Reviewing a decade of research on Engineering Leadership

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Abstract – Academics, industry professionals, and policy makers across North America have shown increasing interest in the topic of engineering leadership. The demand from industries for engineers with diversified skills in a hypercompetitive market as well as the need to produce engineers attuned to the challenges of globalization are pushing universities to invest in engineering leadership education programs. In this context, this article engages with the following two questions: How have scholars addressed the concept of engineering leadership over the past decade? And how could the field of engineering leadership be constructively pursued in the future? The goal of this article is to map the structure of this nascent field by analyzing its scope, geography of application, methodology, relations, contradictions, gaps, and inconsistencies in the literature. By doing so, we explore reasons for the field's structural particularities while also considering new avenues for future studies. We offer some tentative conclusions: articles predominantly presented the results of a pilot program or the outcomes of integration of leadership topics into current courses but in the process the concept of engineering leadership is seldom understood in a situated manner within wider shifts in economy and society. This points to a potential avenue for further research that incorporates a macro level of analysis that adopts a multi-dimensional view of leadership engineering.

Keywords: Engineering leadership, systemic review, education, empirical analysis, leadership practices.

1. INTRODUCTION

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Engineering educators are tasked with the responsibility of training future engineers capable of

dealing with urgent global problems that require both social and technical solutions.

In response, we are seeing a transition in engineering education from understanding engineers as merely the providers of technical solutions to engineers as leaders.

Several engineering schools across U.S and Canada (e.g., Northwestern, Iowa State University, Pennsylvania State University, University of Toronto, etc.) are offering courses or academic degrees in engineering leadership based on their own unique definitions and understandings of the future roles of engineers. In the last decade, a growing body of literature on engineering leadership has emerged from the analysis of programs such as these. This growth has prompted us to conduct an extensive literature review by addressing two research questions: *How have scholars approached the concept of engineering leadership over the past decade? And how could the field of engineering leadership be constructively pursued in the future?*

In answering these two questions, we contribute to this emerging “field” of engineering leadership by doing the first systematic review of articles foundational to the field of engineering leadership. In contrast to previous reviews of the field, we do not review the educational aspect of the engineering leadership field [1] in a specific region (e.g. North America). Instead our review focuses on the broader aspects of interests that have been already addressed by scholars of the field. We provide a big picture view of the field rather than clustering and comparing different educational program of engineering leadership.

Following this introduction, the rest of this article is organized into four sections. First, the authors describe the methodology used to identify and code the relevant engineering leadership articles and propose a conceptual framework to organize the selected articles. In the next section, the authors discuss the broad characteristics of engineering leadership research that emerge from the review, including methods and empirics of the engineering leadership discipline. The subsequent section examines the content of the growing literature in the field, using the proposed framework to present main findings, including key constructs and ideas, and to identify research gaps. Finally the paper offers concluding thoughts and discusses the limitations of this research

2. METHODOLOGY AND ORGANIZING FRAMEWORK

2.1. Selection Process

Our concern in choosing articles for this review was to avoid an ad hoc list of randomly collected publications, which would not provide a representative picture of what is going on in the engineering leadership field. Instead, the authors selected the articles to be included in the review through a systematic procedure, ultimately resulting in a list of 40 articles published in reputed journals or conference proceedings such as Journal of Engineering Education, Journal of leadership studies, Journal of STEM Education and so on. Since the field is pretty nascent, the low quantity of relevant articles, which fully addressed the concept of “engineering leadership,” led us to consider all different types of articles ranging from the scientific and theoretical, to the practical. The authors didn’t restrict the search to specific journals, but instead used Google Scholar and Scopus as a research engine to cross-verify all published scientific articles using the search term “engineering leadership.”

2.2. The Coding Procedure

To facilitate the identification of trends and to standardize the information contained in the articles, the authors coded all articles and incorporated the results into a database to identify the trends in the literature. We coded articles based on their main aspects including:

1. The type of article based on its application, to identify the target audience of the article.
2. The objective of the article, based on its stated or implicit research question and the main conclusions of the article.
3. The scale of focus of the article, in terms of whether the scale is team, program level, policy maker, corporate, industry or national level. In some cases the focus was gender.
4. The concepts and methodology used in the article, for example whether qualitative or quantitative.
5. The theoretical or conceptual framework that has been used by the article.
6. The geographical focus of articles based on the country of study.

3. METHODS AND EMPIRICS IN ENGINEERING LEADERSHIP ARTICLES

The number of articles that can be clustered as empirical (i.e., articles based on data gathering methods that rely on

quantitative, qualitative or mixed methodologies) considerably exceeds the number of theoretical articles (i.e., articles that consider the broader theoretical implications of engineering leadership). Among the empirical articles, several present the outcomes of a pilot educational program in engineering leadership in one or several engineering schools. These articles typically recount the required courses in engineering leadership and explore frameworks to incorporate those courses into engineering curricula ([2][3][4][5][6][7][8][9][10][11][12][13][28]. Others discuss key leadership qualities for engineers and the nature and make-up of these qualities that helps engineering students develop their leadership skills (Wilson, Hargreaves, & Hauxwell-Baldwin, 2015; Hargrove, 2015; Larson et.al, 2015; Lappalainen, 2014; Glass, 2006; Schuhmann, 2010; Kratzer, Leenders, & Van Engelen, 2008; [2] While still others provide instruments to assess, examine, refine and develop curricula, as well as advising materials, methods and predictors of successful leadership in engineering [20]; [21]; [16]; [22]; [22]; [23]. Other papers also attempt to describe the challenges and shortfalls of their own leadership programs [24]. Others still address specific case studies (e.g. the role of student associations in engineering leadership program or the leadership practices of women engineers [25].

The more theoretical set of articles identified present an overview of some of the current practices in engineering leadership programs. These studies attempt to frame the various educational programs in engineering leadership through a conceptual analysis of good practices through differing national and organizational contexts. [26] [27].

The scope of these case studies is largely contained to one engineering school, which may reflect the difficulty associated with finding and collecting reliable large-sample data in leadership programs among engineering schools. However, we have witnessed some survey studies that attempt to reflect the status of engineering leadership development within a broader scope (e.g. Paul and Cowe Falls, 2015) by reviewing others practical studies.

Our review revealed that the use of variety of qualitative methodologies is limited to the case study approach and there is no evidence of using other strong methodologies such as grounded theory, narrative studies, and discourse analysis and so on. The tendency towards doing quantitative or mixed analysis among scholars reflects their positivistic perspective on the field, since this type of research is time and context free. This tendency makes sense within the dominant methodologies and epistemologies most often found in engineering schools. However, since the field bears markings of a pre-paradigmatic stage, the possibility of the introduction of a social constructivist perspective might be of value for future research.

Despite prevalence and increasing numbers of empirical studies that attempt to infuse leadership into engineering programs, the nascent field has not yet gained traction as a legitimate field of study [28]. In this sense, the theoretical and conceptual articles attempt to facilitate the process of grounding the concept of engineering leadership through theoretical contributions and implications for engineers, leadership theorists and engineering educators (eg. [29]; [30]; [28]). They also attempt to bring a consistency among scholars in terms of engineering leadership definition, engineering leadership social structure, scope and goals of program (e.g. Engineering, 1998). In very few cases, they draw upon other theories such as complexity theory to elaborate on the emerging challenges for engineering during complex transition (e.g. Emison, 2011); grounded theory [28], from our experience in other fields, such as engineering studies, the field needs more and stronger theoretical contribution from scholars.

4. THE CONTENT OF ENGINEERING LEADERSHIP ARTICLES: FINDINGS, GAPS, AND FUTURE RESEARCH DIRECTIONS.

In this section we aim to provide a landscape view on the mainstream content of the articles included in the review, identify gaps and underexplored research avenues, and thus help set a research agenda for the academic study of the engineering leadership.

As we showed in the previous section, the majority of articles consist of presenting outcomes of the engineering leadership program in specific curricular or co-curricular programs. These studies attempt to share good practices [6] in order to raise the legitimacy of the field and reach a consensus on a unique definition of “engineering leadership”. Our survey shows that a current attempt to reach a unique definition for the term “engineering leadership” that would apply to all situations might be not only hard to achieve but also counterproductive. On the other hand, having a wide variety of coexisting interpretations and definitions for the same concept, combined with the fact that many articles do not provide any rich theoretical background or definition for engineering leadership is likely to create confusion and hamper theory building in the field. The majority of empirical studies with considerable implications for practice and incremental movement to theory signal the first transition from a messy pre-paradigmatic stage toward a more mature, paradigmatic stage.

In addition, our review reveals that the field hasn’t defined its relationship (in terms of difference or similarities) with other related fields of interest such as “engineering entrepreneurship”, “business leadership” or “global engineering.” By offering a more coherent theory of “engineering leadership” with clearer boundaries,

knowledge and networks among scholars, the field may better position itself as a legitimate field of inquiry (or paradigm).

5. CONCLUSION

The goal for this article was to answer the question: How has the concept of engineering leadership evolved over the past decade? And what would be a likely the trend in future? To that end, the authors conducted a review of a decade (2006-2016) of published articles on the field of engineering leadership. This review concludes that the concept of engineering leadership still is not clearly defined or at least clear to many scholars. Also, in terms of broad direction of the field, it hasn’t evolved dramatically from centering on educational programs to other aspects of the field such as its relationship to other fields and settings outside academia.

Overall, the review leads to a call for precise definitions of the field’s vision, goal and boundary plus explicit analyses of the characteristics of the engineering leadership. In particular, authors, program leaders, policy makers, and corporations need to be particularly clear regarding their definition of leadership in the context of engineering settlement.

Moreover, as many cases and examples originate from North America, a broadening of the empirical base, particularly to other industrialized nations and emerging economies, seems necessary. This broadening of the empirical base would have the added benefit of contributing to a more global view of engineering leadership, not as closely tied to the geographic or cultural idiosyncrasies as it currently is.

This review also shows very little variation across methodology that most of the articles followed. However, there is nothing wrong with using case study analysis as the most favored one for scholars of the field, a deeper analysis of the field toward building rigorous theoretical foundations, calls for explicit attention to other qualitative grounded methodology such as “grounded theory”, “discourse analysis”, “process research”, “ethnography”, and “narrative research”.

As is the case for any study, this article has limitations. First of all, the findings are limited to a decade from 2006. Also, because of resource limitation, this single study didn’t provide an overview on the interlinkage of the field with neighboring discipline such as leadership, management and engineering education. This is strongly recommended for future studies.

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