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REVIEW ARTICLE

Empowering the future of engineering education discipline with Chinese characteristics: Motivation, formation and promotion

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ABSTRACT

Engineering education discipline encompasses a complex interplay of various factors, such as the rapid expansion of engineering disciplines, the enhancement of exceptional engineer training, and the advancement of educational excellence. This paper presents an overview of relevant research and practices in the construction of the engineering education discipline, including scientific investigations, disciplinary frameworks, research institutions, research teams, and research methodologies. Additionally, it highlights the key elements for the development and future promotion of the engineering education discipline. These elements are guided by a focused discipline development approach, driven by strengthened curriculum and teaching initiatives, empowered by the cultivation of outstanding research talents, facilitated by the establishment of a diverse teaching staff, and supported by high-level scientific research. Finally, this paper offers future prospects and reflections on the construction of engineering education discipline with distinctive Chinese characteristics.

Key words: engineering education, engineering education discipline, secondary discipline, outstanding engineer

INTRODUCTION

In order to foster innovation in the field of engineering science and technology, nurture exceptional engineers, and advance theoretical research in engineering education, the Ministry of Education and the Chinese Academy of Engineering have collaboratively launched an initiative to establish a novel secondary discipline in the realm of engineering education. This initiative aligns with the requirements outlined in the notice issued by the Academic Degrees Office of the State Council regarding the promotion of "Engineering Education Discipline" as a secondary discipline in select universities. In 2022, Tsinghua University, Huazhong University of Science and Technology, Tianjin University, and ten other universities successfully completed the pilot work for the initial establishment of this discipline.

As an emerging branch within the broader field of education, engineering education emphasizes the integration of interdisciplinary knowledge systems and technical methods from various fields such as education, engineering, natural sciences, sociology, and management. It operates within a philosophical and methodological framework, rooted in engineering education practice. Engineering education is a professional science that investigates the phenomena and issues of engineering education, aiming to uncover the underlying laws governing

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it. The goals of disciplinary construction in engineering education primarily revolve around two aspects: first, to examine the internal structure of the engineering education system, explore the interrelationships among its elements, and comprehend the fundamental laws of engineering education to establish it as a professional discipline; second, to explore the laws governing the operation of engineering education and talent cultivation based on specific socio-economic contexts and societal needs. This endeavor aims to guide universities in training outstanding engineers aligned with industrial development and national strategy.

In summary, the establishment of the secondary discipline of engineering education and the cultivation of high-level research talents in this field are crucial measures in line with the strategic objectives of making China a leading country in education, science, technology, and talent by 2035. This initiative holds significant strategic and practical value as it promotes institutional collaboration among the government, universities, and the industrial sector, while contributing engineering education expertise to the construction of a Chinese-style modernization.

THE RISE AND DRIVING LOGIC OF ENGINEERING EDUCATION

The emergence of engineering education is an inevitable result of the rapid expansion of engineering education and the complex interweaving of a shortage of high-level research talents. It is also an effective carrier for shaping the governance community of engineering education.

Firstly, the formation of engineering education is an inevitable result of the rapid expansion of engineering education and the relative scarcity of high-level professional research talents. Since the beginning of the new century, China's engineering education has experienced a rapid expansion, forming the largest engineering education supply system in the world. Against the backdrop of unprecedented changes and the great rejuvenation/n of the Chinese nation, China is in a critical period of reform, adjustment, transformation, and upgrading of its industrial economy. Such a historical stage determines the need for a large number of high-quality engineering and scientific talents for social and economic development in our country.[1] According to the data, in 2020, the number of undergraduate engineering students in China exceeded 6 million, accounting for about one-third of the total enrollment. At the same time, more than 90% of undergraduate institutions offer engineering majors. From an international perspective, according to the "China Engineering Education Quality Report," China not only leads in the scale of engineering education but also surpasses engineering education powerhouses such as Russia and the United States by three to five times in terms of enrollment numbers, current student population, and number of graduates in engineering disciplines. Looking at the historical changes over time (Figure 1), from 2001 to 2010, the number of undergraduate engineering students in China increased

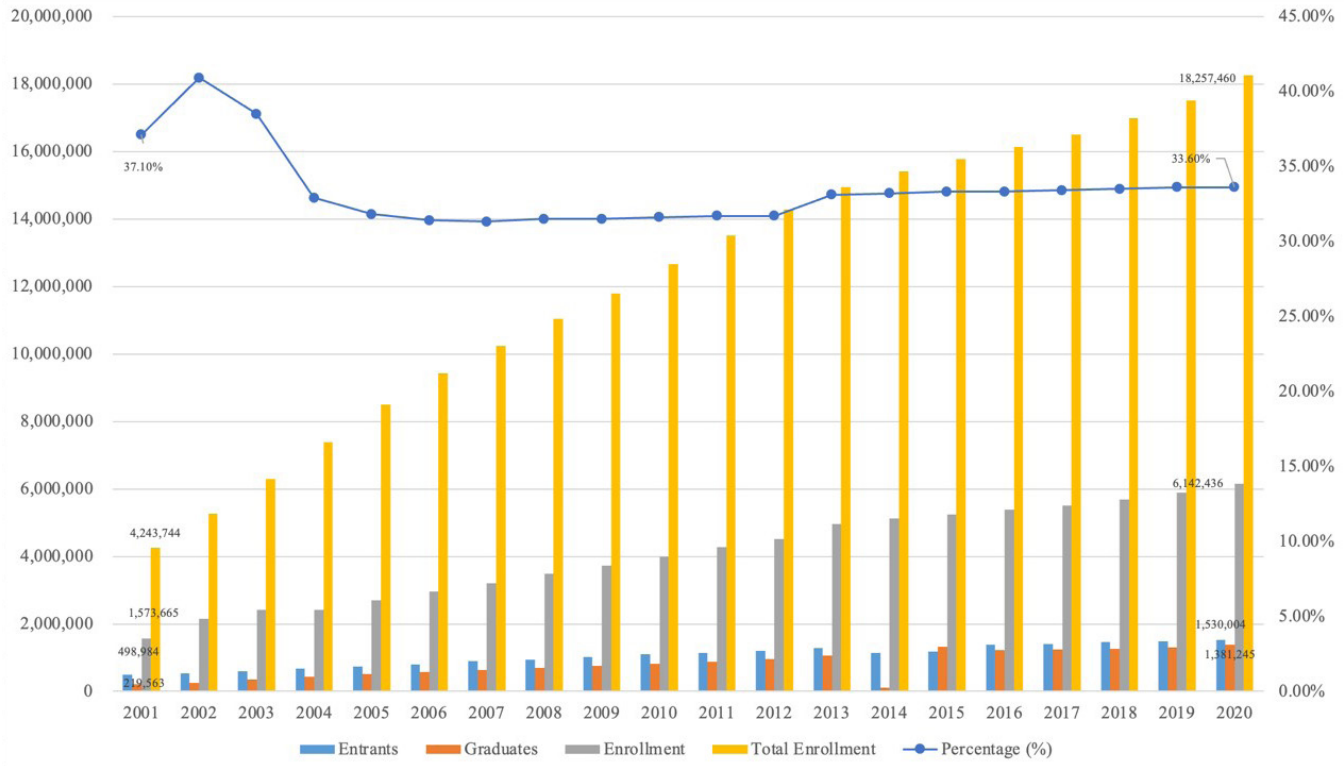

Figure 1. Basic situation of undergraduate enrollment, graduates, and current students in engineering disciplines in Chinese general universities (2001–2020).

from 1, 573, 665 to 6, 142, 436, a growth rate of 290%. The number of undergraduate engineering students accounted for about one-third of the total number of students in higher education. The number of enrollments increased from 498, 984 to 1, 530, 004, a growth rate of 207%. The number of graduates increased from 219, 563 to 1, 381, 245, a growth rate of 529%. Therefore, faced with the ever-expanding scale of engineering education, it is urgent to construct a professional and systematic theoretical research system of engineering education through engineering education and cultivate a large number of high-level research talents to match the scale.

Furthermore, the formation of engineering education science is an effective path to promote systematic reform in engineering education and establish a new paradigm for engineering education. The world is currently undergoing unprecedented changes, with China experiencing continuous evolution in the new industrial revolution and industrial transformation represented by artificial intelligence, blockchain, the Internet of Things (IoT), and big data. Facing new situations, opportunities, and challenges, China proposed the concept of "*New Engineering Disciplines*" in 2016. In early 2017, it successively promoted the "*Fudan Consensus*" "*Tianjin University Action*" and "*Beijing Guidelines*". Two batches of research and practice projects on new engineering disciplines were actively carried out, including the first batch of 612 projects and the second batch of 845 projects, which played a positive role in promoting engineering education reform and practice. Through continuous practice, a number of landmark achievements have been gradually formed, such as Tianjin University's "*Tianjin Plan*", University of Electronic Science and Technology of China's "*Chengdu Plan*", South China University of Technology's "*F Plan*", Harbin Institute of Technology's "*Pi-Shaped Plan*", Peking University's "Construction Plan for New Engineering Disciplines", and Chongqing University's "*Significant Experience*", as well as the Southern University of Science and Technology's "*School of System Design and Intelligent Manufacturing (SDIM) New Engineering Education Reform*".

In 2019, the Ministry of Education issued documents such as the "*Opinions on Accelerating the Construction of High-level Undergraduate Education and Enhancing Comprehensive Talent Cultivation Capacity*", deciding to implement the "*Six Outstanding and One Elite Plan 2.0*", which provided overall planning and specific arrangements for talent cultivation in fields such as humanities, sciences, engineering, agriculture, medicine, and education. The "*Outstanding Engineer Education and Training Plan 2.0*"is a direct and important measure for the reform of engineering education. In May 2020, the Ministry of Education Office issued the "*Guidelines for the Construction of Future Technology Institutes (Trial)*", aiming to explore new models of cultivating leading talents in future scientific and technological innovation. In July of the same year, the Ministry of Education Office and the Ministry of Industry and Information Technology Office jointly released the "*Guidelines for the Construction of Modern Industry Institutes (Trial)*", proposing the cultivation of highly skilled applied, versatile, and innovative talents who can adapt to and lead the development of modern industries. In September 2022, the Ministry of Education and the State-owned Assets Supervision and Administration Commission of the State Council issued the "*Notice on Supporting Pilot Co-construction of National Outstanding Engineering Institutes by Some Universities and Central Enterprises*", proposing to cultivate high-level engineering talents with broad theoretical knowledge, deep specialized knowledge, and the ability to solve complex engineering problems. Overall, China has conducted a large number of engineering education reform and practice activities, and it is urgent to promote related systematic research through the discipline of engineering education science, summarize new ideas, methods, paths, and technologies in the reform, and then form a new paradigm of engineering education research that conforms to the development reality of China.

Lastly, the formation of engineering education science is an effective vehicle for building a community for the governance of engineering education and empowering the cultivation of a large number of outstanding engineers. In the rapidly changing field of science and technology, in many engineering and technological fields, the industry is more familiar with industrial demands and frontier development than universities. Therefore, it requires universities to actively engage with the industry, overcome and solve the serious problem of disconnection between current engineering education and the industry. However, from the practical situation, the problem of disconnection between engineering education and the industry has not fundamentally changed in the past decade. If we can effectively address the issue of deep cooperation with the industry in the future, engineering education will be better able to adapt to the rapid development of industrial requirements, and various issues such as types and classifications, structures and scales, models and evaluations will be resolved. Therefore, based on the discipline of engineering education science, actively conducting research and practice in engineering education can effectively shape an effective vehicle for government leadership, university participation, industry involvement, and student-centered participation in discipline construction. It promotes the formation of a good interactive mechanism and institutional norms among stakeholders, gradually solves the fundamental problem of disconnection between engineering education and the industry, and empowers the shaping of a new pattern for the cultivation of outstanding engineers with Chinese characteristics and international first-class standards.

THE CONSTRUCTION FOUNDATION AND FORMATION OF ENGINEERING EDUCATION DISCIPLINE—ENGINEERING EDUCATION RESEARCH AND PRACTICE

In 2004, Purdue University became the first institution worldwide to establish a Department of Engineering Education, dedicated to conducting research on engineering education, nurturing specialized researchers in engineering education, and guiding the teaching reform of engineering faculty. This initiative has significantly contributed to the development of the discipline of engineering education science.[2] In comparison, although the discipline of engineering education science emerged relatively late in China, there is already a solid foundation and substantial accumulation of research and practice. This foundation can be observed in five aspects: scientific research, disciplinary layout, research institutions, research teams, and research methods.

Firstly, in terms of scientific research, the development of engineering education research in China has lagged behind the advancement of engineering education itself. The embryonic stage of engineering education in China can be traced back to the establishment of various Western-style schools during the Late Qing Dynasty, known as the "Self-Strengthening Movement". At that time, there were no specialized researchers or research institutions dedicated to engineering education. The systematic research on engineering education in China began in the mid-1990s, with a strong emphasis on comparative studies of the development models of engineering education in developed countries such as Germany and the United States. This comparison aimed to provide references for the development of engineering education in China with its unique characteristics. Noteworthy scholars such as Professor Peimin Wang[3] from Zhejiang University, Professor Shouwen Yu[4] from Tsinghua University, and Academician Gaofeng Zhu[5] from the Chinese Academy of Engineering have made significant contributions in this field.

Based on a comparative analysis of the engineering education structures in the United States and Germany, Professor Peimin Wang concluded that German engineering education has clear training objectives, and the engineering education process in universities is generally terminal education. On the other hand, the training objectives of engineering education in the United States are relatively vague, and the engineering education in universities is transitional. Many students shift their focus to fields such as law, economics, or medicine during their education.[3] Professor Shouwen Yu believes that German engineering education aims to cultivate specialized talents, and universities and companies engage in various forms of deep cooperation to ensure that students receive sufficient theoretical learning and practical training. Upon graduation, students already possess the ability to solve engineering problems. In contrast, engineering education in the United States aims to foster versatile talents, and the training of industrial practice skills is handed over to companies after students graduate.[4] Academician Gaofeng Zhu believes that as a rapidly rising nation in the late 19th century, Germany emphasized technical education and industrial practice teaching. The career development path for graduates was becoming engineers equipped with the ability to solve practical engineering problems. In the United States, the emphasis was on scientific education and the freedom of choice and development for students. After graduation, students pursued various career paths, and the training of practical skills for engineering professions was delegated to the business sector.[5]

Furthermore, as one of the scholars who introduced the foreign professional accreditation system to China at an early stage, Professor Jiaju Bi from Tongji University has made a series of achievements in the field of engineering education professional accreditation system construction since the 1990s.[6] In the past decade, research directions such as talent cultivation models with curriculum reform and engineering practice at the core, engineering education professional accreditation systems and standards, Outstanding Engineer Programs, and theories of higher engineering education have gradually become important focuses of engineering education research. Additionally, since the implementation of the New Engineering Education Program in 2017, related research on the program has rapidly expanded, leading to the emergence of numerous representative works such as "The Connotation and Actions of New Engineering Education",[7] "Future-Oriented New Engineering Education in China",[8] "New Engineering Education and New Paradigm: Concepts, Frameworks, and Implementation Paths".[9] In summary, although China has a relatively long history of conducting research on engineering education, has established various research institutions on a considerable scale, and has produced a substantial number of representative achievements, it has not systematically cultivated high-level and specialized research talents through the establishment of a specialized discipline for an extended period.

Next, in terms of disciplinary layout, prior to 2022, Chinese universities did not have separate master's and doctoral programs in the field of engineering education. Apart from Tsinghua University, which established a separate research direction in engineering education for recruiting graduate students, other universities generally offered engineering education research directions as relative branches under the second-level disciplines of higher education and educational economics and management. In order to implement the spirit of the 20th National Congress of the Communist Party of China, deepen the reform of engineering education, promote research and talent cultivation in engineering

education, the Ministry of Education and the Chinese Academy of Engineering jointly supported 10 universities with strong engineering or educational strengths, such as Tsinghua University, Huazhong University of Science and Technology, and Tianjin University, to carry out pilot work in establishing the second-level discipline of engineering education science in 2022. Taking Tianjin University as an example, it took the lead in initiating the establishment of second-level disciplines outside the catalog of engineering education science in June 2022. It plans to carry out professional construction in areas such as engineering education policy, engineering education theory, engineering education curriculum and teaching, and training of outstanding engineers, aiming to cultivate high-level doctoral students who can comprehensively apply interdisciplinary research methods to explore cutting-edge issues in engineering education.

Furthermore, in terms of research institutions, some universities with advantages in engineering education have already formed relatively mature specialized research institutions (Table 1). For example, the Higher Engineering Education Research Center jointly established by the Chinese Academy of Engineering and Beihang University (2003); the Engineering Education Research Center (2008), the Institute of Engineering Education (2008), the United Nations Educationnel, Scientific and Cultural Organization (UNESCO) International Centre for Engineering Education (2015), and the National Engineering Education Multidisciplinary Cross-Innovation Talents Introduction Base (2019) at Tsinghua University; the Department of Engineering Education (2009, now discontinued) and the Engineering Education Research Center (2015) at East China University of Science and Technology; Institute of China's Science, Technology and Education Policy (ICSTEP) at Zhejiang University (2013); the New Engineering Education Institute (2018), the New Engineering Education Center (2018), and the National Center for New Engineering Education Innovation (2019) at Tianjin University; the Engineering Education Institute at Huazhong University of Science and Technology (2019); and the Engineering Education Development Research Center at Shanghai University of Engineering Science (2019). In addition to universities, important institutions related to engineering education include the Engineering Education Professional Committee of the China Higher Education Society, established in 1991, and the China Engineering Education Accreditation Association, established in 2015. The former is a branch of the China Higher Education Society, with Zhejiang University currently elected as the sixth session's chairman unit. The latter is a professional organization authorized by the Ministry of Education and led by the China Association for Science and Technology, composed of nearly 60 industry associations and individuals. It is also the only specialized institution in China responsible for carrying out engineering education professional accreditation work.

Moreover, in terms of research teams, a considerable scale has been initially formed, comprising a group of active academic research groups (Table 2). With the advancement of engineering education reforms such as the Outstanding Engineer Program, New Engineering Disciplines, Future Technology Institutes, and National Outstanding Engineer Colleges, the overall development of engineering education research has shown a trend towards increasing activity. In terms of the total number of published papers and citation frequency, engineering education research is highly concentrated in areas such as engineering education concepts, engineering education accreditation, outstanding engineers, curriculum

Table 1: Overview of major engineering education research organizations in Chinese universities

Serial Number	University	Organization Name	Year of Establishment
1	Chinese Academy of Engineering-Beihang University	Center for Higher Engineering Education Research	2003
2	Tsinghua University	Center for Engineering Education Research	2008
		Engineering Education Institute	2008
		UNESCO International Centre for Engineering Education	2015
		National Engineering Education Multidisciplinary Cross-Innovation and Intelligence Base	2019
3	East China University of Science and Technology	Department of Engineering Education (Discontinued)	2009
		Center for Engineering Education Research	2015
4	Zhejiang University	China Institute of Science and Education Strategy	2013
5	Tianjin University	Center for New Engineering Education	2018
		Institute for New Engineering Education	2018
		National Innovation Center for New Engineering Education	2019
6	Huazhong University of Science and Technology	Engineering Education Institute	2019
7	Shanghai University of Engineering Science	Center for Engineering Education Development Research	2019

Table 2: Representative scholars and relevant achievements in engineering education research

Serial Number	Institution	Scholar	Typical Papers (Citation Count)
01	Department of Higher Education, Ministry of Education, China	Wu Aihua	Accelerating The Development and Construction of Emerging Engineering, Taking Initiative to Adapt to and Lead The New Economy (1614 times), Lead The Innovation and Reform of Higher Education through the Construction of Emerging Engineering Education (370 times)
02	Tianjin University	Gu Peihua	OBE Engineering Education Model in Shantou University (1604 times), From CDIO to EIP-CDIO: A Probe into the Mode of Talent Cultivation in Shantou University (926 times)
03	Tsinghua University	Lin Jian	The Construction of China's New Engineering Disciplines for the Future (1518 times), The Development of General Standards for "A Plan for Educating and Training Outstanding Engineers"(658 times)
04	Dalian University of Technology	Li Zhiyi	Guiding the Reform of Higher Engineering Education with Result-oriented Educational ldeas (1275 times), The results-oriented concept of accreditation in engineering education. (1257 times)
05	Beijing Jiaotong University	Zha Jianzhong	On CDIO Model under "Learning by Doing" Strategy (1042 times), Strategy of Engineering Education Reform in the Era of Economic Globalization (252 times)
06	Zhejiang University	Lu Guodong	Reflections of the Paths of Constructing and Developing Emerging Engineering Education (686 times), Five breakthroughs and preliminary explorations in the construction of "new engineering disciplines."(265 times),
07	Shanghai University of Engineering Science	Xia Jianguo	On the Reform and Development of Engineering Education in Local Universities and Colleges Based on Establishing Emerging Engineering Education (533 times), Reflections on Engineering Education Reform and Emerging Engineering Education Construction (77 times)
08	Wuhan University of Technology	Zhang Anfu	Reflection on the lmplementation of "A plan for Educating and Training Out-standing Engineers' (413 times), Construction of new engineering disciplines in the context of "Made in China 2025." (67 times),
09	Huazhong University of Science and Technology	Li Peigen	On Practical Teaching of Undergraduate Engineering Education in China: Problems and Causes (395 times), What's New for New Engineering Education (326 times)
10	Harbin Institute of Technology	Xu Xiaofei	Exploring the reform of new engineering talent development models for sustainable competitiveness (310 times), Exploration of Emerging Engineering Education and the Cultivation of lnnovative Talents (85 times)
11	Zhejiang University	Ye Min	Emerging Engineering Education: From ldea to Action (270 times), The Originality in New Types of Industry and Emerging Engineering Education (157 times)
12	Beihang University	Zhao Tingting	Comparative study of curriculum design characteristics in US higher engineering education based on the perspective of large-scale engineering projects: A case study of MIT and Stanford School of Engineering (240 times), Integrated curriculum: An urgent issue in the reform of Chinese higher engineering education that needs to be addressed (84 times)
13	Beijing University of Posts and Telecommunications, Datang Telecom Technology& Industry Group	Yang Yigang	A Study on the Technological Innovative Ability Training Based on the outcome-based education (OBE) Mode (235 times), On "Problem of Complex Engineering" in Engineering Education from Perspective of Enterprise Technology Innovation (106 times)
14	Tsinghua University	Wang Sunyu	A Ten-year Review of Engineering Education Accreditation System in China (188 times), "Washington Accord" and significance for reference towards Higher engineering education in China. (148 times)
15	Zhejiang University	Zou Xiaodong	From Hybrid Class to Zhu Kezhen College (132 times), China's Strategy of Constructing a Powerful Country of Engineering and the Reform of Engineering Education (45 times)
16	Chinese Academy of Engineering	Zhu Gaofeng	Reform and development issues in Chinese engineering education (124 times), Chinese Engineering Education: Present and Future (122 times)
17	Shandong University	Sun Kangning	A brief discussion on the issues, strategies, and general education attributes in engineering practical education (110 times), Exploring the integrated teaching model of knowledge, skills, practice, and innovation based on the new engineering discipline.(76 times)
18	Shanghai Jiao Tong University	Yu Tianzuo	From External Assessment to Self-improvement: The Reform of EC2000 and its lmplications (108 times), Continuous Quality lmprovement Based on Accreditation Criteria: Case Study of A Software Engineering Program (43 times)
19	Southeast University	Cui Jun	Returning to Engineering Practice: A Study on the Curriculum Reform of Higher Engineering Education in China (96 times), A Case Study on Curriculum Reform of International Higher Engineering Education: the PBL Curriculum Model in Aalborg University (29 times)
20	Tsinghua University	Yu Shouwen	Higher engineering education in China and the cultivation of engineers. (89 times), Cultivating Outstanding Engineers for the 21st Century (28 times)
21	Beihang University	Lei Qing	Integrated Curriculum: Pressing Issues in the Reform of Chinese Higher Engineering Education. (84 times), The analysis on the training objectives of engineering programs (64 times)
22	South China University of Technology	Xiang Cong	To Cultivate Engineer with Instrumental Rationality and Value Rationality on the Goal of Emerging Engineering Education (3E) (83 times), Exploration and Practice of Students' Creative Ability Development in Material Science and Engineering Specialty (31 times)
23	Central South University	Hu Zhigang	Program Optimization Based on CDIO-CMM for Undergraduate Education in Engineering (74 times), Research on the Assessment and Improvement System of CDIO Competence Maturity for Engineering Students.(67 times)

Continued

Table 2 continued

Serial Number	Institution	Scholar	Typical Papers (Citation Count)
24	Zhejiang Media College	Xu Xiaozhou	The Combination of Entrepreneurship Education and Engineering Education in Olin College of Engineering (55 times) ,System and Method: An Analysis of the Quality Evaluation of Engineering Education in Canada (10 times)
25	Tongji University	Chen Yiyi	New Industrial Revolution Guided Development Trends of International Engineering Education (49 times), The study and practice for training of the engineering quality and practice ability in the civil engineering specialty (45 times)
26	Tianjin University	Hu Dexin	The comparison and reference of international reform of engineering education professional accreditation system under the background of the new industrial revolution (35 times), Institutional Dilemma and Action Path of New Engineering Construction from the Perspective of Discipline Evolution (26 times)
27	Zhejiang University	Gu Zheng	The Classic Mode of University-Industry Cooperation Characterized by Engineering Practice Education: MIT's Initiative (20 times), Introduction to Engineering: A Required Course for Engineering College Students (17 times)

OBE: Outcome-based education; CDIO: Conceive-Design-Implement-Operate; EIP: Ethics-Integrity-Professionalism; EC2000: Engineering Criteria2000; PBL: Project Based Learning; CMM: Capability Maturity Model; US: United States; MIT: Massachusetts Institute of Technology

reform models, talent development innovation, and exemplary reform cases. It has initially formed a cluster of multidisciplinary research collaboration. Tsinghua University, Huazhong University of Science and Technology, Zhejiang University, and other research-intensive universities with strong engineering disciplines are the core forces in engineering education research. In terms of collaboration, more than two-thirds of the papers are jointly authored by two or more authors, which is highly correlated with the complexity and practicality of engineering education research. Overall, engineering education research in China plays a positive role in the education and teaching of frontline engineering teachers, school engineering education reforms, and national engineering education strategies. However, it should be noted that the current structure of engineering education research teams mainly consists of backgrounds in education or management studies, and there is still a lack of deep involvement from engineering teachers and frontline engineering professionals.

Lastly, in terms of research methods, based on the classification technique proposed by scholars such as Ren *et al.* (Table 3),[10] a statistical analysis was conducted on the research methods used in articles published in three authoritative journals in the field of engineering education. Specifically, these journals include "Research in Higher Education of Engineering"(RHEE) in China, "Journal of Engineering Education"(JEE) hosted by the American Society for Engineering Education (ASEE), and "The European Journal of Engineering Education"(EJEE) hosted by the European Society for Engineering Education. This study conducted a statistical analysis of academic articles published in these three journals from 2008 to 2022 using databases such as China National Knowledge Infrastructure (CNKI), Taylor& Francis Online Journals, and Wiley Online Library (excluding some non-engineering education-related articles, reports, short reviews, news, *etc.*). Among them, RHEE had a total of 2, 023 articles, JEE had 414 articles, and EJEE had 693 articles (Table 3).

The data shows that regarding the specific research methods employed in the articles, compared to foreign journals, although RHEE in China exhibits diverse research methods, the most commonly used method is still theoretical speculation, accounting for 21.4% of the total published articles. In comparison, foreign journals have a lower proportion of articles using purely theoretical speculation methods, accounting for only about 1%. JEE more frequently employs methods such as questionnaire surveys, experimental measurements, interviews, and case analysis. EJEE, on the other hand, predominantly adopts case analysis and questionnaire surveys.

CORE ELEMENTS AND PROMOTION PATH OF ENGINEERING EDUCATION DISCIPLINE CONSTRUCTION

In recent years, significant achievements have been made in the theoretical research and practice of engineering education in China. However, there are still numerous practical issues that need to be addressed. For example, the overall strategic planning for the development of engineering education is not yet clear, and there is a severe phenomenon of homogenized development among institutions. The engineer registration system is generally lacking, and there is a lack of effective integration with the certification system. The construction of engineering faculty lags behind, and there is a general lack of engineering practice experience. The development of majors and curriculum systems is slow, and they are not adapted to the transformation and upgrading of industrial structures. Cooperation with the industry is not close enough, leading to a gap between design education and industry demands. These issues require the organization of research teams in the form of disciplinary construction within engineering education to systematically investigate and address them.

Table 3: Comparative analysis of research methods in three major engineering education journals

	Research in Higher Engineering Education (*n* = 2023)	Journal of Engineering Education (*n* = 414)	European Journal of Engineering Education (*n* = 693)
Theoretical Speculation	432 (21.4)	4 (1.0)	9 (1.3)
Empirical Research	1591 (78.6)	410 (99.0%)	684 (98.7)
Case Study	367 (18.1)	45 (10.9)	204 (29.4)
Experience Summary	282 (13.9)	6 (1.4)	37 (5.3)
Literature Analysis	264 (13.0)	34 (8.2)	68 (9.8)
Questionnaire Survey	263 (13.0)	86 (20.8)	127 (18.3)
Historical Analysis	154 (7.6)	3 (0.7)	7 (1.0)
Mathematical Modeling	82 (4.1)	14 (3.4)	8 (1.2)
Comparative Analysis	73 (3.6)	34 (8.2)	56 (8.1)
Mixed Methods	36 (1.8)	37 (8.9)	57 (8.2)
Bibliometrics	27 (1.3)	42 (10.1)	4 (0.6)
Interviews	20 (1.0)	45 (10.9)	57 (8.2)
Ethnography	19 (0.9)	16 (3.9)	32 (4.6)
Experimental Measurement	4 (0.2)	48 (11.6)	27 (3.9)

Data was expressed as *n* (%)

Universities should start from the systematic and comprehensive development of disciplines and consolidate the core elements and promotion path of engineering education discipline construction. Specifically, this includes five aspects: the development direction of the discipline, curriculum and teaching construction, cultivation of outstanding research talents, diversified faculty, and high-level scientific research.

Guiding development through the consolidation of disciplinary development directions

The level of disciplines is the most important manifestation of the academic level and comprehensive strength of universities, and the development directions of disciplines play a fundamental and guiding role in promoting the construction of the engineering education discipline. In the planning of the New Engineering Discipline Construction, the main bodies are divided into three categories: engineering-dominant universities, comprehensive universities, and general local universities. Different types have strong heterogeneity and complementarity in their functional positioning and discipline construction characteristics.[11] Engineering-dominant universities have a strong historical background in engineering, complete disciplinary systems, and strong comprehensive strength. In the construction of the engineering education discipline, they should focus on serving major national strategies, industrial structural adjustments, and engineering education reforms to empower the construction of a strong engineering education nation. Comprehensive universities have significant advantages in interdisciplinary fields such as humanities, sciences, engineering, and management. In the construction of the engineering education discipline, they should focus on utilizing their comprehensive disciplinary advantages to explore cutting-edge international engineering science and technology and support policy-driven first-class engineering technology research and development. General local universities are the mainstay of higher education in China, accounting for over 90% of the total number of universities. In the construction of the engineering education discipline, they should focus on serving the practical needs and development characteristics of the local socio-economic context, effectively enhancing the social service function of the construction of the engineering education discipline. Overall, for different types of universities, the focus and direction of the construction of the engineering education discipline should vary. However, they should avoid a "one size fits all" homogenized competition mode and an "expansion for the sake of expansion" mode. Instead, they should be based on the disciplinary laws of engineering education, comprehensive assessment of national strategic needs, and social development demands, highlight disciplinary priorities and characteristics, and thereby drive the comprehensive and sustained improvement of the engineering education level of universities.

Specifically, first, on the basis of considering the logical demands of national strategic planning, university disciplinary construction, and market demand for talent, a systematic ecosystem for academic research, talent cultivation, and social service development centered around the construction of the engineering education discipline group should be established. Second, efforts should be made to promote communication and exchange between engineering education and other fields such as education, engineering, and management, break down barriers between disciplines, promote interdisciplinary

involvement and deep integration, and effectively promote the cluster-based development of the engineering education discipline. Third, active integration into the historical trend of internationalization in higher education should be pursued by absorbing advanced engineering education concepts and resources from overseas, strengthening exchanges and cooperation with international mainstream engineering education organizations such as the International Federation of Engineering Education Societies and the American Society for Engineering Education, and effectively enhancing core competitiveness and international influence. Fourth, a sound mechanism for dynamic evaluation and adjustment of the engineering education discipline should be established. As an emerging discipline, it should gradually establish a virtuous ecological pattern of evaluation-driven construction and improvement, highlight performance-oriented evaluation, emphasize the service function, and continuously iterate in a cyclical manner, ultimately forming a scientific and reasonable direction for the development of the discipline.

Driving development through strengthening curriculum and teaching construction

As the final mile of systematic transformation in higher education, curriculum and teaching play a crucial role and are the key to the success or failure of the construction of the engineering education discipline. In the construction of the curriculum and teaching in engineering education, first, it is necessary to draw on the mainstream teaching models in international engineering education and promote the transformation of engineering education from a unidirectional knowledge transmission mode to a comprehensive competence-enhancement mode through project-based teaching. The application of the outcome-based education (OBE) concept in engineering education teaching should be strengthened. This can be achieved by developing high-order learning standards, fostering an interactive teacher-student communication culture, implementing evaluation mechanisms focused on student achievement of capabilities, stimulating students' learning autonomy, and incorporating backward design in teaching processes.[12] These measures effectively enhance the effectiveness and relevance of teaching in engineering education.

Second, a modular curriculum system should be established to provide students with more autonomy in their choices. As an emerging discipline, a comprehensive curriculum system for the engineering education discipline has not yet been fully developed in universities. In the future design of engineering curriculum systems, a modular curriculum system should be gradually constructed, covering areas such as humanities and general education courses, engineering science general education courses, foundational courses in engineering education, core courses in engineering education, practical courses in engineering education, and interdisciplinary courses. This empowers knowledge transmission, competency development, and value shaping throughout the entire process of engineering education talent cultivation.

Third, efforts should be made to strengthen the development of disciplinary textbooks and typical cases in engineering education. With respect to the characteristics and practical needs of the training of master's and doctoral students in engineering education, expert teams in the field of engineering education research should be organized to gradually compile a series of textbooks related to the discipline. Additionally, typical cases related to research training, teaching practice, and talent cultivation should be developed.

Fourth, reforms should be promoted in the interdisciplinary talent cultivation of engineering education. Engineering education has a strong interdisciplinary nature, so barriers between traditional schools, colleges, and disciplines should be broken down during the cultivation process. In terms of institutional design, students should be given greater autonomy in course selection and research training, allowing for a more extensive breadth of knowledge and enhanced critical thinking.

Empowering development through the cultivation of excellent research talents

In the context of the ongoing new industrial revolution, future engineering practices are characterized by increased complexity, intelligence, abstraction, and integration. To grasp the development trend of future engineering science and technology and comprehensively assess the practical demand for research talents in engineering education, it is necessary to scientifically design the talent cultivation goals of engineering education. Specifically, the talent cultivation goals of engineering education aim to cultivate outstanding talents and qualified successors to the socialist cause who possess a sense of patriotism, a global perspective, innovative spirit, and practical abilities. These talents are proficient in advanced and modern theories and practical models of engineering education research, understand the current situation and basic trends of engineering education in our country, possess comprehensive knowledge of teaching, research, and management methods in engineering education, are proficient in at least one foreign language, capable of independently conducting academic research on cutting-edge issues in engineering education, and can effectively engage in high-level teaching, management, and decision consulting in the field of engineering education. Therefore, specific requirements should be set for students in the enrollment of engineering education programs. For example, in terms of research attitude, students should have a passion for the research of engineering education and the ability to integrate academic research with national strategic needs and socio-economic development. In

terms of foundational knowledge, they should have a basic understanding of educational sciences, engineering, economics, management, policy studies, and other related disciplines, and effectively integrate them into their research on engineering education. They should also have the ability to read and analyze literature in at least one foreign language, and possess excellent skills in literature search, organization, and analysis. They should adhere to academic norms in conducting scientific research in engineering education and demonstrate a rigorous academic attitude and scholarly cultivation. Moreover, they should actively participate in various engineering practices, observe the mechanisms of engineering education issues and their solutions, gradually develop research thinking, practical thinking, innovative thinking, and expansive thinking in engineering education research. In summary, the cultivation of excellent research talents in engineering education is a complex and systematic task that involves multiple subjects and levels. It requires in-depth collaboration between governments, universities, and enterprises, as well as coordinated cooperation among different types of universities, departments, and disciplines.

Empowering development through the construction of a diverse faculty team

The level of faculty construction directly influences the dimensions, strength, and depth of disciplinary development in engineering education. It is a crucial element in promoting engineering education as a first-class discipline. The discipline of engineering education requires a well-structured, diverse, and high-quality faculty team. This necessitates strong support from the government and industry, as well as top-level design in the planning of engineering education discipline construction within universities.

Firstly, it is essential to establish a faculty configuration system primarily consisting of full-time teachers specialized in engineering education, supplemented by teachers with multidisciplinary backgrounds such as engineering and management. Collaboration and communication with teachers from different disciplinary backgrounds should be strengthened. Secondly, it is important to promote deep cooperation between industry, academia, and research, and to advance the construction of a dual-qualified faculty team with profound theoretical knowledge and extensive practical experience. Due to the emphasis on practical issues in the field of engineering, the disciplinary characteristics of engineering education largely lie in the high requirement for teachers' problem-solving abilities in practice. Therefore, it is necessary to promote deep cooperation among the government, universities, and enterprises to enhance teachers' abilities in scientific research and practical application. Furthermore, experienced engineers or senior management personnel from the industry can be invited to serve as teaching instructors and student mentors in the field of engineering education, effectively connecting research talent cultivation with the practical needs of society. Finally, a sound system for teacher evaluation, appointment, and incentives should be established. Guided by the principle of breaking away from the traditional practice of solely measuring teachers' performance based on academic achievements, efforts should be made to prevent the inclination of engineering disciplines towards a purely scientific focus. Emphasis should be placed on evaluating teachers' teaching abilities, student development abilities, and think tank services.[13] Additionally, a relaxed atmosphere for research and teaching should be fostered, and scientific and rational evaluation, appointment, and incentive mechanisms should be implemented to truly drive the initiative of teachers to engage deeply in scientific research and talent cultivation in engineering education.

Promoting development through high-quality scientific research

The research focus of the discipline of engineering education should concentrate on major national strategies, urgent needs of industrial development, and practical issues in the discipline. It should integrate knowledge and theories from fields such as educational sciences, engineering, and management. Based on international mature research theories, methods, and technical foundations, research in engineering education should take root in China. The design of research directions in engineering education can consider the following three aspects: (1) Comprehensive interdisciplinary research: It involves the comprehensive use of new theories, methods, and technologies from fields such as educational sciences, management, economics, and engineering. The research should focus on interdisciplinary, cross-domain, and cross-organizational studies, emphasizing the organic integration of theoretical research and practical research. (2) Relying on high-level longitudinal and horizontal research projects: This includes taking on the responsibility of national major engineering education reform strategies, practical bottlenecks in the industry, and the construction of fundamental theories in engineering education. Effective methods to promote engineering education reform should be provided. (3) Focusing on providing solid policy support for national guidelines and policies, as well as the cultivation of outstanding engineers. Building on the spirit of President Xi Jinping's speech at the National Conference on Talents, China has proposed an organic connection between the reform of outstanding engineer training and the training of engineering master's and doctoral students. Exploring and forming a full-chain higher engineering education system that consists of outstanding undergraduate programs, high-level master's programs, and outstanding doctoral programs. Therefore, engineering education should actively provide scientific advice and overall planning suggestions for major national education policies, laws, and regulations,

while also offering scientific consultation and planning recommendations for the cultivation of outstanding engineers.

Specifically, the main research directions in the field of engineering education currently include but are not limited to the following four aspects: (1) Basic theoretical research in engineering education: This includes the nature, purpose, principles, functions, structure, and development models of engineering education, as well as related theoretical frameworks and the history of engineering education. (2) Research on engineering education policies and systems: This encompasses the construction of engineering education systems, research on quality standards, quality assurance systems, evaluation models and methods, disciplinary construction and evaluation, accreditation of engineering education programs, regular monitoring of education quality, and research on the quality and standards of dissertations. (3) Research on curriculum and teaching reform in engineering education: This involves the cultivation goals and concepts, teaching methods, instructional tools, learning modes, curriculum evaluation, textbook development, engineering practice, and teacher evaluation. (4) Research on the laws governing the cultivation of outstanding engineers: This includes the evaluation criteria for outstanding engineers, the integration of industry-academia collaboration in talent cultivation, the system of registered engineers, and the development of engineering practice capabilities.

FUTURE PROSPECTS AND REFLECTIONS ON THE CONSTRUCTION OF ENGINEERING EDUCATION DISCIPLINE

The construction of the engineering education discipline requires a solid foundation in engineering

Engineering education is an interdisciplinary field that draws upon knowledge from various disciplines, but it primarily needs to be grounded in the foundations of engineering. It should incorporate the theories and methods of engineering science. The aim of engineering education is to study and explore the theories, methods, and practices of engineering education. In the development of the engineering education discipline, it is crucial to establish a strong foundation in engineering science. This requires a deep understanding and application of engineering science, engineering technology, engineering management, and engineering culture in order to better cultivate students and professionals with practical engineering application capabilities.[14]

Firstly, engineering science provides an important theoretical foundation for the construction of the engineering education discipline. The theories and principles involved in engineering have significant guiding roles in teaching methods, curriculum design, and practical components of engineering education. The construction of the engineering education discipline needs to draw upon these theoretical foundations of engineering and combine them with disciplines such as education and psychology to research how to effectively impart engineering knowledge to students and cultivate their engineering practice abilities. For example, engineering education can learn from the theories and methods of disciplines such as engineering management, engineering project management, and systems engineering to study how to better organize and manage engineering education practical activities. This requires graduate students to understand the entire lifecycle of engineering projects and be familiar with various engineering technologies and standards.

Secondly, engineering science provides a practical foundation and methodology. The construction of the engineering education discipline needs to emphasize the importance of practical teaching and project training, and engineering is inherently a practical-oriented field. By studying engineering, the construction of the engineering education discipline can draw upon and apply the experiences and methods of engineering practice, design and implement more effective practical teaching programs, and cultivate students' problem-solving abilities and engineering practical skills.

Lastly, engineering science provides a background and experience in the engineering industry. One of the goals of constructing the engineering education discipline is to cultivate professionals who meet the needs of the engineering industry. This requires the construction of the engineering education discipline to understand the characteristics, demands, and development trends of the engineering industry. By establishing a solid foundation in engineering science, the engineering education discipline can better align with the engineering industry, understand the problems and challenges in engineering practice, and thereby provide better guidance for students' learning and professional development.

The construction of the engineering education discipline requires multidisciplinary and cross-organizational collaboration

Engineering education is a complex system engineering that involves knowledge and skills education, as well as the cultivation of qualities. It requires the integration and application of specialized knowledge and resources from different disciplines and organizations. The construction of the engineering education discipline needs to accumulate theoretical knowledge and draw upon methods from both engineering and humanities and social sciences to establish a unique knowledge system and theoretical framework. This is an important approach to formulating interdisciplinary studies. To cultivate individuals with both

engineering and educational expertise, higher requirements are placed on the construction of the engineering education discipline. The discipline's structure, teaching content, and curriculum system must continually adapt to the needs of socio-economic development.[15] In addition to engineering, the discipline of engineering education also needs to incorporate knowledge from disciplines such as education, psychology, and management. For example, cooperation with education can research curriculum design, cooperation with psychology can study learning motivation and strategies, and cooperation with management can investigate the application of project management in engineering education. This can enhance the scientific and targeted nature of engineering education research and, consequently, improve the effectiveness of engineering education. Furthermore, the discipline of engineering education needs to closely collaborate with engineering enterprises. For instance, joint research on long-term development planning in engineering education, cooperative design of talent training programs that meet industry needs, and the establishment of collaborative teaching and practical platforms between universities and enterprises can enable students cultivated within the discipline to gain a deep understanding of the current industrial situation, industry demands, and the growth patterns of engineering professionals. This goes beyond conducting superficial engineering education research by simply referring to existing literature. In summary, the construction of the engineering education discipline in China requires breaking down disciplinary barriers and organizational obstacles, strengthening interdisciplinary theoretical exchange, and promoting collaboration between universities and enterprises. This necessitates establishing mechanisms for horizontal communication among relevant faculties within universities and also requires enterprises to broaden their cooperation models with universities to facilitate the sharing and co-construction of knowledge and solutions.

The construction of the engineering education discipline requires innovative research paradigms

Traditional engineering education research mainly adopts speculative research methods that lack systematic argumentation and lack support from empirical data and case studies. This approach fails to provide specific and actionable theoretical guidance or decision-making basis, making it difficult to truly address the problems encountered in engineering education practice. To promote the development of the engineering education discipline, it is crucial to innovate research paradigms. Firstly, a data-driven research paradigm should be established, emphasizing the cultivation of big data analysis capabilities and utilizing a combination of quantitative and qualitative research methods. By using first-hand data and case analysis to test theories, identify problems, and produce research outcomes with practical implications, a foundation can be provided for engineering education management and decision-making. To achieve this, it is necessary to establish an engineering education database to collect data and cases related to various engineering education activities, thus providing authentic materials for empirical research in engineering education. Secondly, efforts should be made to enhance the infrastructure and research investment in engineering education, establish research funds specifically for engineering education, and develop high-level research platforms.[16] By constructing a set of high-level research platforms, cutting-edge and interdisciplinary research can be conducted. Strengthening cooperation with top international universities, gathering high-level talent from both domestic and international sources, building high-level international research teams, and enhancing the influence of China's engineering education discipline in the international academic community. Thirdly, it is necessary to establish high-level engineering education journals. Currently, there are few domestic journals dedicated to engineering education research. Apart from a few journals such as Journal of Higher Engineering Education, the research outcomes of engineering education are scattered across various journals. Academic journals serve as the battleground for engineering education research, and it is necessary to plan and establish a set of high-level engineering education research journals with international influence. By innovating research paradigms, producing more practical, systematic, and in-depth research outcomes, the overall level and social impact of engineering education research in China can be improved, ultimately forming a theoretical system for engineering education with Chinese characteristics that is at the forefront internationally.

In conclusion, as an emerging discipline, the construction of the engineering education discipline should involve the collaborative efforts of multiple stakeholders, including the government, universities, research institutions, and industry. It requires the establishment of comprehensive research centers, the cultivation of excellent engineering education researchers, and the production of high-level practical outcomes. Gradually, a sound ecosystem for the engineering education discipline can be developed, contributing to the empowerment of China as a strong nation in engineering education with distinct characteristics and world-class standards.

DECLARATION

Author Contributions

Fu J: Data curation, Writing—Original draft preparation, Writing—Reviewing and Editing. Hu DX: Conceptualization, Methodology. Wang SY: Supervision.

Conflict of Interest

Wang SY is the Editor-in-Chief of the journal. The article was subject to the journal's standard procedures.

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