



An Exploration on the Reform of China’s Engineering Education under the Background of ‘Made in China 2025’

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Introduction

In 2015, Chinese government proposed Made in China 2025, which is the first ten-year strategy of upgrading the country's manufacturing sector under the background of the new scientific and technological revolution and industry transformation. This strategy puts forward the basic development guidelines of "innovation driven, quality prioritized, structure optimized, and talent oriented", and decides to gather all kinds of innovation resources in the ten key areas such as new information technology, high-end numerically-controlled machine tools and robotics, aerospace and aeronautical equipment, ocean engineering equipment and high-tech ships, modern railway equipment, engineering saving and new energy vehicles, power equipment, agricultural machinery, new material, biological medicine, and high performance medical equipment, in order to enhance the development of these industries. The goal is to become a powerful manufacturing country by the 100th anniversary of China (2049) through "three-step" strategic goal.

The implementation of Made in China 2025 and the realization of the goal of China's becoming a powerful manufacturing country requires a group of manufacturing talents with good quality, considerable quantity and reasonable structure. Without doubt, engineering talents are the most important component of this group, and they are significant to the development of manufacturing industry. This raises a new challenge to the higher engineering education in China, requiring which to connect with Made in China 2025 comprehensively in aspects such as talents quality, quantity, major structure, hierarchical structure and regional structure, and meet the demands of ten key fields on engineering talents.

Since 1978, China's Engineering Education has made a significant progress both on scale and quality. However, facing the new industrial revolution and domestic manufacturing transformation and upgrading, many problems like cultivation concept, cultivation content, teaching content and cultivation resources should be improved to adapt to the needs of science, technology and economic development in the new era.

This research makes a further analysis on the current situation of Chinese higher engineering education and the its problems facing the demand of Made in China 2025, and puts forward six main tasks and 8 countermeasures for the future reform and development of engineering education in China.

The Strategic Background of China as a Manufacturing Power

The International Challenge of the New Industrial Revolution

The next 5~15 years represents the transformation period driven by the new industrial revolution where the traditional industrialization will interweave and alternate with the new

industrialization, the transition period where the industrialization and informatization will mingle and integrate deeply with each other as well as the changing period where the global economic pattern will change profoundly along with the rise and fall of regional economic powers [1]. The “superposition of the three periods” provides an important strategic opportunity for the accelerating development, transformation and upgrading of the manufacturing industry. From 2011 to 2013, the US has successively announced the launch of *Advanced Manufacturing Partnership, A National Strategic Plan for Advanced Manufacturing* and *National Network for Manufacturing Innovation*. In 2013, German released *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0*. Later, Japan released *White Paper on Manufacturing Industry* in 2014; Britain released the strategy of *Made in UK 2015*; France released the initiative of *New Industrial France* ... All the developed countries are making its strategic arrangements on the area of emerging technologies and advanced manufacturing technologies, aiming to recreate a new-type industrial system with sustained competitiveness in the future, strengthen the comprehensive national strength and obtain the dominance for the future world [2]. Therefore, the competition in the manufacturing industry will represent the key to the future competition of major countries, and in this process, the support from the engineering science and technology talent is indispensable, which brings new challenges for the reform of China’s engineering education.

The Urgent Demands for Domestic Transformation and Upgrading

Currently, China’s economic development has changed from the circulation of gross expansion into a period with higher-level forms, more complicated labor divisions and more reasonable structures [3]. The breakthrough development in the new-generation information technologies including the cloud computing, big data, mobile internet, internet of things and artificial intelligence is accompanied with the manufacturing industry and industrial transformation, which not only provides a golden chance for the rapid development, transformation and upgrading of China’s manufacturing industry, but also brings new challenges to our higher education of engineering and in particular, the training of multi-level engineering talents that aims to answer the adjustment of both the international and domestic market demands. Nowadays, the innovation and entrepreneurship have become the theme of the times and the “mass entrepreneurship and innovation” requires the higher engineering education to further strengthen the training for innovative and inter-disciplinary engineering talents. Meanwhile, the industrial trends like “INDUSTRIE 4.0” and “Made in China 2025” require us to accelerate the forming of the educational philosophy of “green development, inclusive development and harmonious development” and require the engineering science and technology talents to be have better holistic views, engineering values, scientific values and social outlooks [4]. With a new environment of domestic and international engineering education, the focus would be how to create a new norm of China’s engineering education.

An Analysis on the actual condition of China’s Higher Engineering Education under the New Situation

The Large Scale of Higher Engineering Education

Ranking 1st in the world in terms of the scale of engineering education, China has become a veritable country powerful in engineering education. By 2015, there are already 2368 engineering colleges and universities (including independent colleges and universities) and 16284 undergraduate majors concerning engineering, among which nearly 8000 are related to the key areas listed in *Made in China 2025*, taking up nearly 50% of the total number of undergraduate majors. Besides, students who are studying in the regular institutions of higher learning are also increasing significantly. In 2015, the number of students with an engineering-related major reached 10.4 million, taking up 39.1% of the total college students in China and 38% of the global students with an engineering-related major in the world (see Table 1). The expansion of the education scale enables more youths to receive higher education and thus lays a solid human resource basis for the development of China's industrialization.

Table 1-The number and proportion of engineering graduates in major countries (or regions, economies)

Countries/regions/economies	Total number of graduates	Number of engineering graduates	The proportion in the total number of engineering graduates in the country (region)(%)	The proportion in the total number of global engineering graduates (%)
Asia	10, 691, 433	1,826,360		72.1
China	3,038,473	964,583	31.7	38.1
India	5,469,330	548,907	10.0	21.7
Japan	558,692	87,544	15.7	3.5
EU	2,602,040	193,030		7.6
France	311,026	22,707	7.3	0.9
German	386,090	43,818	11.3	1.7
Britain	389,296	16,435	4.2	0.6
Non-EU	1,518,411	150,015	5.9	5.9
Russia	1,406,050	142,806	10.2	5.6
North America	2,404,584	160,066	6.3	6.3
Canada	168,183	9,471	5.6	0.4
Mexico	425,754	67,332	15.8	2.7
The US	1,810,647	83,263	4.6	3.3
World's Total	20,433,355	2,534,843		

Data Source: United States National Research Council-- "Science & Engineering Indicators" (2016)

The Significant Increase of the Quality of Higher Engineering Education

With the development over several years, the quality of China's higher engineering education has increased significantly. In terms of the output, there are 4,642,506 patents in China by the

end of 2014, among which 4,032,362 are domestic ones, increasing by 10.9% compared to the last year while 610,144 are from overseas, increasing by 9.1% [5]. Meanwhile, as suggested in “2016 Research Rankings for Global Universities for Engineering (RRGUE)”, Massachusetts Institute of Technology (US) ranks 1st, followed closely by Tsinghua University and Harbin Engineering University in China. Meanwhile, in Mainland China, Shanghai Jiao Tong University, Zhejiang University, Huazhong University of Science and Technology, Peking University and South China University of Technology are all among the top 50. There are totally 28 universities from China among the 150 university, proving the significant growth of the influence of China’s engineering researches. According to the “rankings for engineering majors in universities released by US News & World Report 2016”, the engineering major in Tsinghua University ranks the 1st among the global universities listed by 2016 US News. Therefore, 10 universities (two more than those in 2015) from China were selected, proving the outstanding general power of China’s engineering disciplines.

Main Issues in the Higher Engineering Education

In terms of the cultivation concept, science and education has not been integrated yet and the phenomenon of “non-engineering” teachers still remains serious. Currently, the faculty team of China is lacking in “double-qualified” teachers who have both an abundant engineering background and a high academic level [4]. Under the influence of the competitive scientific research mechanism and the strategy of promoting the universities to transform the scientific and technological fruits, some universities, including especially those engineering universities and colleges, have focused on excessively on the orientation of scientific and technological fruits and the function of social services [6], but at the same time they have ignored the basic education principle for the teaching of scientific researches and deviated from the working principle of “an integrated development of science and education”. In terms of the cultivation content, the demands and supplies are still not unified while the specialty setups and knowledges systems are still lagging behind. The education and curriculum structure for China’s engineering majors have always been constrained by a relatively rigid specialty catalogue [7]. The thin division of specialties, strict limitations on major changes, narrow scope of students’ knowledge and the failure to make timely adjustment according to the market demands and the trend of the cross-discipline and comprehensive development are all inconstant with the economic transformation and industrial upgrading in China. In terms of the teaching content, the industry has not truly engaged in the training for engineering talents while new technologies and processes of enterprises have also not been included in the teaching content. As a result, the teaching content cannot satisfy the needs to digest and then innovate introduced technologies, equipment and production lines and the knowledge system development of some specialties are even lagging behind the development of the industrial technologies. In terms of the cultivation resources, there is still a lack of collaboration between industries and schools and outstanding conflicts of structural demands and supplies. The current engineering education tend to enter an ivory tower, but the collaboration of universities and enterprises in the quality construction of aspects including the curriculum system, faculty team and practice platform is still not close enough while the effect is also not

sustained enough. The reform of the engineering education has not fully reflected the development demand of science & technology and economy in the new period. Meanwhile, the construction of platforms for inter-disciplines and newly-emerging disciplines are lagging behind and there are a lack of synergy between the training of engineering talents and the development of industrial economy.

Main Tasks

To actively face the new challenges, we should regard meeting the talent strategic demand of *Made in China 2025* as the fundamental orientation and reform motivation, consider the optimization and sustained improvement of the quality of training for talents with engineering technologies as the key path and important measure, advance the innovation of the system and mechanism of China's engineering education and promote the open synergy and integrated sharing of educational resources. Meanwhile, we should also cultivate a batch of high-quality engineering talents with strong sense of social responsibilities, spirits of innovation, awareness of entrepreneurship, abilities of innovation and entrepreneurship and international visions and establish a multi-level and diversified backup team of engineering talents so as to satisfy the basic demands of the industry for talents with engineering technologies and support vigorously the innovative development of China's manufacturing industry.

One, study, judge and grasp the large demands for talents and establish a coordinated mechanism for industrial demands and talent training. Likely, we should adapt actively to the industrial reform and development, make deep analysis on the demands including the quality, quantity and structure of engineering talents and make proper top-level designs and prospective plans for the team construction and training for talents [9]. In addition, we should also analyze the knowledge structure, ability element and quality framework of talents scientifically and establish a complete standard system for the engineering talent training based on the objective development laws of talents so as to form the coordinated mechanism for industrial demands and talent training.

Two, conform closely to the development strategy for manufacturing talents and improve the cultivation structure of engineering talents. We should establish and complete a talent training structure that can adapt to and support the demands of industrial development, build a specialty set-up assessment system involved by both industries and enterprises and add rare and special specialties according to the needs. Furthermore, we ought to guide the universities and colleges to positively meet the demands of economic and social development, establish a talent training alliance with close collaboration of industries, universities and researches, adjust actively the quantity, type and level structure of the talent training and accelerate the cultivation of various backup engineering talents urgently needed by the manufacturing industry in China.

Three, deepen the reform of engineering education constantly, strengthen international exchanges & cooperation and make innovations on the mechanism of engineering talent

training. We should continue to keep the education reform oriented towards the quality improvement and content development, actively open to the outside world and seek for cooperation, draw lessons from advanced foreign educational philosophies and methods and introduce and digest high-quality foreign educational resources [10]. Meanwhile, we should also promote the construction of the talent training system integrating both industries and education and realize the highly-efficient allocation of educational resources with innovative mechanisms. Furthermore, we should determine the goal of talent training according to the talent training standard system, restructure the solution of talent training, optimize the process of talent training and improve the quality of talent training.

Four, strengthen the construction of the talent training system integrating both industries and education and promote the comprehensive and deep cooperation between universities and enterprises. We should stimulate further the activity of trainings for talents combining industries and schools, give full play to the important role of industrial resources in the training for talents with engineering technologies, establish and improve the talent training system integrating both industries and education and promote the comprehensive and deep collaboration between universities and enterprises in the faculty team, curriculum module, practice base, major projects, key laboratories, etc.

Five, continue to optimize and update the resources of engineering talent training and promote the opening and sharing of high-quality educational resources. We should actively adapt to the new challenges and new requirements for the development of the manufacturing industry, integrate the forces of all social sectors to optimize and update the resources of engineering talent training so as to create high-quality educational resources including the faculty, teaching materials, curriculum, laboratories, etc [11]. Based on advanced information technology methods and innovative management modes, we should establish a mechanism and platform for the opening and sharing of educational resources, build an engineering education system that combines the popular science education, continued education and degree education and increase the allocation efficiency of educational resources.

Six, establish a social assessment system for the talent training quality and build a sustained improvement mechanism for the engineering education quality. We should promote the construction and improvement through assessments, introduce the third-party assessment institution, actively participate in the international assessment and certification, build and improve the social assessment system for the talent training quality, create an information feedback mechanism for the training of talents and keep improving the quality of engineering talent training.

Policy Suggestions

One, set up a system to release the condition reports and demand reports for talents in the manufacturing industry. Centered on the ten key areas such as the new-generation information technology industry put forward in *Made in China 2025*, we should entrust the third-party institutions like the relevant industrial association (academic society) to make

investigations and researches on information including the number, distribution, structure, sources and salary of talents, form the reports concerning the condition of industrial talents and release the reports annually to the society. Given all these, we should release the forecast report for talent demands according to the industrial development planning, put forward the quantity, types, levels and specifications of talents needed by the industry, guide universities and colleges to adjust and optimize the talent training structure and strengthen the adaptability of talent training to the strategic development of the country.

Two, establish and improve the standard system of manufacturing-related talents. We should set up a level assessment system for industrial talents, entrust the third-party institutions like the relevant industrial association (academic society) to formulate the job qualification (practice) standard and level assessment standard for manufacturing-related personnel with engineering technologies and establish the job qualification system for engineers in the manufacturing industry. Meanwhile, we should also set up and improve both the national standard for the quality of teaching for undergraduate majors related to the manufacturing industry and the basic standard for the relevant disciplines and degrees of postgraduates. We should promote the universities to determine the positioning of specialized talents, formulate the training standard for them, revise the talent training scheme and improve the adaptability of talent trainings to the talent demands of the industry and enterprises.

Three, improve the specialty set-up and adjustment mechanism. We should revise and improve the regulation for the specialty catalogue and specialty set-up, establish a specialty set-up assessment system involved by both industries and enterprises and build the specialty dynamic adjustment mechanism and specialty set-up pre-warning mechanism. Based on the needs, we can add rare and characteristic specialties listed in *Made in China 2025*. In addition, we should guide universities to respond to the demands of regional economic and social development more timely, set up majors urgently needed by the emerging industries in strategies like “Internet +” and “Made in China 2025” and build a specialty cluster that can adapt well to the industrial structure.

Four, establish a long-term mechanism where both the industry and the enterprise engage in the talent training. We should actively study and formulate relevant policy measures, determine the responsibilities and duties of enterprises to involve in the talent training and motivate the activity of enterprises to engage in the talent training. We should also include the involvement of enterprises in the talent training into the social responsibility report of enterprises and regard their involvement as a testing content in the national regulations concerning the policy and financial support for enterprise. Furthermore, we should study and formulate the fiscal benefit policy and legal security measures for enterprises to engage in the talent training, ensure multiple rights and interests of enterprises, schools and students in the joint cultivation process of universities and enterprises and form a sustained nurturing mechanism for the cooperation between enterprises and schools. We ought to identify the responsibilities and duties in talent training of the manufacturing innovation center (industrial technology research base) and major projects planned by “Made in China 2025”. Meanwhile,

we should also encourage universities to actively participate in the knowledge updating program for specialized technicians, undertake the training tasks for senior managerial personnel and specialized personnel in enterprises and strengthen the education and services with the collaboration of industries, universities and researches.

Five, build and improve the bidirectional flow mechanism for enterprises & institutions and talents. We should improve the salary and position management system for employees in enterprises and institutions, break the system and mechanism barrier of talent flow and promote the personnel to flow reasonably in enterprises and institutions. Meanwhile, we should allow institutions of higher learning and scientific researches to set up a certain proportion of flowing posts to attract entrepreneurs and science & technology talents with innovative practice experiences to work as a part-time staff.

Six, deepen the reform of the talent training mechanism in universities and colleges. We should promote different types of universities to build a multi-level and multi-type talent training system based on the innovation chain of the manufacturing industry. We should update the knowledge system and teaching contents, meet the demands of the integration between informatization and industrialization, focus on the overlapping and fusion of disciplines and strengthen the cultivation of engineering abilities and qualities. We should improve the system of practice teaching and accelerate the establishment of a long-term mechanism for students to practice and be trained in industries and enterprises. Meanwhile, we should also deepen the reform of innovation and entrepreneurship education, integrate the innovation and entrepreneurship into different procedures throughout the talent cultivation process, enable all students to receive the education and get all the faculty members to involve in the education. Furthermore, we should strengthen the construction of the practice platform and build a batch of comprehensive engineering training center according to the key areas planned in “Made in China 2025”. We should support universities to accelerate the construction of campus practice platforms such as the engineering practice center, intern and training base, makerspace, etc. We should support the universities to jointly establish an innovation center (industrial technology research base) and a batch of talent training bases outside the campus so as to nurture multi-level and multi-type high-quality engineering talents with innovation spirits, entrepreneurship awareness as well as the abilities of innovation and entrepreneurship.

Seven, combine the full-time and part-time system to improve the engineering practice abilities of the faculty. We should not only build a system to train the teaching ability and engineering practice ability of engineering teachers, but also establish and standardize the system for engineering teachers to receive trainings or rotational trainings in enterprises regularly so as to promote teachers to update their engineering knowledge, grasp new practice skills, enrich the experience of engineering practice and strengthen constantly the ability of engineering practice. Meanwhile, we should also establish and standardize the system for part-time engineering teachers, encourage universities to invite high-level engineering technicians and managerial staff with abundant practice experience from enterprises as the part-time teachers and identify the responsibilities and basic teaching requirements of these

part-time instructors. We should also select excellent technicians and managerial personnel across the country and build a talent pool of part-time instructors to promote the resource sharing among part-time teachers.

Eight, improve the international level of the talent team in the manufacturing industry. We should promote the engineering education to open to the outside world and cultivate inter-disciplinary talents with both an international vision and a global competence. We should create an all-round and multi-level cultivation mode based on international cooperation and build an international talent training system. We should also support China's Professional Certification Organization for Engineering Education to join the international mutual recognition agreement in order to realize the international effective equivalence of our talent training quality. Meanwhile, we should select various kinds of excellent talents in multiple ways and in particular, we should organize specialized technicians to receive trainings overseas and explore the establishment of the international training base. Furthermore, we should strengthen the introduction of intelligence in the manufacturing industry and bring in more leading talents and badly-needed talents. We should set up a special foundation for the international exchanges among manufacturing talents and support the international cultivation, training and introduction of talents in the manufacturing industry.

Contribution

This study would provide a new angle for scholars in China and abroad to comprehensively understand Made in China 2025 and how higher engineering education in China responds to it. Especially this study will provide detailed the reliable materials for the international engineering education researchers to understand the new progress of Chinese engineering education. The solutions and proposals in this study could also provide beneficial reference for Chinese government and universities to improve higher engineering education.

Conclusion

This study considers that China's engineering education has faced many problems on cultivation concept, cultivation content, teaching content and cultivation resources under the background of new industrial revolution and the strategy of Made in China 2025. For existing issues and domestic strategies, this study put forward 6 main tasks and 8 countermeasures in order to cultivate engineering talents having social responsibility, entrepreneurship, international outlook.

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