Research on Engineering Leadership Elements of Excellence and Top-notch Innovative Talents in Engineering

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Abstract. With the implementation of the Education and Training Program for Engineer Excellence and the emphasis on the cultivation of excellence and top-notch innovative talents in the report of the Twentieth National Congress, the cultivation of outstanding excellence and top-notch innovative talents has become more and more important. As the core competence of engineers, the cultivation of engineering leadership is a necessary path for engineering excellence top-notch innovative talents to grow into outstanding engineers. This study constructs a model of engineering leadership elements for engineering excellence top-notch innovative talents by coding domestic and international literature using the grounded theory and combining the content of the leader interviews for engineers of excellence and the requirements for the cultivation of excellence and top-notch innovative talents. The study finally extracted six elements of engineering leadership: strategic vision leadership, technical leadership, business leadership, team leadership, generic leadership and self-leadership. These elements of engineering leadership provide theoretical guidance for engineering excellence and innovation talents to improve their engineering leadership, and help them reach the requirements of excellent engineers in the new era faster. Meanwhile, combined with the news interviews of outstanding engineers, it is found that “Patriotic Sentiment” is a very key element in the detailed elements of engineering leadership, and it is the basis for the cultivation and enhancement of various elements of engineering leadership. In the engineering leadership education of engineering outstanding and top-notch innovative talents, universities should clarify and strengthen the education of “Patriotic Sentiment”.

Keywords: Excellence and Top-notch Innovative Talents; Engineering Leadership; Element Model; Grounded Theory

1 Introduction

At present, China's higher education is dedicated to nurturing top-tier innovative talents, especially outstanding engineers in the field of engineering technology. In response to the call from the 20th National Congress report to enhance the quality of

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talent cultivation, universities are actively establishing colleges for outstanding engineers to explore pathways for talent development. This paper focuses on engineering leadership, and through literature analysis and interviews, constructs a model of engineering leadership elements for excellence and top-notch innovative talent in engineering, aiming to provide guidance for the cultivation of top innovative talents in the field of engineering in China.

2 Problem Statement

In the 21st century, the field of engineering technology is characterized by increasingly large-scale projects, rising complexity, expanding personnel involvement, and a broadening scope of disciplines. To accomplish engineering projects and solve engineering challenges within such a complex environment, it is no longer sufficient for engineers to possess only specialized engineering knowledge. Engineering leadership is poised to become a core competency for the "next generation of engineers."[1]. Engineering leadership consists of capabilities and values that transform technical people from individual contributors into those who can lead teams to deliver a complex multi-disciplinary product [2]. In the new era's demand for cultivating top-notch innovative talents in engineering, the elements of engineering leadership should be adjusted according to the requirements of the times and national conditions. This study aims to refine engineering leadership elements of excellence and top-notch innovative talents in engineering in line with contemporary and national demands. It will integrate grounded coding of literature, insights from interviews with distinguished engineers, and the competency framework from Beijing University of Posts and Telecommunications, forming a model of engineering leadership elements of excellence and top-notch innovative talents in engineering that offers a theoretical foundation for cultivating such talent in Chinese universities.

3 Preliminary Construction of Engineering Leadership Elements

3.1 Research Objects and Methods

This study selected CNKI and Web of Science as the main search databases to obtain 37 relevant authoritative journal documents and 3 master's and doctoral theses, and then used the MAXQDA 2018 software to adopt the grounded theory research methodology to code, analyze and process the content of the literature. The screened literature was imported into the MAXQDA software, after which the text was coded at three levels by reading and understanding these materials, and the constituent elements of engineering leadership were gradually identified from disorder to system and from data to theory.

Open Coding.

In this study, in the open coding stage, the imported literature materials were interpreted word by word and sentence by sentence, the corresponding initial concepts were summarized, and the more abstract and generalized categories were formed after several tests and mergers [3]. After careful deliberation and repeated proofreading, a total of 818 labels, 128 concepts and 45 initial categories were formed, and the results of open coding are shown in Table 1.

Table 1. Open Coding Result (Excerpt)

Coding	Initial Categories	Initial Concepts	Original Statements
B1	Sustainable Development Capability	b1: Sustainable Development b2: Engineering-Ecology Integration Capability	A1: The combination of engineering ecological concepts, engineering ecological awareness, and integration capabilities forms the Engineering-Ecology Integration Capability. A2: The term "sustainable development" was proposed by the United Nations World Commission on Environment and Development in its 1987 report "Our Common Future," which is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." ... A6: Have a profound understanding of the principles of sustainable development.
B2	Risk Assessment and Control Capability	b3: Risk-taking Capability b4: Viewing Life as a Process of Exploration b5: Crisis Anticipation Capability b6: Crisis Management Capability	A7: I need to understand the potential risks of this project. A8: Students will understand the value of intelligent fast failure and will be confident in assessing and taking risks. ... A26: Awareness of crises and the ability to handle major emergencies and crises.
.....			
B45	Learning Capability	b126: Self-learning Ability b127: Lifelong Learning Ability b128: Proactive Learning Ability	A804: Capable of integrating knowledge across interdisciplinary fields, continuously updating oneself, absorbing new knowledge, new methods, and new concepts to address various issues, demonstrating strong self-confidence and flexibility. A805: Continuously learning new knowledge to keep pace with current technology. ... A818: Proactive learning.

Axial Coding.

Axial coding, the second stage of procedural coding in grounded theory, delves into the deeper logical connections between categories identified in open coding, synthesizing them into more concise main categories [4]. In this study, 45 initial categories were refined and clustered into six main categories of engineering leadership: "Strategic Vision Leadership," "Technical Leadership," "Business Leadership," "Team Leadership," "Generic Leadership," and "Self-Leadership", as detailed in Table 2.

Table 2. Axial Coding Result (Excerpt)

Encoding	Main Category	Corresponding Category
C1	Strategic Visionary Leadership	B1: Sustainable Development Capability B2: Risk Assessment and Control Capability B3: Strategic Foresight and Planning Capability B4: Visionary Capability
C2	Technical Leadership	B5: Technological Change and Innovation Capability B6: Project Design and Management Capability B7: Technological Appreciation and Application Capability B8: Engineering Expertise
.....		
C6	Self-Leadership	B42: Personal Mentality B43: Personal Charm B44: Self-Management Ability B45: Learning Capability

Selective Coding.

Selective coding is the third stage of the procedural coding of rootedness theory, which requires extracting the decisive core categories on the basis of principal axis coding [5]. In this study, six main categories were analyzed in depth, and the core category was finally identified as "Engineering Leadership".

4 Supplementary Optimization of Engineering Leadership Elements

4.1 The Reasons Why Outstanding Engineers Become Leaders

January 19, 2024, "National Engineer Award" commendation meeting held in Beijing, China's outstanding representatives of the majority of engineers and technicians, as a typical example to be commended. They have a mission in mind, burying their heads in the "neck" key core technologies, and eventually become a leader in the field of expertise. After the commendation ceremony, many media interviews with these outstanding engineers, this study analyzes the content of the report interviews, digs out the common characteristics of the outstanding engineers, and comes up with the key reasons for them to become the industry leaders. The results of the analysis are shown in Table 3.

Table 3. Analysis of Interviews with Distinguished Engineers

National Sentiment	1) In multiple reports, distinguished engineers have a unanimously emphasized their patriotic sentiments, Wan Buyen, the creator of the "Hai Niu ll" drill, resolutely chose the ocean as his "dedication to the nation" based on national needs. After years of hard work at sea, he developed China's own deep-sea drilling rig. 2) Zhou Li, the leader of the fuxing high-speed train's research and innovation team, was driven by the dream of "great national equipment." After five years of scientific research, he broke through several core railway technologies, show casing Chinese wisdom to the world. Nan Rendong, the first chief engineer of the "China Sky Eye," returned to the construction site despite suffering from lung cancer, and his words, " If there is the slightest flaw in the 'Sky Eye,' I would not be able to face the country!" resounded through the mountains and rivers.

High Sense of Responsibility	1) Facing doubt that "Chinese people cannot build the 'Bind's Nest," Li Jiulin, the chief engineer of Beijing Urban Construction Group Co, Ltd, took on the challenge and became the chief engineer of the "Bid's Nest" project, regarding the realization of domestic production of high-strength steel as a mission that must be completed. 2) Out of a sense of professional responsibility, Su Quanke, the "pulse taker" of the quality of the Hong Kong Zhuhai Macao Bridge and the chief engineer of the project, said, "After so many years of work I have always regarded the quality of the project as my life, "Regarding the project as life" is the level of responsibility that a leading engineer should have. 3) Xue Feng, the chief architect of China Construction Design Institute Co, Ltd, proposed," What we should do is to be architects for the people, serving the people; I think this is the spirit of engineers." In response to the current situation of "many elderly people in villages," he designed a systematic aging adaptation, from the village layout built around tees to the color matching of every brick and tile, all of which required multiple confirmations with the construction team.
Rich Engineering Experience	1) Su Quanke, the chief engineer of the Hong Kong Zhuhai Macao Bridge project, has participated in the construction of the Shantou Bay Bridge, Taishan Bay Bridge, Xiamen Haicang Bridge, and other bridges, accumulating rich experience in bridge design, construction, and supervision for the construction of the Hong Kong Zhuhai Macao Bridge. 2)Nan Rendong, the People's Scientist, emphasized," Without a diamond drill, you can't do porcelain work" No mater the size of the project, it requires the hard work of accumulating day by day and dripping through stone. 3)The engineers from Harbin Institute of Technology's National Academy for 0utstandimeEneimeers said in an interview with the People's Daily that Harbin institute of Technology places special emphasis on students participation in engineering practice projects in the training of engineers, and requires student to have practical outputs, such as research results that can support the design and argumentation reports of major engineering project schemes , participation in the formulation of national or industry standards, or invention patents to the content of the discipline and profession.

Modern engineers' rise to industry leadership is inseparable from the role of engineering experience, “Patriotic Sentiment” and the sense of responsibility driven by these feelings. Engineering experience and sense of responsibility have been extracted during the grounded theory study of the literature, categorized under the experience accumulation of generic leadership and the personal mental elements of self-leadership, respectively. However, "Patriotic Sentiment" were not previously included, hence this element is supplemented. "Patriotic Sentiment" reflect an individual's emotions, attitudes, and values, closely to personal patriotism, national and ethnic identification, responsibility, and belonging. Thus, this study incorporates "Patriotic Sentiment" into the personal mental category under self-leadership within engineering leadership.

4.2 Bupt Requirements for Excellence and Top-Notch Innovative Talent Development Capabilities

Beijing University of Posts and Telecommunications, a leading "211 Project," "985 Advantageous Discipline Innovation Platform," and "Double First-Class" institution, is at the cutting edge of technological and industrial shifts, developing a premier innovative talent training system. It has integrated training programs from undergraduate to doctoral levels across key schools and a dedicated College of Outstanding Engineers, following the "Implementation Plan for the Cultivation of Top-notch Talents" to nurture leading engineering innovators [6-8]. The capability requirements for nurturing top-tier innovative talents in universities essentially encapsulate all the findings from the second-level coding of literature studies, as detailed in Table 4.

Table 4. BUPT Training Capability Requirements Table (Excerpt)

Academy	Cultivation Capability Requirements	Corresponding competency Elements
Computer Science College	1. Engineering Knowledge - Possess a solid foundation in mathematics, natural sciences, and engineering basics, systematically master professional knowledge in the fields of computer systems and networks, have a basis in communication theory and technology, and be able to apply this knowledge to solve complex engineering problems.	Technical Leadership
	.....	.....
	12. Lifelong Learning - Have the ability for independent learning and lifelong learning, and be able to adapt to the continuous development and changes of computer systems and network technology in the future.	Self-Leadership
Future College	1. At the undergraduate level, strengthen the foundation of mathematics and science, enhance the integration of multidisciplinary knowledge, intensify scientific research training and engineering practice, highlight innovation capabilities, and cultivate interdisciplinary comprehensive abilities.	1、Business Leadership 2、Technical Leadership 3、Self-Leadership
	.....	.....
	7. Organize innovative educational practices such as industry cognition and student salons to enhance students' resilience in facing future opportunities and challenges, improve their self-awareness and self-development planning levels, and help each student plan a personalized path to success.	Self-Leadership
School of Information and Communication Engineering	1. Possess the relevant mathematical and natural science knowledge required for work in the field of information and communication, and have basic professional knowledge in electronic circuits, signal and information processing, electromagnetic fields and waves, computer technology and applications, information and communication systems, and be able to apply this knowledge to solve complex engineering problems in the field of information and communication.	Technical Leadership
	.....	.....
	12. Have the awareness of independent learning and lifelong learning, be able to keep track of the development trends in the field of information and communication, and have the ability to continue learning and adapt to development.	Self-Leadership

5 Engineering Leadership Elements Model Construction

Based on the coding and supplementary optimization of engineering leadership elements, this paper constructs a model of engineering leadership elements for excellence and top-notch innovative talent in engineering. The engineering leadership of top-notch innovative talent in engineering is primarily composed of "Strategic Vision Leadership," "Technical Leadership," "Business Leadership," "Team Leadership," "Generic Leadership," and "Self-Leadership," as shown in Figure 1. All the detailed elements contained in the aforementioned six major leadership elements are shown in Table 5.

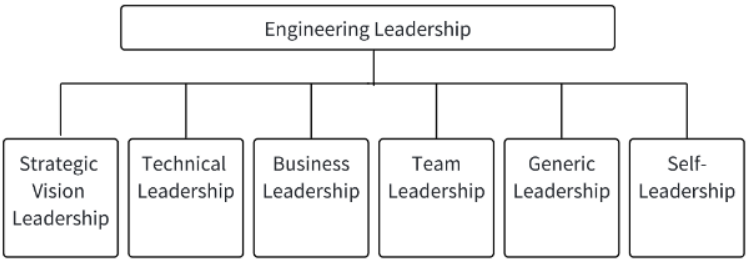

Fig. 1. Model of Engineering Leadership Elements for Excellence and Top-notch Innovative Talents in Engineering

Table 5. Engineering Leadership Elements of Excellence and Top-notch Innovative Talents in Engineering: Detailed Breakdown Chart

Engineering Leadership Elements of Top-notch Innovative Talents in Engineering					
Generic Leadership	**Team Leadership**	**Self-Leadership**	**Business Leadership**	**Technical Leadership**	**Strategic Vision Leadership**
Decision-making Ability Comprehensive Knowledge Analytical Ability Organizational Innovation Ability Environmental Adaptability Logical Reasoning Ability Problem-solving Ability Integration Ability Balancing Ability Experience Accumulation Industry and Societal Influence Perception Ability Demand Grasping Ability Observation Skills Reflective Ability International Engineering Ability Adaptability Imagination	Team Building and Collaboration Communication and Coordination Ability Interpersonal Ability Team Cohesion Personalized Coaching Ability Execution Ability Shared Leadership Managerial Innovation Ability Institutionalization Ability	Personal Mindset Personal Charisma Learning Ability Self-management Ability	Product Planning and Marketing Ability Market Analysis and Innovation Ability Business Thinking and Knowledge Cost Analysis and Control Ability Customer Service Ability Project Operation Ability	Engineering Expertise Technology Change and Innovation Ability Project Design and Management Ability Technology Appreciation and Application Ability Strategic Technological Thinking	Vision Ability Risk Assessment and Control Ability Strategic Foresight and Planning Ability Sustainable development ability

Strategic vision leadership refers to the leadership ability in project strategy and vision within engineering activities, including four aspects of ability elements: sustainable development ability, risk assessment and control ability, strategic foresight and planning ability, and vision ability [9]. Technical leadership refers to the leadership ability to achieve strategic vision, oriented towards project implementation, conceptual innovation, and technical realization, including four aspects of ability elements: technology change and innovation ability, project design and management ability, technology appreciation and application ability, and engineering expertise [10]. Business leadership refers to the leadership ability guided by business thinking to achieve product commercialization, including six aspects of ability elements: customer service ability, market analysis and innovation ability, business thinking and knowledge, cost analysis and control ability, product planning and marketing ability, and project operation ability [11]. Team leadership refers to the ability to promote team cooperation and problem-solving in the context of engineering activities, including various ability elements such as team

building and collaboration, communication and coordination ability, interpersonal ability, team cohesion, personalized coaching ability, execution ability, shared leadership, managerial innovation ability and institutionalization ability [12]. Generic leadership refers to the leadership abilities that are applicable in strategic vision, business, technology, team, and self-leadership, including various ability elements such as experience accumulation, environmental adaptability, logical reasoning ability, problem-solving ability, industry and societal influence, and reflective ability [13,14]. Generic leadership acts like a lubricant for the application of other leadership abilities, binding them together into a more powerful engineering leadership, which is very important for the smooth advancement of engineering projects. Self-leadership refers to the leadership ability in recognizing, managing, and developing oneself during engineering activities, which includes four aspects of ability elements: Personal charisma, Personal mindset, self-management ability, and learning ability [15].

6 Conclusions and Insights

This study employs grounded theory to analyze relevant literature, in conjunction with interviews of outstanding engineers and the capability requirements for nurturing top-tier innovative talents in universities, to explore the elements of engineering leadership among these exceptional engineering talents. It identifies six key leadership capabilities for engineering excellence and innovative talent: Strategic Vision Leadership, Technical Leadership, Business Leadership, Team Leadership, Generic Leadership, and Self-Leadership. Notably, the study reveals that in the context of China's rising global stature, the "Patriotic Sentiment" within Self-Leadership's "personal mindset" is crucial for engineering and innovative leadership. This sentiment profoundly influences the development of the other leadership capabilities. The findings suggest that higher education should integrate ideal and belief education with professional training for engineering excellence and innovative talent, embedding it in the graduation capabilities of engineering students to ensure the continuous of the "red gene" in the engineering community.

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