Paper ID #18746

Engineering Leadership in a Chinese Industrial Context: An Exploration using the Four Capabilities Model

Dr. Jiabin Zhu, Shanghai Jiao Tong University

Jiabin Zhu is an Associate Professor at the Graduate School of Education at Shanghai Jiao Tong University. Her primary research interests relate to the assessment of teaching and learning in engineering, cognitive development of graduate and undergraduate students, and global engineering. She received her Ph.D. from the School of Engineering Education, Purdue University in 2013.

Miss Hu Yu, Shanghai Jiao Tong University

Yu Hu is a graduate student at the Graduate School of Education in Shanghai Jiao Tong University. She obtained a B.S. in biotechnology from Hebei Normal University. Her current interest focuses on the cognitive development of engineering graduate and undergraduate students, the assessment of teaching and learning in graduate education.

Miss Tianyi Zheng, Shanghai Jiao Tong University

Engineering Leadership in a Chinese Industrial Context: An Exploration Using the Four Capabilities Model

Abstract: Future engineers should not only serve as technical experts in their respective fields, but also take the leadership roles in the age of knowledge economy. To understand the essence of engineering leadership, this study applied the Four Capabilities Model (4-Cap model) to understand and operationalize the core capabilities required for engineers in a Chinese industrial context. The 4-Cap model is composed of four dimensions in defining leaders' capabilities, that is, sensemaking, relating, visioning and inventing. By a qualitative study among twenty-three working engineers from different companies and industries, this study identified a comprehensive list of key skills or attributes that are needed for engineering leadership. This work also illustrates practical examples for these skills and attributes based on the analyses from the interview transcripts. The comprehensive list of skills and attributes will help inform the design and implementation of leadership training programs and deepen our current understanding of engineering leadership in different cultural contexts.

Keywords: Engineering leadership; Chinese Industrial Context; Four Capabilities Model

Introduction

Future engineers should not only serve as technical experts in their respective fields, but also take the leading roles in the age of knowledge economy by possessing multiple skills and attributes, in particular leadership [1]. Accordingly, new criteria for competent engineers have been proposed in recent years. For instance, *The Engineer of 2020-Visions of Engineering in the New Century* in the U.S. indicated that future engineers need to develop analytical skills, practical ingenuity, creative capability, communication skills, concepts of business and management, leadership, ethical standards and a sense of professionalism [2]. *Educating the Engineers for the 21 Century-the Industry View*, published by the Royal Academy of Engineering in the U.K., stressed requirements for future engineers to be equipped with creativity, innovation and leadership [3]. As can be observed, there is a growing demand for countries and universities to develop leadership among engineers and engineering students.

In response to the new demands for excellent engineers, a number of universities and engineering colleges in different countries have launched engineering leadership programs. A prior extensive comparison of these programs suggests that Gordon-MIT Engineering Leadership Program appears to have built their program on a comprehensive theoretical framework, namely, the Four Capabilities Model (4-Cap model), which is composed of four core capabilities for future engineers: sensemaking, relating, visioning and inventing [4] [5]. This framework has allowed a more systematic leadership training for their engineering students to acquire varied skills and traits that are encompassed within the framework [6].

Literature Review

Universities and engineering colleges have been taking efforts to improve the quality of engineering education and to develop students' leadership abilities. Engineering leadership programs have emerged in universities in a number of countries, and different initiatives have been carried out to achieve these goals. For example, Gordon-MIT Engineering Leadership Program established an integrated curriculum program to develop leadership characteristics and skills among engineering students through a cooperation with MIT Sloan Business School [6]. Royal Academy of Engineering in the U.K. involves engineering students in leadership training by setting up Engineering Leadership Standard/Advanced Award programs [7]. The Engineering Leadership Development Minor (ELDM) at Penn State University requires engineering students to complete a minor degree through taking related leadership classes and obtaining corresponding credits [8].

Engineering leadership has been increasingly considered as a key aspect for engineers' training [9]. Multiple definitions can be found in current literature as to the essence of engineering leadership. Gordon-MIT Engineering Leadership Program portrays engineering leadership as a process to promote teams to implement common goals; it represents a series of capabilities and skills that help engineers to accomplish a multi-disciplinary project, which is often characterized as a team-working process instead of individual efforts [10]. The National Society of Professional Engineers (NSPE) points out that leadership skills represent essential professional capabilities that contribute to public health, safety and welfare [11]. By an analysis of different engineering leadership program outcomes, one can understand the varied emphases of these programs in their training. For example, the training outcomes of Engineering Leadership Program in Cornell University were listed as students' self-knowledge, management skills, collaboration, leadership, professional conduct and skills, et cetera. [12]. The engineering leadership program in the University of Colorado, Boulder, aims to develop engineering students who possess technical knowledge, multi-disciplinary knowledge, global collaborative skills, innovative skills, problem-solving skills and so on [13]. Our prior findings based on a comprehensive analysis of the text materials of twenty-one engineering leadership programs from five countries suggested that, interpersonal communication, teamwork, technical excellence, leadership knowledge and visioning/setting goals were the key attributes emphasized in these engineering programs [5]. However, few programs have documented a systematic theoretical framework of engineering leadership concerning the essence of engineering leadership in guiding the leadership training process.

As to the conceptual understanding of engineering leadership, several researchers have conducted studies on the essence of engineering leadership. Rottmann, Sack and

Reeve collected qualitative data through nine focus groups and seven interviews with engineers to explore their perceptions of engineering leadership. Based on grounded leadership theory, they mapped a compound model of engineering leadership to merge technology and social skills together [14]. Ancona and her team developed a 4-Cap model based on leadership researches and students' feedbacks in leadership classes. This framework contains four core capabilities – sensemaking, relating, inventing and visioning [15] [16]. The 4-Cap model was then applied within the engineering context. Through a series of workshops, stakeholders at MIT, including alumni, industrial representatives, military leaders and faculty members, together designed their leadership program based on the 4-Cap model to cultivate profound and wide leadership knowledge and skills among all MIT engineering students. This program identified specific capabilities of engineering students within each of the dimensions of the 4-Cap model [17].

In China, some leading universities have also started to launch training programs for engineering students with a specific focus on leadership [18]. However, because of the unique characteristics of leadership that may result from different cultural contexts [19-20], it is necessary to understand the essence and the demonstrations of engineering leadership in a Chinese context before a robust training program is constructed. Therefore, in this work, we tried to explore the essence and practical demonstrations of engineering leadership in a Chinese industrial context from the perspectives of working engineering professionals in the context of the 4-Cap Model. To be specific, we will address two research questions: 1) What is the essence of engineering leadership for working engineering professionals in a Chinese industrial context? 2) What are the practical demonstrations of engineering leadership for working engineering professionals in a Chinese industrial context?

Theoretical Framework

The 4-Cap model contains four core capabilities: (1) Sensemaking, that is, to analyze and understand the current situation of the tasks via observation and intuition in a project with a variety of data; to shape and map a new and reliable situation for team members; (2) Relating, which involves leaders' abilities in inquiry (e.g. to fully understand each member of the group), advocacy (e.g. to be sure of their own standpoints) and connecting (e.g. to build a good relationship across the whole organization); (3) Visioning, i.e., to set up and articulate inspiring goals which are attainable, and to encourage team members to complete these common goals through feasible methods; (4) Inventing, which involves solving problems and transforming a vision into a reality through creative ways, processes and structures. Change signature is composed of core values, beliefs and personal attributes of leaders. Leaders' leadership styles vary according to individual's beliefs and attributes. To sum up, this framework represents a combination of innovation and execution in engineering [15] [16]. It should be noticed that the four aspects are not isolated, but interrelated and intertwined with each other (Figure 1).

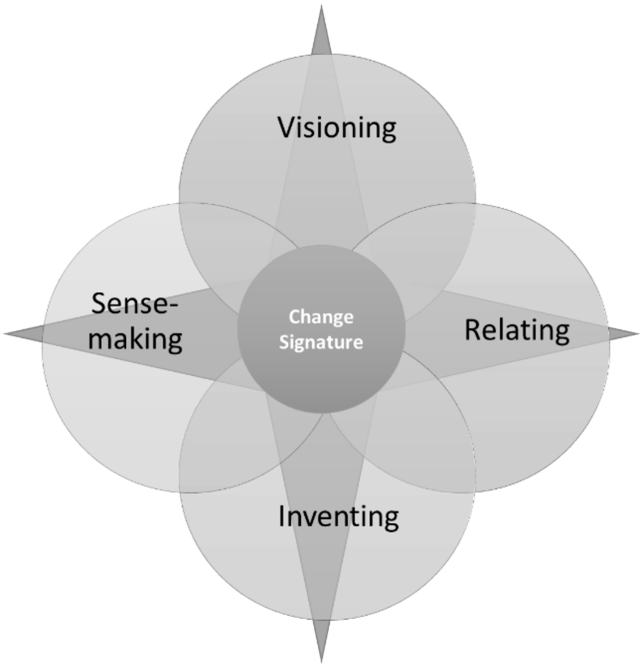

Figure1 Theoretical framework-the Four Capablities Model [15] [16]

Method

Purposeful sampling was used to recruit working engineers for this study. Via professional networks, we initially recruited ten participants who were currently working in industry as practicing engineers. Another thirteen engineers were then recruited through snowball sampling. A total of twenty-three engineers were recruited for this study. Semi-structured interviews were conducted on a one-on-one basis. Each interview lasted for about one to one and a half hours. For the sake of privacy safety, appropriate procedures were followed to protect the privacy of the participants. All identifiers were removed and pseudonyms were used in this report to protect the confidentiality of the participants.

It should be noted that in the process of purposeful sampling, we intentionally included engineers who were from varied industries and different types of companies, with varied years of working experiences, with different genders, and graduated from different types of universities. This sampling strategy was followed to ensure the diversity and representativeness of the participants. Sampled industries include information technology, electronics industry, automobile industry, aerospace industry, chemical industry and construction industry. Sampled company types include private companies, state-owned companies, joint ventures, and foreign companies in China. Sampled university types include 985, 211, and non-985/211 universities in China. The Project 211 (1995) and the Project 985 (1998), were initiatives launched by the Ministry of Education in China to enhance the academic and research quality of major Chinese universities by increased investment [22]. A detailed distribution of interviewees' demographic information is shown in Table 1 according to their respective industries.

Table 1. Demographic Information of Interviewees

Pseudo-nym	Gender	Industry	Working Exp.	Company Type	Education	Univ. Type	Position /Title
Ethan	M	Electronics	15 yrs	Private	Bachelor	Non-985/211	Senior Engineer
Edward	M	Electronics	14 yrs	Foreign	Master	211	Project Manager
Eddy	M	Electronics	11 yrs	Foreign	Bachelor	211	Department manager
Elias	M	Electronics	9 yrs	Foreign	Bachelor	Non-985/211	Department manager
Eve	F	Electronics	8 yrs	Foreign	Bachelor	Non-985/211	Engineer
Eric	M	Electronics	7 yrs	Foreign	Master	211	Software Engineer
Alice	F	Automobile	9 yrs	State-Owned	Master	985,211	Project Manager
Aaron	M	Automobile	8 yrs	State-	Bachelor	211	Engineer
Alex	M	Automobile	8 yrs	Owned	Bachelor	211	Project Manager
Albert	M	Automobile	5 yrs	Joint venture	Bachelor	985,211	Director
Austin	M	Automobile	3.5 yrs	Foreign	Bachelor	985,211	Module Director
Isaac	M	IT	15 yrs	State-Owned	Bachelor	211	Director
Ian	M	IT	11 yrs	State-Owned	Bachelor	211	Project Manager
Ishmael	M	IT	10 yrs	State-Owned	Bachelor	211	Web Group Leader
Isiah	M	IT	10 yrs	State-Owned	Bachelor	985,211	R&D Group Leader
Ivan	M	IT	9 yrs	State-Owned	Bachelor	Non-985/211	Support group leader
Caleb	M	Chemical	8 yrs	Foreign	Ph.D.	985,211	Engineer
Calvin	M	Chemical	7 yrs	Foreign	Bachelor	985,211	Engineer
Cindy	F	Chemical	1 yrs	Foreign	Ph.D.	211	R&D Engineer
Carissa	F	Chemical	1 yrs	Foreign	Ph.D.	985,211	R&D Engineer
Celina	F	Chemical	15 yrs	Foreign	Ph.D.	Non-985/211	R&D Manager
Tom	M	Aerospace	24 yrs	State-Owned	Bachelor	985,211	Senior Manager
Jack	M	Construction	2 yrs	Private	Bachelor	985,211	Architect

A semi-structural interview protocol was used to collect data. The interview protocol was designed through the guidance of our theoretical framework [21]. Three rounds of pilot interviews were conducted to modify the interview protocol. The finalized protocol included fourteen questions. Generic questions such as, “Let’s talk about a project that you have recently completed. Could you please describe the process how you and your team completed this project", and "What kind of roles do you think you were playing in completing the project" were asked to explore their past project experiences. Specific questions were also designed in each dimension of the 4-Cap model. For example, in the dimension of sensemaking, a question was asked as, "Could you please describe the process of starting a new project". The purpose of these questions was to explore the practical demonstrations of the 4-Cap model in a Chinese industrial context. Additional questions were asked to explore the ways through which certain skills were acquired. Nonetheless, for this report, we focus on the exploration of the essence of engineering leadership and the practical demonstrations of the 4-Cap model in a Chinese industrial context. A complete interview protocol can be found in the Appendix.

In the process of qualitative data analysis, a structured codebook provides a reliable frame for the coding process [23]. For our data analysis, five a priori codes were defined based on the 4-Cap model, that is, sensemaking, relating, visioning, inventing and change signature. Based on these a priori first-level codes, open-coding was used to identify the next-level codes throughout the transcripts. Four transcripts with rich information were chosen based on an initial understanding of transcripts for the purpose of constructing a codebook. A team of three coders were engaged in the process of building the codebook. Four rounds of auditing were conducted to reach an agreement among the coders on the codebook. The coding process was performed through the Atlas.ti software. Results from all of the twenty-three transcripts were included in this work-in-progress. Here, we reported the frequency counts for the codes that have exhibited higher counts than others in the transcripts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes. This information is provided to show how prevalent these codes are across all of the participants.

Findings

Through an analysis of the interviews with Chinese engineers, this study identified detailed skills or attributes within each of the dimensions of the 4-Cap model of engineers in an industrial context, which includes private companies, state-owned companies, joint ventures, and foreign companies in China. Specifically, we illustrate sample codes from each of the dimensions of the model, that is, sensemaking, relating, inventing, visioning and change signature. Quotes from each dimensions are also provided to serve as examples.

A. Sensemaking

Sensemaking involves analyzing and articulating current complicated situation through various data, observation and stakeholders. Codes with high frequencies in this category include understanding the requirements to complete a task, understanding customers' needs, decision-making, collecting information, seeing the big picture and so on. Table 2 lists the top ten codes with the highest frequency counts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes.

Table 2 Sense-making Capabilities

Codes	Frequency counts	Interviewee counts (No.)
Understanding the requirements to complete a task	60	20
Understanding of customers' needs	59	21
Understanding team members' performance and skill levels	58	17
Analyzing and controlling cost and revenue	57	18
Risk assessment and management	50	16
Being sensitive to changes and new trends	50	18
Decision-making	46	14
Collecting information	41	20
Seeing the big picture	35	16
Feasibility analysis	31	14

Most engineers talked about the necessity to understand customers' needs before proceeding with a project. To understand customers' needs can include understanding their goals, specific requirements, their criteria for a project, and problems that need to be solved. In terms of understanding customers' needs, Ishmael, having worked in information technology for ten years, pointed out that,

Say, problems C, D, and E were proposed by customers. But what they proposed were not needs, it was his (or her) direct perception, say, the product does not have this, or that (function). Does that mean it will be all set if you add on the functions that they suggest? Not necessary. …We cannot cover all users, right? You may need to consider additional investigation or additional data source, some of the needs are more of niche market, some of them are more of mass market, so then we can formulate a goal and execute it.--Ishmael

Here, Ishmael summarized about understanding customers' needs, making sense of them, and conducting further investigation before actually making a plan. Some engineers also mentioned the importance of conducting a cost and revenue analysis in starting a project. For example, Elias noted,

> *I need to know how to set up the project. To achieve goals of the company, I must calculate how much manpower and cost I will put into this project. Then I need to learn about potential risks in this project. --Elias*

Cost and revenue analysis represents an essential part of financial components for a project. Engineers need to conduct an analysis of the human resources and materials cost. Additionally, they also need to pay attention to the expected profit. Conducting an effective cost and revenue analysis represents a key capability of a group leader to ensure the accomplishment of a project.

B. Relating

Relating consists of inquiry, advocacy and connecting. Relating refers to leaders' understanding of team members, clarifying their own standpoints and building a functional relationship. Codes with high frequencies in this category include communication and cooperation across teams, expressing ideas, problems and suggestions in an appropriate manner, building the team, establishing trust and so on. Table 3 lists the top ten codes with the highest frequency counts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes.

Table 3 Relating capabilities

Codes	Frequency counts	Interviewee counts (No.)
Communication and cooperation across teams	82	22
Expressing ideas, problems and suggestions in an appropriate manner	66	20
Helping each other	60	21
Building the team	56	21
Facilitating the individual development of each member	51	15
Communication (generic)	48	19
Persuading others	45	15
Establishing trust	37	17
Building interpersonal relationships	35	16
Understanding each member’s needs	34	13

Our data indicate that engineers need to build functional and stable relationships inside and outside the team. These relationships and connections will help build trust and rapport with others who would potentially help with the projects. Also, a good relationship can contribute to forming a peaceful atmosphere of team. It can help team members to reach their full potential. Austin shared his experience about building the team,

> *Firstly, as a friend, a leader may know his members well. Secondly, if he can become a friend of his members, that means there is a short emotional distance between them, and that is not an official leader-member relationship. Because he treats others as equals, members are willing to talk to him. --Austin*

To form a healthy working relationship, establishing trust constructs an essential part. It helps engineers to be recognized by the team so that the team members will follow him in a confident manner. Eddy mentioned that,

Using your ability in data analysis, making use of your accumulated knowledge, including the degree to which you master the skill, you can convey, you can convince others to trust in you, so as to guide the path toward a certain direction.—Eddy

Here, Eddy shared how his expertise helped establish trust from his team members. Our findings suggest that engineers can also establish trust or credibility through firm engineering knowledge and skills, rich project experiences, or excellent communication skills.

C. *Visioning*

Visioning, that is, to set up and articulate inspiring and attainable goals, and to encourage team members to apply feasible methods to achieve common goals. Codes with high frequencies in this category include building common goals and directions among members, visualizing visions, building the connections between a vision and the expectations of stakeholders and so on. Table 4 lists the top ten codes with the highest frequency counts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes.

Table 4 Visioning Capabilities

Codes	Frequency counts	Interviewee counts
Building common goals and directions	49	17
Encouraging others	28	14
Understanding the meaning behind a task	19	8
Visualizing visions	19	11
Guiding the directions of projects	18	9
Building the connections between a vision and the expectations of stakeholders	14	9
Explaining the benefits for group members in a clear manner	14	10
Emphasizing the goals or reminding the members about the goals	11	9
Building interpersonal relationships	11	8
Constructing a company culture	11	7

A good company requires a decent company culture or value, which is often expressed via its vision or goals. Ideally a company's vision permeates in the different projects and tasks within a company. In our study, we found that engineers took into account their companies' cultures while they establish a common vision with the team members. Austin pointed out that,

To build a company culture, it is important for the leader, in the process of building his department, to instill it (company culture) into the process, say, for each employee to have grasped 60 to 70 per cents of it. Then, it will be okay. He (or she) will be very successful if he (or she) can do it. --Austin

For engineers, to convey the vision can include communicating the vision in a specific or vivid manner, or visualizing a vision. To visualize a vision means that engineers, especially engineering leaders, articulate and portray visions through metaphors, stories, drawings or other ways to help members to understand a point. As noted by Peng,

> *I explained a problem by drawing, changing rigid engineering equations into schema. I would consider how to visualize equations, inputs and outputs to make my team members understand this problem. I would show the result to them in a deductive manner. --Eric*

D. Inventing

Inventing means engineering leaders' coming up with inventive methods, processes and structures to deal with problems and to accomplish a vision, and their encouraging members to try problem-solving in a creative manner when encountering new tasks and changes. We identified more codes in this dimension than the other dimensions. This is probably because problem-solving lies in the core of engineering. We listed top twenty codes in this dimension. Codes with high frequencies in this category include identifying and analyzing problems, assigning tasks, breaking down a complex task, abilities in engineering design and so on. Table 5 lists the top twenty codes with the highest frequency counts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes.

Table 5 Inventing Capabilities

Codes	Frequency counts	Interviewee counts
Engineering technical knowledge and skills	131	23
Delegating tasks	97	22
Controlling or monitoring project progress	89	23
Conducting accountability check	80	21
Analyzing problems	71	19
Time management	66	21
Abilities to learn	59	19
Rich experiences	58	17
Identifying problems	50	17
Seeking external resources and help	50	17
Courage to try new things	47	17
Making flowchart or schemes	47	18
Proposing ideas or suggestions	44	18
Discussing with others	42	13
Abilities to summarize	38	17
Abilities in engineering design	35	13
Breaking down a complex task	34	15
Problem solving (generic)	33	15
Quality control	33	12
Abilities to execute a task	32	13

Solving problems lie in the core of an engineer' skills. To solve a problem in a creative manner can require rich experiences in addition to a solid foundation of engineering knowledge and abilities to apply technology. In our study, we found a number of skills that are related to an engineers' solving problems in a creative manner. Engineers may show the skills of seeking external resources and help, breaking down a complex task, delegating tasks and monitoring project progress. For example, an interviewee described,

> *When we met this kind of problem, I generally gathered all members together to analyze this problem from the very beginning. We described this problem in detail,*

and analyzed possible reasons for this problem. We might inquire other professional experts. If they didn't know how to solve this problem either, our team would analyze this problem together. –Austin

As we can see from the quote, different strategies or processes can be used to ensure problems getting solved. In addition to solving problems in a creative manner, inventing also includes different formats of creative ideas. For example,

Many creative ideas can basically come from two ways. One is integrating, the other is deconstructing. That is, to integrate several things, it then becomes a new idea; another, to deconstruct an integral thing into several ones, they become several small creative ideas. --Ethan

E. Change Signature

Change signature represents the unique leadership styles and actions of a leader. It influences all the four dimensions in the framework. We listed top fifteen codes in this dimension. Codes with high frequencies in this category include taking initiative, being responsible, optimism, dedication, professionalism and so on. Table 5 lists the top ten codes with the highest frequency counts. Also included are the counts of interviewees whose transcripts have shown the corresponding codes. It can be seen from the table that taking initiative and being responsible are the most mentioned codes. More than ten interviewees have pointed out the importance of these two characteristics for an engineer.

Table 5 Characteristics or Attributes in Change Signature

Codes	Frequency counts	Interviewee counts
Taking initiative	35	10
Being responsible	35	13
Showing justice and equity	13	7
Being detail-oriented	13	5
Dedication	11	7
Self-confidence	10	7
Expressing oneself	9	5
Professionalism	9	8
Being objective	8	6
Patience and perseverance	8	5
Kindness	8	6
Openness	7	6
Optimism	7	3
Pursuing perfection	7	4
Sincerity	5	4

Leaders' attitudes and behavioral characteristics can impact their decision-making and leadership styles. Taking initiative was often mentioned by engineers,

…that you are willing to actively find ways to push these things, to solve these things, this is the attitude of taking initiative. It is one of the most key factors to determine whether a project will succeed or not.--Austin

Also, engineers commented that attitudes such as being optimistic can greatly impact the group. For example,

> *One is being optimistic, another is freedom. That is, allowing them to be themselves, as much as possible, right. Meanwhile, to impact them, so that they can be more optimistic. This is important. If you are optimistic, you will never be desperate. Even when you meet with a bottleneck, there will be a solution, and it is not the end. --Austin*

Discussion

To summarize, our preliminary findings from a qualitative study among twenty-three engineers in a Chinese industrial context have generated a comprehensive list of skills and attributes framed in the context of the 4-Cap model. These skills and attributes construct a framework of capabilities from the dimensions of sensemaking, visioning, relating, and inventing, with core attributes identified as change signature. All of these skills and attributes form a systematic framework, which can be informative to guide engineering leaders' training. Moreover, this work tried to explore the actual demonstrations of engineering leadership in workplaces. It operationalized the 4-Cap model in a Chinese industrial context, which included private companies, state-owned companies, joint ventures, and foreign companies in this study. The unique perspectives of these Chinese engineers and practical examples in the fast-developing economy have rendered this comprehensive list of skills and attributes useful for the training of future engineers.

Moreover, our preliminary analyses have suggested several differences in the skills and attributes of engineering leadership across industries. For example, engineers from the electronics and information technology industry have demonstrated strong sensitivity to changes and new trends in their fields. This means that they are sensitive to changes in the field or the market and can make timely decisions or judgement on the nature of the change or on the developmental trend concerning the change. Another example comes from engineers from automobile industry. We found that because engineers in the automobile industry often worked on a certain part of a vehicle, they needed to collaborate with many other teams. Therefore, these engineers seemed to have paid more attention to the interconnectivities among different parts. That is, the change on one part can often lead to the change on some other part; changes in one technique may also lead to changes in the use of another technique. These preliminary findings suggest the uniqueness of engineering leadership in different industries. Nonetheless, this work-in-progress only present some findings from an initial comparison across different industries. We expect additional differences in the skills and attributes in engineering leadership across different industries shall appear with a deep examination of the data.

In addition to analyzing differences in the skills and attributes from engineers across different industries, we also expect to analyze differences in the skills and attributes from engineers of different company types and with varied years of practices in our further effort. Additional analysis will also be conducted to identify effective education methods as related to the skills and attributes listed in this study. We also will explore how the effective education methods were related with their prior education and the different types of universities from which the engineers graduated. This information will help improve the design and development of engineering leadership programs. However, we also acknowledge that due to the limitation of the number of participants, the findings require validations from future similar studies.

Finally, a thorough comparison is yet required to compare current findings to prior studies in the North-American context [14-16], which had also explored the essence and/or the demonstrations of engineering leadership. Leadership can have different meanings within varied cultural contexts [19-20]. We expect that an understanding of engineering leadership within different cultural contexts will further facilitate engineers' training to be competent leaders in an increasingly global context.

Conclusion

This study explored the practical demonstrations of the four dimensions of the 4-Cap model within a Chinese industrial context. Within each of the dimensions, specific skills or attributes were identified. A comprehensive list of skills or attributes emerged through the qualitative data analyses. These findings are expected to provide feedback to universities and engineering colleges to inform the design and implementation of engineering leadership training programs among students, and to provide constructive suggestions to curriculum design. Future comparisons of current findings and prior studies that were performed in a North American or a European context will also help deepen our current understanding of engineering leadership in different cultural contexts.

Acknowledgement

This research was supported by Chinese Ministry of Education, Humanities Social Science Study Program (15YJC880147).

Bibliography

[1] Kumar, S. & Hsiao, J. K. (2007). Engineers learn 'soft skills the hard way': Planting a seed of leadership in engineering classes. *Leadership and Management in Engineering, 7*(1): 18-23.

[2] National Academy of Engineering (NAE). (2004). *The Engineer of 2020: Vision of Engineering in the New Century*. Washington, DC: National Academies Press.

[3] Spinks, N., Silburn, N. & Birchall, D. (2006). *Educating the Engineers for the 21st Century-the Industry View*. London: Royal Academy of Engineering.

[4] *Bernard M. Gordon MIT engineering leadership program developing tomorrow's engineering leaders.* Retrieved from http://gelp.mit.edu/capabilitiesofeffectiveengineeringleaders

[5] Hu, Y. & Zhu, J. (2016). The Design and Implementation of Engineering Leadership Programs: A Comparative Study. *The 5th Annual ASEE International Forum*.

[6] Graham, R., Crawley, E. & Mendelsohn, B. R. (2009). *Engineering Leadership Education: A Snapshot Review of International Good Practice.* Cambridge, MA: Bernard M. Gordon-MIT Engineering Leadership Program

[7] *Royal academic of engineering.* Retrieved from http://www.raeng.org.uk/grants-and-prizes/schemes-for-students

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

[9] Paul, R. & Falls, L. C. (2015). Mapping career success competencies to engineering leadership capabilities. *IEEE Frontiers in Education Conference. IEEE, 1-6.*

[10] *Bernard M. Gordon MIT engineering leadership program developing tomorrow's engineering leaders.* Retrieved from https://gelp.mit.edu/

[11] Musselman, C. (2010). Leadership in engineering. Why is that important in engineering education? *National Society of Professional Engineers.* Retrieved from http://www.nspe.org/resources/blogs/pe-licensing-blog/leadership-engineering-why-important-engineering-education

[12] *Cornell engineering.* Retrieved from http://www.engineering.cornell.edu/resources/leadership_program/

[13] *College of engineering & applied science- university of Colorado boulder.* Retrieved from http://www.colorado.edu/engineering/leadership

[14] Rottmann, C., Sacks, R. & Reeve, D. (2015). Engineering leadership: Grounding leadership theory in engineers' professional identities. *Leadership, 11*(3):351-373.

[15] Ancona, D. (2005). Leadership in an age of uncertainty. *Center for Business Research Brief, 6*(1): 1-3.

[16] Ancona, D., Malone,T. W., Orlikowski, W. J., & Senge, P. M. (2007). In praise of the incomplete leader. *Harvard Business Review, 85*(2): 92-100, 156.

[17] *Bernard M. Gordon-MIT engineering leadership program capabilities of effective engineering leaders.* Retrieved from https://gelp.mit.edu/sites/default/files/documents/leadershipcapabilities.pdf

[18] Xie X. (2014). Exploring the pathways to develop Engineering Leadership with an orientation For Engineering Practice, *China Higher Education* (12):52-54.

[19] Lankau, M. J. ; Chung, B. G. (2009) A comparison of American and international prototypes of successful managers. *Journal of Leadership Studies 3*(1):7-18.

[20] House, R., Javidan, M., Hanges, P. & Dorfman, P. (2002). Understanding cultures and implicit leadership theories across the globe: An introduction to project GLOBE. *Journal of World Business*, *37*: 3-10.

[21] Merriam, S. B. (2006). Transformational learning and HIV-positive young adults. In V. A. Anfara Jr. & N. T. Mertz (Eds), Theoretical frameworks in qualitative research (pp.23-38). Thousand Oaks: SAGE Publications

[22] Ministry of Education of the People’s Republic of China. (2008). *Project 211, Project 985 and graduate education reform*. Retrieved from http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_2442/200810/39607.html (In Chinese)

[23] MacQueen, K. M., McLellan, E., Kay, K. & Milstein, B. (1998). Codebook development for team-based qualitative analysis. *Cultural Anthropology Methods, 10*: 31–36.

Appendix: Interview Protocol on Engineering Leadership

(1) First, let's talk about a project that you have recently completed. Could you please describe the process how you and your team completed this project?

(2) What kind of roles do you think you were playing in completing the project? Can you give some examples?

(3) What roles do you think other team members were playing in completing the project? What were their contributions? Please give some examples.

(4) Could you please describe the process of starting a new project? (Sensemaking)

(5) Could you please describe how the members in your team communicate with each other in the process of a project? (Relating)

(6) In completing the project, what are some actions that you have taken to help your team members to achieve a common goal? (Visioning)

(7) Have you ever encountered any difficulties in a project? If so, how did you and your team resolve them? Please give some examples. (Inventing)

(8) Based on the discussion above, can you make a summary of the skills and abilities that you think you have in completing a project?

(9) What are some other skills or abilities that you think very important to your work?

(10) What are some abilities that you believe important to your work but have not yet acquired?

(11) How did you acquire and develop these abilities?

(12) What do you think of the meaning of leadership in your work environment?

(13) What are the abilities that you think an ideal leader in your industry or sector should demonstrate?

(14) Do you have anything to add concerning today's topic?