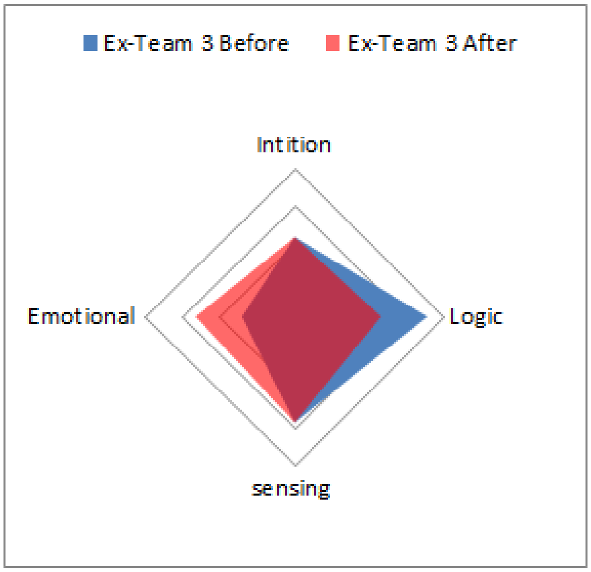
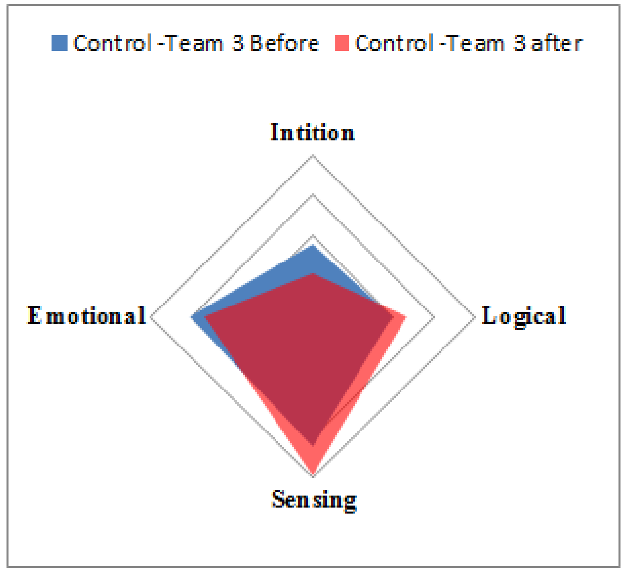


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 3

Experimenral Group

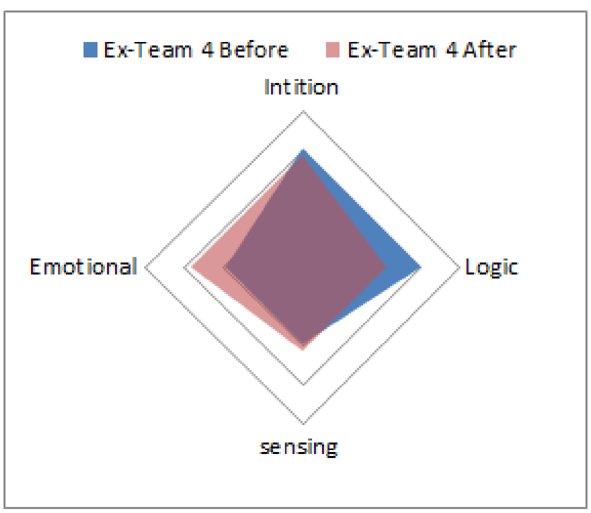


Control Group

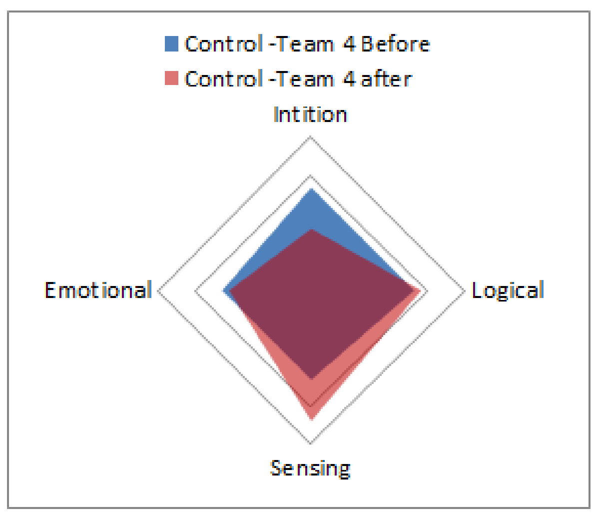


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 4

Experimenral Group

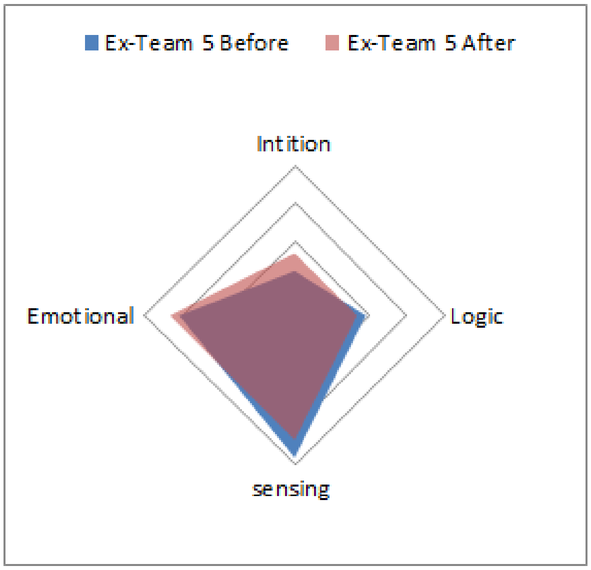


Control Group

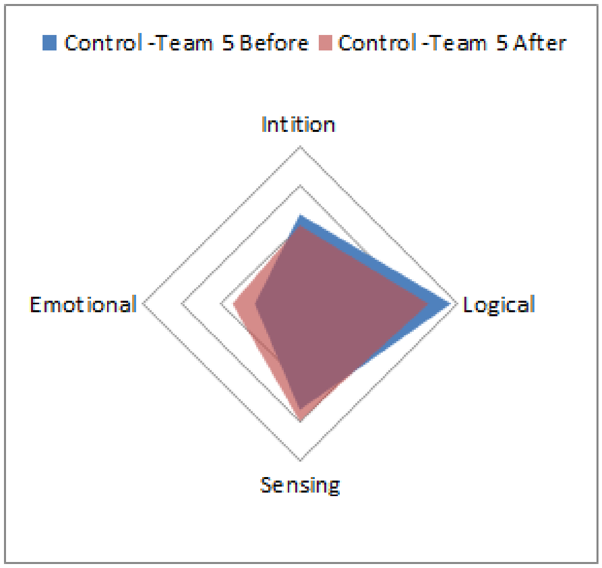


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 5

Experimenral Group

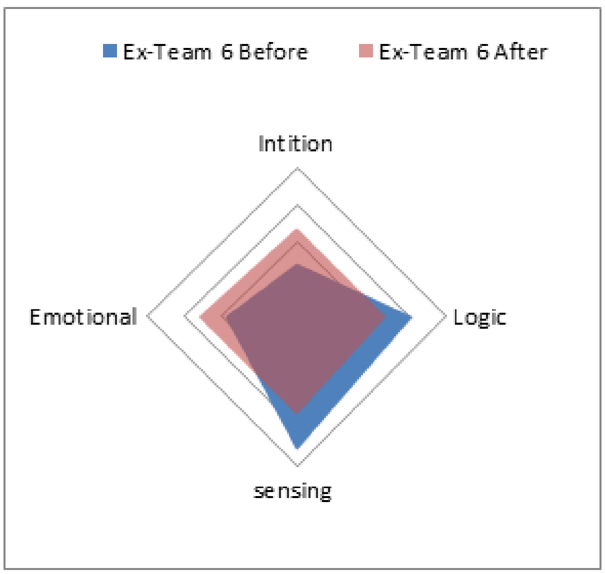


Control Group

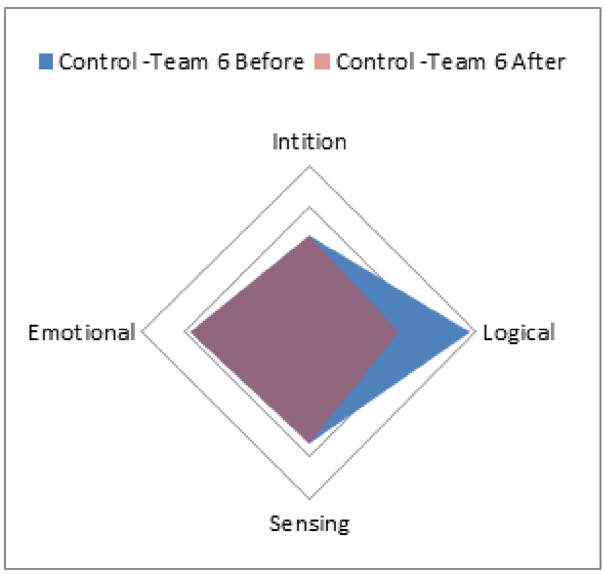


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 6

Experimenral Group

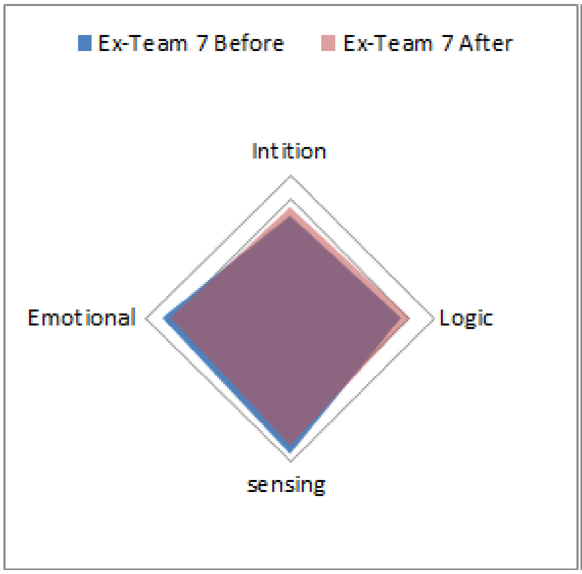


Control Group

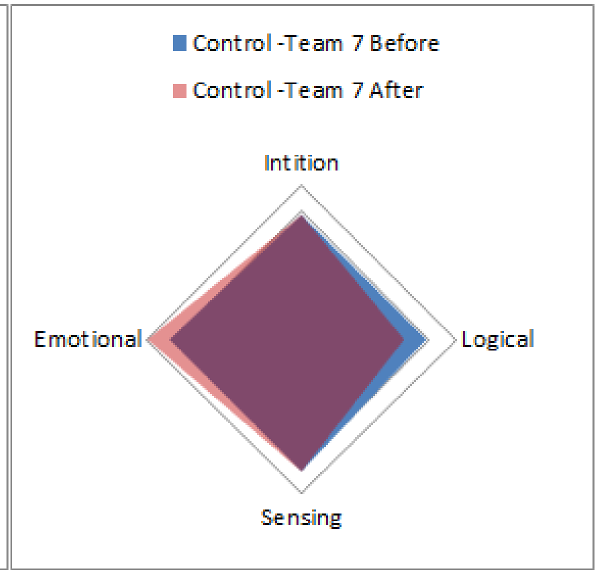


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 7

Experimenral Group

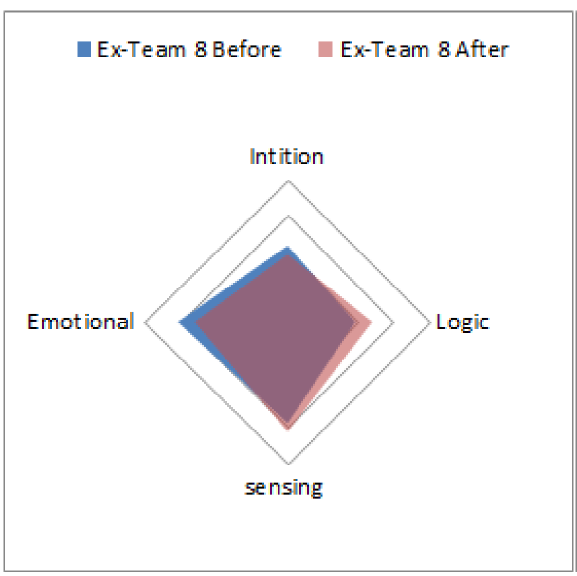


Control Group

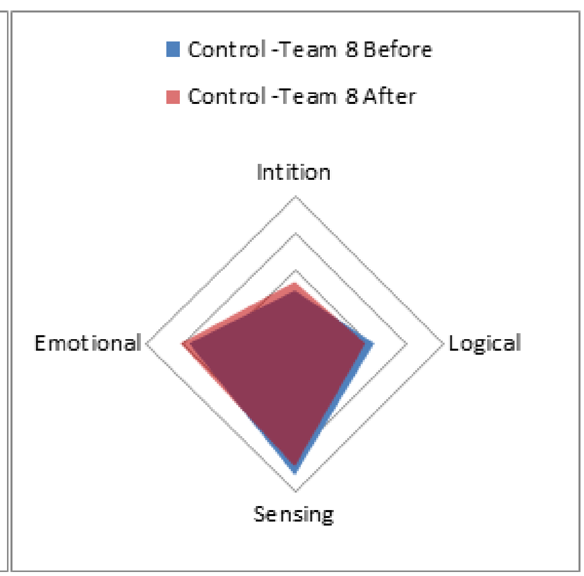


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 8

Experimenral Group

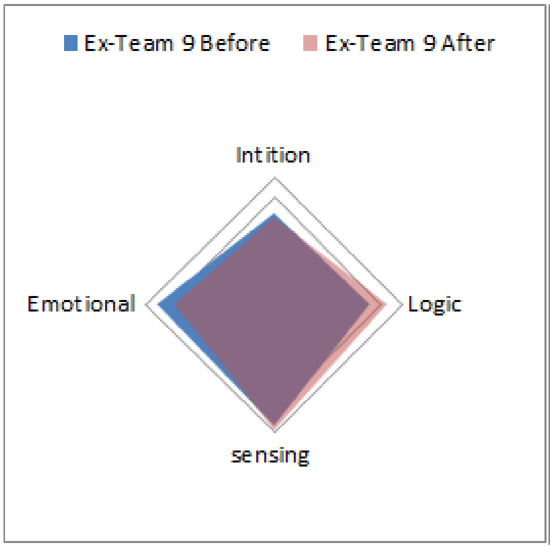


Control Group



Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 9

Experimenral Group



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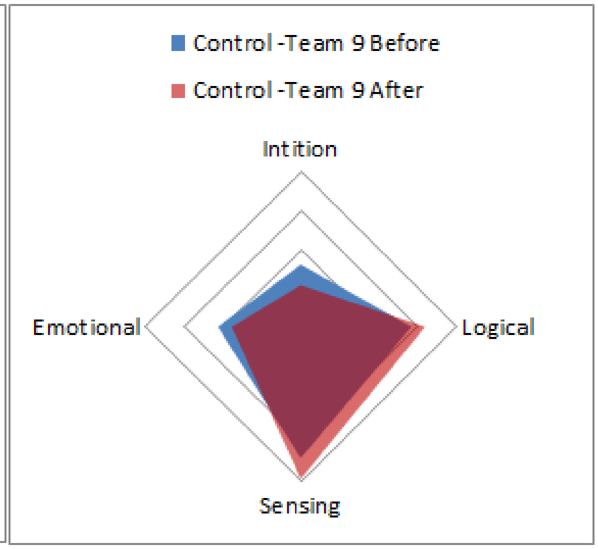
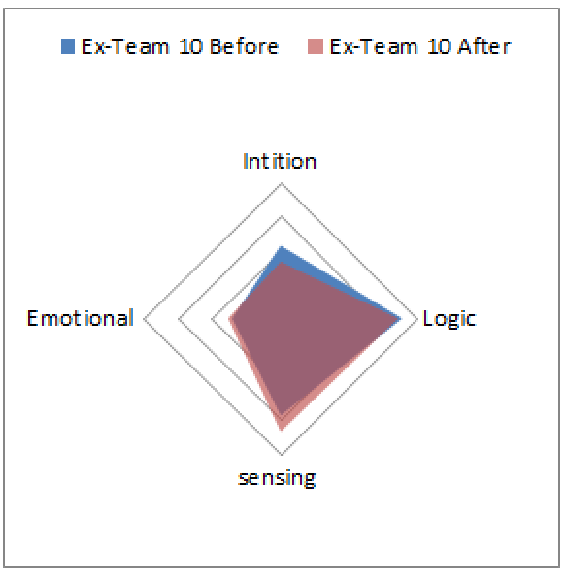


Radar Chart of The balanced Effect of 3D virtual Leadership Simulation: Average Leadership Style: Team 10

Experimenral Group



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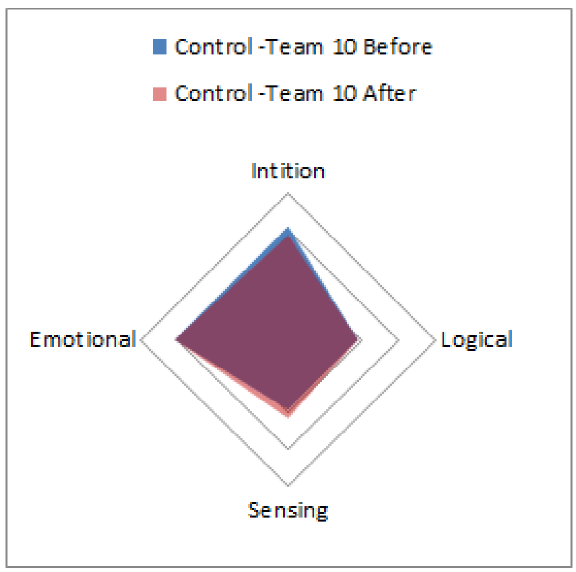

REFERENCES

Abraham, S. C. (2006). *Strategic planning*: A practical guide for competitive success. Mason, OH: Thomson South-Western.

Alrayes, A., & Sutcliffe, A. (2011). Students' attitudes in a virtual environment (secondlife). *Journal of Virtual Worlds Research, 4*(1), 4-17.

Babuscia, A., Craig, J. L., & Connor, J. A. (2012). Teaching practical leadership in MIT satellite development class: CASTOR and Exoplanet projects. *Acta Astronaut*, 77, 138-148.

Bamodu, O., & Ye, X. M. (2013). Virtual reality and virtual reality system components. *Advanced Materials Research, 765*(1), 1169.

Bass, B. M. (1998). *Transformational Leadership: Industry, Military, annd Educational Impact*. Hillsdale, NJ: Lawrence Erlbaum.

Bayless, D. J. (2010). *Leadership education for engineering students*. Paper presented at the 40th ASEE/IEEE Frontiers in Education Conference, Washington, DC.

Bhide, S., Riad, R., Rabelo, L., Pastrana, J., Katsarsky, A., & Ford, C. (2015). *Development of virtual reality environment for safety training*. IIE Annual Conference.Proceedings, , 2302-2312. Retrieved from https://login.ezproxy.net.ucf.edu/login?url=http://search.proquest.com/docview/1792029019?accountid=10003

Bradley, J. H., & Hebert, F. J. (1997). The effect of personality type on team performance. *Journal of Management Development, 16*(5), 337-353. doi:10.1108/02621719710174525

Brashears, A., Meadows, A., Ondrejka, C., & Soo, D.. (2003l). *Linden scripting language guide*. San Francisco, CA: Linden Language Lab. Retrieved from http://redwood.colorado.edu/jkb/csci1220/docs/Linden%20Scripting%20Language%20Guide.pdf

Briggs-Myers, I., McCaulley, M. H., Quenk, N. L., & Hammer, A. L. *Manual: A guide to the development and use of the Myers-Briggs Type Indicator* [measurement instrument]. Palo Alto, CA: Consulting Psychologists Press.

Brown, F. W., & Reilly, M. D. (2009). The *Myers-Briggs Type Indicator* [measurement instrument] and transformational leadership. *Journal of Management Development, 28*(10), 916-932. doi:10.1108/02621710911000677

Callaghan, M. J., McCusker, K., Lopez Losada, J., Harkin, J. G., & Wilson, S. (2009). Engineering education island: Teaching engineering in virtual worlds. *Innovations in Teaching & Learning in Information & Computer Sciences, 8*(3), 2-18.

Caza, A., & Rosch, D. M. (2014). An exploratory examination of students' pre-existing beliefs about leadership. *Studies in Higher Education, 39*(9), 1586-1598.

Cheng, A., Auerbach, M., Hunt, E. A., Chang, T. P., Pusic, M., Nadkarni, V., & Kessler, D. (2014). Designing and conducting simulation-based research. *Pediatrics, 133*(6), 1091-1101.

Chorafas, D. N., & Steinmann, H. (1995). *Virtual reality : Practical applications in business and industry*. Englewood Cliffs, NJ: Prentice Hall.

Cianfrani, C. A., Tsiakals, J. J., & West, J. E. (2002). *The ASQ ISO 9000:2000 handbook*. Milwaukee, WI: ASQ Quality Press.

Clinebell, S., & Stecher, M. (2003). Teaching teams to be teams: An exercise using the Myers-Briggs type indicator and the five-factor personality traits. *Journal of Management Education, 27*(3), 362-383. doi:10.1177/1052562903251353

Collins, J. C. (2001). *Good to great : Why some companies make the leap--and others don't* (1st ed.). New York, NY: HarperCollins.

Conine, T. E. (2014). The virtual simulation: A tool for leadership education in global corporations. *Global Business & Organizational Excellence, 33*(5), 17-28. doi:10.1002/joe.21560

Cox, M. F., Cekic, O., & Adams, S. G. (2010). Developing leadership skills of undergraduate engineering students: Perspectives from engineering faculty. *Journal of STEM Education: Innovations & Research, 11*(3/4), 22-33.

Cox, M. F., Cekic, O., Ahn, B., & Zhu, J. (2012). Engineering professionals' expectations of undergraduate engineering students. *Leadership & Management in Engineering, 12*(2), 60.

Crumpton-Young, L., McCauley-Bush, P., Rabelo, L., Meza, K., Ferreras, A., Rodriguez, B., . . . Kelarestani, M. (2010). Engineering leadership development programs: A look at what is needed and what is being done. *Journal of STEM Education: Innovations & Research, 11*(3/4), 10-21.

Cruz-Benito, J., R., García-Peñalvo, F. J., & Pizarro, L. E. (2015). Discovering usage behaviors and engagement in an educational virtual world. *Computers in Human Behavior, 47*, 18-25. doi:10.1016/j.chb.2014.11.028

Dimitris N., Chorafas, H. S. (1995). *Virtual Reality Practical Application in Business and Industry*. Englewood Cliffs: Prentice Hall PTR.

Elattar, A. A. (2014). *A holistic framework for transitional management. [electronic resource]*: Orlando, Fla. : University of Central Florida, 2014.

Farr, J. V., & Brazil, D. M. (2009). Leadership Skills Development for Engineers. *Engineering Management Journal, 21*(1), 3-8.

Figueiredo, A. (2006). *Managing learning in virtual settings the role of context*. Hershey, PA: Information Science.

Fox, J., Ahn, S. J., Janssen, J. H., Yeykelis, L., Segovia, K. Y., & Bailenson, J. N. (2015). Avatars versus agents: A meta-analysis quantifying the effect of agency on social influence. *Human-Computer Interaction, 30*(5), 401-432. doi:10.1080/07370024.2014.921494

Froh, J. P. (2003). *An exploratory study on visionary leadership development in an electrical engineering program at the undergraduate level.* (Doctoral dissertation). Capella University, Ann Arbor. Retrieved from https://login.ezproxy.net.ucf.edu/login?url=http://search.proquest.com/docview/305212734?accountid=10003

Girvan, C. (2013). *What is a virtual world? Definition and classification*. Retrieved from http://sfx.fcla.edu/ucf?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=ProQ:ABI%2FINFORM+Global&atitle=&title=An+exploratory+study+on+visionary+leadership+development+in+an+electrical+engineering+program+at+the+undergraduate+level&issn=&date=2003-01-

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Gurdjian, P., Halbeisen, T., & Lane, K. (2014). Why leadership-development programs fail. *McKinsey Quarterly*, 121.

Harper, R. (2003). *Inside the smart home*. New York: Springer.

Hartmann, B. L., & Jahren, C. T. (2015). Leadership: Industry needs for entry-level engineering positions. *Journal of STEM Education: Innovations and Research, 16*(3), 13-19.

Harvard Business School Press. (2004). *Creating teams with an edge: The complete skills to build powerful and influential teams*. Boston, MA: Author

Hasler, B. S., Tuchman, P., & Friedman, D. (2013). Virtual research assistants: Replacing human interviewers by automated avatars in virtual worlds. *Computers in Human Behavior*(4), 1608. doi:10.1016/j.chb.2013.01.004

Hebbel Seeger, A., Reiners, T., & Schaffer, D. (Eds.) (2013). *Synthetic worlds: Emerging technologies in education and economics*. London: Springer.

Hooi, R., & Cho, H. (2014). Avatar-driven self-disclosure: The virtual me is the actual me. *Computers in Human Behavior, 39*, 20-28. doi:10.1016/j.chb.2014.06.019

Hudson, K., Taylor, L. A., Kozachik, S. L., Shaefer, S. J., & Wilson, M. L. (2015). Second life simulation as a strategy to enhance decision-making in diabetes care: A case study. *Journal of Clinical Nursing, 24*(5-6), 797-804. doi:10.1111/jocn.12709

Hunger, J. D., & Wheelen, T. L. (2011). *Essentials of Strategic Management*. Englewood Cliffs, NJ: Prentice Hall.

Ibn-e-Hassan, I., Talib, N., Riaz, A., & Iqbal, M. (2014). Influence of national and engineering culture on team role selection. *International Journal of Technology & Design Education, 24*(1), 91-105. doi:10.1007/s10798-013-9242-z

Kahai, S., Jestire, R., & Huang, R. (2013). Effects of transformational and transactional leadership on cognitive effort and outcomes during collaborative learning within a virtual world. *British Journal of Educational Technology, 44*(6), 969-985.

Kichuk, S. L. (1999). *The effect of general cognitive ability, teamwork ksa's, and the 'big five' personality factors on the performance of engineering design teams: Implications for the selection of teams.* (Doctoral dissertation). Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=1999-95003-006&site=eds-live&scope=site Available from EBSCOhost psyh database.

Kimble, C. (2014). *Building effective virtual teams: How to overcome the problems of trust and identity in virtual teams*. Retrieved from https://arxiv.org/pdf/1404.7761.pdf

Kotnour, T., Hoekstra, R., Reilly, C., Knight, R., & Selter, J. (2014). Infusing leadership education in the undergraduate engineering experience: A framework from UCF's eli2. *Journal of Leadership Studies*, 4, 48.

Krumm, S., Terwiel, K., & Hertel, G. (2013). Challenges in norm formation and adherence: The knowledge, skills, and ability requirements of virtual and traditional cross-cultural teams. *Journal of Personnel Psychology, 12*(1), 33-44. doi:10.1027/1866-5888/a000077

Laglera, J. L. M., Collado, J. C., & de Oca, J. (2013). Effects of leadership on engineers: A structural equation model. *Engineering Management Journal, 25*(4), 7-16.

Leedy, P. D., & Ormrod, J. E. (2013). *Practical research : Planning and design.* (10th ed.). Boston, MA: Pearson.

Lemheney, A. J., Bond, W. F., Padon, J. C., LeClair, M. W., Miller, J. N., & Susko, M. T. (2016). Developing virtual reality simulations for office-based medical emergencies. *Journal of Virtual Worlds Research, 9*(1), 1-18.

Lepsinger, R. (2012). The virtual challenge: It's more than cultural differences. *People & Strategy, 35*(1), 10-11.

Lesko, C. J., & Hollingsworth, Y. A. (2013). Architecting scalable academic virtual world grids: A case utilizing Opensimulator. *Journal of Virtual Worlds Research, 6*(1), 2-16.

Life, M. A., Narborough-Hall, C. S., Hamilton, W. I. (1990). *Simulation and the user intrface*. London: Taylor & Francis.

Lin, H., & Wang, H. (2014). Avatar creation in virtual worlds: Behaviors and motivations. *Computers in Human Behavior, 34*, 213-218. doi:10.1016/j.chb.2013.10.005

Matrix of change. MIT Center for Coordination Science. Retrieved from http://ccs.mit.edu/moc/index.html

Maxwell, H. L., Adams, R., & Lake, D. (2014). *Make large-scale virtual training a reality*. A paper presented at MODSIM World, 1-11. Hampton, VA.

McCleskey, J. A. (2014). Situational, transformational, and transactional leadership and leadership development. *Journal of Business Studies Quarterly, 5*(4), 117-130.

Miller, M. A. (2015). *The Internet of things: How smart TVs, smart cars, smart homes, and smart cities are changing the world*. Indianapolis, IN: Que.

Morgeson, F. P., DeRue, D. S., & Karam, E. P. (2010). Leadership in teams: A functional approach to understanding leadership structures and processes. *Journal of Management, 36*(1), 5-39.

Morrison, R., & Ericsson, C. (2003). *Developing effective engineering leadership.* London: Institute of Engineering & Technology.

Nair, M. (2004). *Essentials of balanced scorecard.* Hoboken, NJ: John Wiley & Sons.

Nanjundeswaraswamy T. S. (2014). Leadership styles. *Advances In Management*, 57-62.

National Academy of Engineering. (2004). *The engineer of 2020 : Visions of engineering in the new century*. Washington, DC: National Academies Press.

Nils-Goran Olve, Roy, J., & Wetter, M.. (1997). *Perfomance drivers: A practical guide to using the balanced scorecard*. Chichester, UK: John Wiley & Sons.

Olude-Afolabi, O. (2011). *A systems-based approach to assessing leadership styles in engineers.* (71), ProQuest Information & Learning, US. Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2011-99020-408&site=eds-live&scope=site Available from EBSCOhost psyh database.

OpenSimulator. (2014). Retrieved from http://opensimulator.org/wiki/Main_Page

Overfield, D. V. (2016). A comprehensive and integrated framework for developing leadership teams. *Consulting Psychology Journal: Practice and Research, 68*(1), 1-20. doi:10.1037/cpb0000053

Özgen, S., Sánchez-Galofré, O., Alabart, J. R., Medir, M., & Giralt, F. (2013). Assessment of engineering students' leadership competencies. *Leadership & Management in Engineering, 13*(2), 65-75. doi:10.1061/(ASCE)LM.1943-5630.0000168

Pappo, H. A. (1998). *Simulations for skills training.* Englewood Cliffs, NJ: Educational Technology.

Pellerin, C. J. (2009). *How NASA builds teams: Mission critical soft skills for scientists, engineers, and project teams*. Hoboken, NJ: John Wiley & Sons.

Peter Andersen, L. Q. (2004). *Virtual applications: Application with virtual inhabited 3d worlds*. London: Springer.

Phillip, L. H., & Johanna, S. H. (2008). Virtual teams: A leader's guide. *Team Performance Management, 14*(1/2), 86-101.

Putman, P. G. (2013). *Virtual simulation in leadership development training: The impact of learning styles and conflict management tactics on adult learner performance.* (73), ProQuest Information & Learning. Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2013-99111-269&site=eds-live&scope=site Available from EBSCOhost psyh database.

Quenk, N. L. (2000). *Essentials of Myers-Briggs Type Indicator* [measurement instrument] *assessment* New York: John Wiley & Sons.

Reeve, D., Evans, G., Simpson, A., Sacks, R., Olivia-Fisher, E., Rottmann, C., & Sheridan, P. (2015). Curricular and co-curricular leadership learning for engineering students. *Collected Essays on Learning and Teaching, 8,* 1-16.

Richard, B. W., Holton, E. F., & Katsioloudes, V. (2014). The use of discrete computer simulation modeling to estimate return on leadership development investment. *The Leadership Quarterly*, 5, 1054. doi:10.1016/j.leaqua.2014.03.002

Rodríguez Montequín, V., Mesa Fernández, J. M., Balsera, J. V., & García Nieto, A. (2013). Using MBTI for the success assessment of engineering teams in project-based learning. *International Journal of Technology and Design Education, 23*(4), 1127-1146.

Rosch, D. (2015). Effects of classroom-based team experiences on undergraduate student leadership development: When practice does not make perfect. *Journal of Leadership Education, 14*(3), 104-118. doi:10.12806/V14/I3/R7

Sanchez-Segura, M. I., (Ed.). (2005). *Development future interactive systems*. Hershey, PA: Idea Group.

Schuhmann, R. J. (2010). Engineering leadership education--the search for definition and a curricular approach. *Journal of STEM Education: Innovations & Research, 11*(3/4), 61-69.

Sequeira, L., & Morgado, L. (2013a). Mechanisms of three-dimensional content transfer between the OpenSimulator and the Second Life Grid® platforms. *Journal of Gaming & Virtual Worlds, 5*(1), 41-57. doi:10.1386/jgvw.5.1.41_1

Sequeira, L. M., & Morgado, L. (2013b). Virtual archaeology in Second Life and OpenSimulator. *Journal of Virtual Worlds Research, 6*(1), 2-16.

Showanasai, P., Lu, J., & Hallinger, P. (2013). Developing tools for research on school leadership development: An illustrative case of a computer simulation. *Journal of Educational Administration, 51*(1), 72-91.

Sidor, S. M. (2007). *The impact of computer based simulation training on leadership development*. (Doctoral dissertation). University of Central Florida, Orlando, FL.

Siewiorek, A., Gegenfurtner, A., Lainema, T., Saarinen, E., & Lehtinen, E. (2013). The effects of computer-simulation game training on participants' opinions on leadership styles. *British Journal of Educational Technology*, *44*(6), 1012-1035.

Siewiorek, A., Saarinen, E., Lainema, T., & Lehtinen, E. (2012). Learning leadership skills in a simulated business environment. *Computers & Education*, *58*(1), 121-135.

Simpson, A. E., Evans, G. J., & Reeve, D. (2012). A summer leadership development program for chemical engineering students. *Journal of Leadership Education*, *11*(1), 222-232.

Strang, S. E., & Kuhnert, K. W. (2009). Personality and leadership developmental levels as predictors of leader performance. *The Leadership Quarterly*, *20*(3), 421-433. doi:10.1016/j.leaqua.2009.03.009

Stuart, R. (1996). *The design of virtual environments*. New York: McGraw-Hill.

Tolga K. Capin, I., Magnenat-Thalmann, N., Thalmann, D.. (1999). *Avatars in networked virtual environments*. Totonto: John Wiley & Sons.

Varvel, T., Adams, S. G., Pridie, S. J., & Ruiz Ulloa, B. C. (2004). Team effectiveness and individual Myers-Briggs personality dimensions. *Journal of Management in Engineering*, *20*(4), 141-146. doi:10.1061/(ASCE)0742-597X(2004)20:4(141)

Virtual Leader Leadership Style Workbook. Retrieved from http://www.simulearn.net/pdf/VirtualLeaderWorkbook.pdf

von der Pütten, A. M., Krämer, N. C., Gratch, J., & Kang, S.-H. (2010). 'It doesn't matter what you are!' Explaining social effects of agents and avatars. *Computers in Human Behavior, 26*(6), 1641-1650. doi:10.1016/j.chb.2010.06.012

What is OpenSimulator? (2016). Retrieved from http://opensimulator.org/wiki/Main_Page

Widmann, B. S. (2014). *Influence of leadership style on work engagement of knowledge workers in an engineering organization.* (74), ProQuest Information & Learning. Retrieved from https://login.ezproxy.net.ucf.edu/login?auth=shibb&url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2014-99090-304&site=eds-live&scope=site Available from EBSCOhost psyh database.

Williams-Bell, F. Kapralos, B., Hogue, A., Murphy, B., & Weckman, E. (2015). Using serious games and virtual simulation for training in the fire service: A Review. *Fire Technology, 51*(3), 553-584. doi:10.1007/s10694-014-0398-1

Wysocki, R. K. (2002). *Building effective project teams*. New York: John Wiley & Sons.