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Engineering Leadership: Transitioning from ”Soft Skill” to Hard Data

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Abstract

This paper explores the growing use of data to guide leadership decisions and direction and the implications for engineering leadership development. While engineers (and others) have conventionally considered leadership as an imprecise "soft skill," a review of relevant leadership literature reveals that myriad sources of (hard) data are already in use to inform functions of leadership. The trend to do so is increasing dramatically. Accordingly, it is appropriate to reconsider how best to prepare engineers to exercise leadership in organizations as they evolve into the future. Indeed, organizations increasingly need engineers to practice effective leadership, a workplace trend that is now embodied in ABET criteria for competencies among engineering graduates. An important benefit of exploring data-informed, data-influenced, and data-driven leadership is to mitigate the common reluctance of engineers to embrace leadership opportunities. Specifically, this paper is oriented to the development of a module on leadership activities associated with workforce analytics for an existing undergraduate course in engineering leadership. The module will complement the existing course in two primary ways: 1) taking advantage of the course theme that there is much in common between the engineering and leadership skill sets, and 2) a significant laboratory project on present and future data innovations. The paper reports on an extensive literature review that leads to adaptation to an engineering audience and the subsequent design of the course module. The design of the module is based on a flipped classroom approach in which students engage in preparation on their own and then apply concepts they have learned in group-based and all-class discussion activities that draw upon critical questions of applying these concepts. In so doing, we intend to help students think and behave as prototypical engineering leadership practitioners.

Introduction

The typical engineer spends the majority of his or her career either in a team or in management and leadership roles[1]. Even entry-level engineers are expected to function well as team members and exercise leadership as appropriate to a role. One can therefore consider the practice of engineering as a triad composed of technical competence, management, and leadership with no clear dividing line[2]. For these reasons, companies seek graduates with leadership skills[3]. However, industry offers mixed signals; even with a stated high level of interest, leadership development there is often haphazard[4]. For example, none of the engineering graduates surveyed by Watson[5] were provided any formal training in leadership by their employers. As Kumar and Hsaio[6] cleverly concluded, engineers must learn "soft skills the hard way." In academia, the situation has historically been little better. There is sparse room for leadership education in crowded curricula at universities, and few engineering faculty members have the knowledge or skill for teaching leadership[4,6]. Unsurprisingly, there are significant deficiencies in engineering education for the social skills needed in the workplace[7]. It is generally accepted that students will have to acquire leadership skills when they reach the workplace[8].

Nevertheless, developments are in motion to address these concerns. Interest in engineering leadership is growing as both industry and academia recognize the intrinsic leadership needs of the profession. Contrary to stereotype, engineering is inherently a social activity[9,10]: it has *both* technical and humanistic elements[11]. Responding to growing demand, ABET[12] now requires student outcomes that include leadership in a team setting for undergraduate engineering programs.

Exploring Leadership

As Hoschette[1] demonstrated, over time in his or her career, the engineer reaches management and leadership roles that have greater responsibility. We could characterize this progression by saying that engineers are hired for their technical skills as well as their fledgling management/leadership skills. One cannot separate its practice from management and leadership.

Nevertheless, most people, whether engineers or not, view the discipline as all about technical skill. Rottmann, et al.[11] found that engineers commonly held the belief that leadership was the domain of a few charismatic individuals at the top of a hierarchy who issue directives. In contrast to the egalitarian profession of engineering, the engineers in their study viewed leadership as elitist. They summarized this part of their study as follows: "The majority of engineers… found leadership to be imprecise, impractical, elitist, and just 'not us.'"

Despite these negative feelings, a curious finding surfaced when Rottmann et al.[11] removed the terms "leader" and "leadership" from their questions. Engineers identified three characteristics or behaviors in their superiors: 1) technical competence, 2) facilitation of collaborative optimization, and 3) organizational innovation. In addition to technical competence, such individuals facilitate collaboration, optimize processes, and seek to innovate, including the organization. Essentially, technical competence provides the ticket to entry into engineering leadership and determines context for practicing it. The researchers summarized that what engineers value in their superiors is *servant leadership with technical mastery.*

In short, engineers have no trouble identifying healthy leadership behaviors; cultural baggage associated with the words "leader" and "leadership" causes their distaste. We can also assert that the conventional dissociation of skills related to engineering and leadership promotes the belief that engineering and leadership are markedly different. It is common to refer to the engineering skill set as *hard skills* and the management and leadership skill set as *soft skills.* Such terminology reinforces the Rottmann, et al. survey findings: engineering is precise, but leadership is not.

Given the importance of leadership in the practice of engineering, it is important that we find ways to make leadership more familiar, attractive, and attainable to engineers while also preparing them with the skills and tools they will need for the workplace. Aucoin[13] demonstrated the striking similarities between the engineering method and leadership[14] and between the mental skills used by engineers and leaders[15]. Further investigation demonstrates just how similar the practice of leadership is to engineering. Both are innovation and optimization exercises performed on systems. To generalize, engineering performs such operations on engineered or physical systems while leadership performs them on social systems.

While not discounting that leadership involves and requires important behaviors that are in a different domain from technical practice, the most important conclusion here is to think more expansively about what "leading" means. We can characterize leadership as *any* behavior that enhances, optimizes, and innovates collaboration in an organization. Inevitably, such expansive thinking makes it far easier to see engineering and leadership as having very similar thought processes and objectives.

Additionally, there are ongoing significant developments in management and leadership that further make them appear more like engineering. Increasingly, organizations are using data to guide management and leadership activities. Such developments represent a move from what was once a predominantly qualitative activity to one that has substantial quantitative elements. This paper describes the development of a module within an existing engineering leadership course to introduce students to the use of data in leadership.

Engineering Leadership Course

The undergraduate Electronic Systems Engineering Technology (ESET) program resides within the Engineering Technology and Industrial Distribution (ETID) Department at Texas A&M University (TAMU). The ESET curriculum requires students to take an engineering leadership course, ESET 319. The course may also be taken as an elective by other engineering students who pursue an engineering project management minor. Students typically take the course in junior year.

ESET 319 encompasses a number of integrated topics that provide for personal development and effectiveness, interactional effectiveness in workplace relationships, especially in teams, understanding organizational systems, and related topics for holistic development through the remainder of their college work and then well into their careers. The course carries two credits for lecture and one credit for laboratory. In the laboratory students are organized into teams to practice effective teamwork. In entirety, the course is oriented to help students gain competency in skills that are largely overlooked or treated in passing in engineering curricula but are nevertheless critical to personal development and successful practice in the profession.

The thematic emphasis throughout ESET 319 is recognizing the strong connections between engineering and leadership. As supported by the foundation previously mentioned, we capitalize on engineers' rich skill set and demonstrate how similar it is to the leadership skillset. Furthermore, we also leverage the extensive expertise engineers have in systems and recognize that organizations are systems. This perspective enables engineers to readily see leadership in familiar terms of innovation and optimization. We give considerable attention to what optimizes human performance individually and collectively (e.g., with the topics of motivation and team dynamics), just as we would do with materials, components, or equipment in an engineering setting. In this way, leadership becomes familiar, accessible, and attractive.

Data Innovations Project

One can readily observe the ongoing and increasing proliferation and impact of data in how we live and work. Our graduates enter a workplace that will increasingly rely upon the acquisition and analysis of data and will use it to guide management and leadership actions. Organizations gather and use data about their products, services, customers, and employees. Given that our engineering graduates will likely enter supervisory positions, there is a high likelihood that they will use data as part of their responsibilities. Many engineers will develop sensors and algorithms in these endeavors, and accordingly it is important that they develop this expertise before graduating.

The motivation for the Data Innovations Project in the existing ESET 319 course was to provide students with an opportunity to learn about highly influential topics in data science that might otherwise be missing in their curriculum. These topics are seeing use in nearly all aspects of engineering and business and will only continue to see growth. The revised version of the project will take this knowledge and show how it is being used by leadership to make informed decisions.

The initial use of this project was in the course laboratory in Fall 2020 as an effort for students to work in teams to research significant data innovations in current use and development. The following topical areas are included in the data innovations project: 1) Internet of Things (IoT), 2) data analysis (analysis), 3) data analytics (analytics), 4) machine learning (ML), and 5) artificial intelligence (AI).

Based upon the positive experiences among students with the Data Innovations project in Fall 2020, we are revising the project to take this knowledge and show how it is being used to inform leadership decisions and actions.

Module Development: Pre-Class Preparation

Starting in Spring 2021, we have implemented a *flipped classroom* approach to this course. With this approach, students engage with content on their own, essentially teaching themselves the module content, and in so doing prepare for live class activities that involve clarification, application, and problem solving. Prior to live class, we provide written lecture notes and a series of short lecture videos. The following content in the Data-Enhanced Insights will be covered in the lecture notes and videos. These set the stage for learning and activities in the live class. It should be noted that content from elsewhere in the course will be addressed by reference for students. For the purposes of this paper, additional information is provided for the benefit of readers.

Data-Enhanced Insights

One could readily assert that in some form data has long been used for insights for management and leadership activities. Notwithstanding that truth, what is significant is that the volume of data and how it is used have changed dramatically in recent years, and that this trend is accelerating. As of 2018, 84 percent of companies stated that workforce analytics (a term that will be described shortly) is a high priority[16].

The demarcation for this shift is commonly attributed to the phenomenon known as *Moneyball.* This term refers to a practice initiated in 2002 by the Oakland Athletics Major League Baseball team. In the midst of poor performance, the Athletics moved from heuristics to more intensive use of data about players to gain a situational on-field advantage while also minimizing salaries. This experience became the subject of a book and major movie. Teams throughout sports soon incorporated this practice in their operations and *sports analytics* has become a major endeavor.

It is helpful to recognize that sports analytics is simply one implementation of the more general effort to optimize the use of the human talent available to an organization. This effort may be given various terms such as human resources (HR) analytics, people analytics, or workforce analytics. This latter term has possibly become the most common[17]. One can more formally define the function as, "the discovery, interpretation, and communication of meaningful patterns in workforce-related data to inform decision making and improve performance" (Chapter 2). This definition necessarily relates workforce analytics to the activities of management and leadership.

One can observe that sports has led business in the use of workforce analytics. However, non-sports organizations have caught the trend, and accordingly, there have been a number of publications that demonstrate the application of *Moneyball*-like approaches[18,19,20]).

With this background, it is worthwhile to define the more common terms used in gaining insights on patterns in data. *Data analysis* deals with applying statistical and logical techniques to condense, describe, or evaluate sets of data. This has long been practiced by companies to gain insights about their production processes, supply chain, and the like. In more recent years, and with processing power that can handle massive data sets, data analysis is being used to predict customer behavior and employee performance. Other practical applications include predictions of elections, the weather, and sporting events. *Data analytics* covers the wider scope of not just analyzing data but also the methods in which it is gathered, sorted or stored, and further insights into how to process the information or draw meaningful conclusions.

The concept of *artificial intelligence* dates back to the 1950s and is based on the notion that human intelligence could be so precisely described that a machine would be able to replicate it. Over time this has ranged from predicting outcomes in chess, to emulating speech, on to image or facial recognition, and eventually emotions and some level of consciousness. *Machine learning* is a more recent field within artificial intelligence that uses algorithms to build a model based on sample data that is then used to decide or predict an outcome based on new data. Given enough data and time, these models are proven to be extremely accurate. Machine learning is the power behind facial recognition, medical image diagnosis, financial trend predictions, and many other cutting-edge fields. Newer algorithms are able to eliminate the need for training data sets and can derive their own models based on observing raw data.

In addition to these terms, it is worthwhile to define three others to describe how data may be used in leadership activities particularly with regard to making decisions on the data. *Data-informed* decision making implies that data that provides information and prompts questions and

deliberation. *Data-influenced* decision making implies that we consider other factors in our decisions, e.g., organizational values and strategy. *Data-driven* decision making that is motivated by objective information and less by intuition[21].

Uses of Data in Leadership

There are numerous commercial platforms available for a range of workforce analytics functions, including recruiting, performance measurement, compensation, workforce planning, and retention. Furthermore, analytics is also being used for real-time correlations between coaching and engagement, as well as for patterns of time management[22,23,24,25]. Facial scans can be used to detect and analyze employee emotions[26].

Google's Project Aristotle was an ambitious example of how data can be used for insights for leadership[27,28]. Carried out over multiple years, the objective was to identify elements that differentiate effective teams from those that are not. Google studied the characteristics of hundreds of teams and analyzed massive amounts of data to tease out patterns. While the results of Google's analysis supported some elements of sound and long-established leadership practice, nevertheless other elements had either no or ambiguous support. Of particular note, there was no support for the conventional wisdom that effective teams are composed of the "right" people.

Other implementations are in early stages of exploration or development. There are applications for using wearables to measure stress and anxiety, and worker health, safety, and well-being. In the midst of the Covid-19 pandemic, there have been efforts to use wearable biometric data to predict when workers might be infected[29,30]. While initial work has been done in sports to characterize the elusive factor, *team chemistry*[31], doing so in the workplace is generally seen to be a "Holy Grail" goal[32].

Connection to Engineering Leadership

The icon of quality management, W. Edwards Deming, said, "Without data, you're just another person with an opinion." Engineers have long made extensive use of data in understanding, designing, testing, and optimizing engineered systems. With regard to the Deming quote, one may give particular attention to the use of statistical process control in manufacturing. Engineers implicitly accept and embrace data from engineering processes. In a related sense, data from our social processes in organizations is equally important.

Ethical and Application Considerations

Every technology can be used for both worthwhile and troublesome purposes, and so it is with workforce analytics. Monitoring and surveillance of workers offers the prospect of boosting productivity, performance, engagement, and morale, as well as providing information to enhance leadership practice. Notwithstanding these benefits, there are also potential *creepy* aspects to tracking members of an organization. Employees may readily perceive the technology to be overly invasive and Big Brother-like and used against them[16,29]. Accordingly, ethical and application considerations are critically important in addressing workforce analytics and leadership.

Historical perspective is useful to this topic[33]. In the early 1900s, *scientific management* was the predominant approach to organizing work. It involved dissecting steps in production, and then continually optimizing these steps to maximize productivity. Beneath this approach were two core

beliefs: 1) management had the expertise to figure out such things, and labor did not, and 2) workers would rather not work, so their motivation depended on either a reward or threat. Over the coming decades, the *human relations movement* reflected the growing attention given to the psychological and social needs of individuals in their work and how such attention produced improvements in productivity. Into this context, Douglas McGregor[34] proposed two contrasting belief systems among managers. *Theory X* managers operate from the belief that people really do not want to work and therefore must be bribed or coerced into working. One can say that Theory X is based on the belief that work is only a transaction: pay for work. Theory X approaches bring about compliance, not motivation. In contrast, *Theory Y* managers believe that people do want to work, and the task of such managers is to put conditions in place that facilitate this motivation.

Unquestionably, workforce analytics can be perceived as threatening by employees. How do we best apply workforce analytics to reap its benefits while avoiding its abuses? The question is best answered with having clarity about our beliefs and values–this is the message in Theory X and Y. This territory is best navigated by organizational values and culture that emphasize the wellbeing of *both* the organization and its members. Accordingly, guidance of the application of analytics must be a shared and collaborative endeavor that is undertaken with transparency. Such an approach will encourage individuals to embrace the technology and therefore obtain its benefits. Failure to follow this approach may lead to distrust and resistance, leading only to compliance or attempts to defeat or trick the system. Ultimately a human focus is needed[35], and an ethics charter can assist this objective[29].

Module Development: Live Class

With this content background in the students' pre-class preparation, we can now turn our attention to the live class activities. Live and in-class activities are intended to provide opportunities for clarification, application, problem solving, and sense making. For clarification purposes, students are offered the opportunity to ask questions concerning material that may be confusing or difficult to understand from their pre-class preparation. As of this writing the final implementation of the module has not been accomplished but will be within weeks. However, the framework for the remainder of in-class activities will likely be as follows.

For the foreseeable future, the enrollment for this course is expected to be approximately 75 or more students per semester. The nature of activities in a live class is substantially influenced by the large size of the class and the present remote delivery method resulting from Covid-19. Accordingly, we commonly send students into breakout rooms to discuss prompt questions in small groups. When we reconvene together, representatives report the findings of each breakout group. Any student can follow up if they so wish.

We anticipate that the prompt questions for this topic will be based around an application scenario that the students may encounter in their future careers. Such a scenario approach makes the consideration more real and personal. It also gives students the opportunity to apply course concepts to the scenario at hand. We anticipate that the subject class time will allow for three prompt questions. The following are three scenarios that may be used in the breakout groups and

all-class discussions. All three scenarios involve a company-wide facial recognition system to monitor employee engagement and use the information to boost productivity.

Scenario 1 supposes that the student is early in his or her career and has become aware that the employer is already using this system without having consulted with or informed lower-level employees. Scenario 2 supposes that the student is now in charge of a work group and has been approached by superiors to help plan and roll out the use of such a system. In Scenario 3, the student leads a team that has been commissioned by the employer to design and develop such a system to be sold to other organizations.

Each prompt question is intended to use educator Parker Palmer's[36] approach of bringing *big questions* into the midst of the room. Palmer reported that this method of vigorous engagement makes it easier to learn to think like a prototypical member of a profession.

Prompt questions are intended to invite students to wrestle Based on the scenarios, here are three possible prompt questions that may be presented to students to discuss and agree upon in their breakout groups.

1. Based on Scenario 1, as an individual, what is your reaction to learning about the system that your employer has implemented? What, if anything, would you say or do about it? In your answer, apply concepts of motivation that have been covered in the course.
2. Based on Scenarios 2 and 3, in your leadership role, what approach would you take to plan and implement the proposed system? In your answer, incorporate concepts of motivation (including Theory X and Y), and culture that have been covered in the course.
3. Considering all scenarios, and answering both as an individual and in a leadership role, how can the subject system be used in a way that promotes the humanity of employees? In your answer, incorporate concepts of motivation (including Theory X and Y), culture, and servant leadership that have been covered in the course.

After conclusion of all-class discussions, there will be a mini lecture accompanied by a few prepared slides to provide a synthesis of the topic. This mini lecture is improvised in part based on the proceedings of the discussions but will weave in learnings from other lectures, as well as what an engineering approach to this form of leadership might look like. An example of such a mini lecture is now presented in the following section as discussion.

Discussion

Workforce analytics is already well established, and its use is growing. Notwithstanding real concerns over abuse, the proverbial genie will not return to the bottle. The issue for students who will practice engineering leadership is how to apply it effectively and in a way that does not promote abuse.

Leadership is ultimately an intervention activity. To practice leadership, we see what needs to be changed or done and act upon the organizational system in a way that brings the system to a better state. More extensive use of data offers the potential to provide better insights to guide leadership decisions and actions. Furthermore, analytics permits such insights and interventions to occur much more quickly than ever before[22].

It was not long ago that insights on employee engagement and morale were derived from annual surveys. But that lengthy wait is no longer acceptable[29]. Engineers have long taken for granted the benefits of real-time data on adjusting processes to promote the quality of manufactured components. Workforce analytics offers the opportunity to bring a similar capability to the social processes of an organization. Whether for an engineered or social system, we are most effective when we work with objective and timely data.

Argyris[37] reminds us that when performing any leadership intervention to be clear about the strategy for the intervention. Clarity is promoted by returning often to first principles in leadership that involve our beliefs, values, and knowledge about people as individuals and in organizational relationships. We would do best to practice behaviors that uphold the humanity of employees and not to consider them as components in an organizational machine, e.g., choosing Theory Y over Theory X. With all leadership interventions a key guiding principle is to *keep our brains engaged!* Every leadership intervention is ultimately an experiment, and therefore what we seek is incremental change[38]. Every intervention experiment generates more data and learning.

If we use workforce analytics properly it will enhance our humanity; troublesome application of it will strip away humanity and treat people as objects[35]. Fledgling engineering managers/leaders will themselves be analyzed and will likely participate in the analysis of others. This content has been developed to help them prepare themselves for considering how this technology can enhance our humanity. Perhaps surprisingly, this exploration helps us see how the practice of leadership is evolving to become less about soft skills and more reliant on hard data.

Limitations and Future Work

The curricular exploration of workforce analytics in leadership is an exploratory one intended to provide students with information, stimulate thought and discussion, and orient them to appropriate application of the technology. It is intended to present the topic through the lens and skill set of engineering. The work presented here is primarily the result of secondary research and professional experiences. This is a new exploration, implemented for the initial time in Spring 2021, therefore we do not yet have data on its effectiveness; accordingly, it is a work in progress. It is not intended to supplant current approaches to leadership development of engineers as they all have merit. Observation of the use in the course and coupled with student surveys and evaluations will be important to guide future use of this content module. For the first implementation of this module, a simple post survey will be used after the conclusion of the module. This post survey will include questions to gauge whether the students found the material to be interesting, valuable, and engaging, all based on Likert scoring. It is worthwhile to emphasize that the exploration of this topic is valid to the extent that it is found useful by students, faculty, engineers, and organizations.

Conclusions

This paper has provided the results of the development of a curricular content module in leadership implications of workforce analytics for an undergraduate engineering leadership course. The presentation of this content to students is intended to provide them with information, stimulate thought and discussion, and orient them to appropriate application of the technology. It is intended to present the topic through the lens and skill set of engineering. The presentation is consistent with the thematic framework of the course that demonstrates the extensive common ground between engineering and leadership. Such common ground can make leadership familiar, accessible, and attractive to engineers, thereby innovating and accelerating leadership development for them. The presentation approach demonstrates that leadership is evolving to become less of a soft skill and incorporate more hard data. In this way engineers can further perceive the practice of leadership to be more like engineering.

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