Annual Meeting of the New Champions 2018

2018新领军者年会

The 4th industrial revolution and the innovative society

第四次工业革命与创新型社会

Emerging Engineering Education-the Intelligent Engine and Driving Force of the 4th Industrial Revolution

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Emerging Engineering Education—the Intelligent Engine and Driving Force of the 4th Industrial Revolution

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Abstract: The rise of the 4th industrial revolution is changing development modes of all industries in the world, bringing about new challenges to the industrial development around the world, and presenting new directions for the talent training. The future engineering talents have three characteristics: interdisciplinary and comprehensive abilities, awareness about emerging fields and the new industrial system. In the 4th Industrial Revolution, countries explore and reform the training mode of engineering talents one after another. The exploration of China is mainly represented in three aspects: firstly, develop majors related to strategic emerging industries; secondly, explore the talent training systems and mechanisms to facilitate in-depth integration of production and education; thirdly, accelerate the training of talents urgently needed in key fields.

It is of strategic significance for the development of China to follow the tendency of the 4th industrial revolution, aim at international competition, and accelerate the construction of the Emerging Engineering Education. We aim to strengthen moral education and cultivate people, deal with changes and shape the future and integrate the spirit of carrying forward with innovation, coordination with sharing. Through training diversified and innovative engineering talents, we will transform traditional industries and develop new ones, so as to meet demands of national strategic development and builds new edges in international competition. The Emerging Engineering Education provides an intelligent engine and driving force for the 4th industrial revolution, as well as a brand-new perspective and "Chinese solution" for the world higher engineering education.

Catalog

Since the early 21st century, the 4th industrial revolution marked by intelligent robot and the Internet of Things has flourished. In order to occupy the commanding height of industrial and technological innovation, all countries in the world have raced to take strategic measures. The U.S. put forward "re-industrialization", "advanced manufacturing" and other measures, and promulgated the strategic plan "National Network for Manufacturing Innovation (NNMI)" in 2012. Germany introduced the Cyber-Physical System (CPS) and the Internet of Things technologies into manufacturing and introduced the "Industry 4.0" strategy in 2013. The U.K. put forward the policy of manufacturing development and recovery in 2013, i.e. "Industry 2050 Strategy of the U.K." ("The future of manufacturing: a new era of opportunity and challenge for the UK"). France put forward the "New Industrial France" strategy in 2013 to rebuild industrial strength by engineering education innovation. China implemented the strategic plan of "Made in China 2025" in 2015, in order to build our country into a manufacturing powerhouse. At the 19th National Congress of the Communist Party of China, General Secretary Xi Jinping clearly pointed out that we should accelerate the development of manufacturing power and advanced manufacturing, promote the in-depth integration of internet, big data and artificial intelligence with the real economy, as well as cultivate new growth points and gather momentum in such fields as middle and high-end

consumption, innovation guidance, green & low carbon, sharing economy, modern supply chain and human capital service. We should optimize and upgrade conventional industries, accelerate the development of modern service industry, and improve the level according to international standards. We should promote our country's industry to march toward the middle and high end of global value chain and cultivate several world-level advanced manufacturing clusters.

1 The 4th industrial revolution calls the emerging engineering talents

The World Economic Forum annual meeting 2016 in Davos was themed "Mastering the 4th Industrial Revolution", and focused on how the new industrial revolution promotes the world economic and social transformation. In the same year, Klaus Schwab introduced the book "The 4th Industrial Revolution" and pointed out that the 4th industrial revolution is coming, and its main features were integration of various technologies, blurring boundary among physical world, digital world and biological world, new technology capabilities, and huge influences on political, social and economic systems. The rapidly developing 4th industrial revolution put forward new requirements for engineering talents.

1.1 Engineering talents having interdisciplinary and comprehensive

abilities

Among the current and future emerging industries, most involve such scientific fields as information, materials, energy and life. Instead of incremental changes, these technologies bring revolutions by combining basic science with technology and multi-disciplinary integration. For example, "quantum chip", "quantum computing" and "quantum communication" need not only solid physical foundation and in-depth understanding about quantum mechanics, but also knowledge in semiconductor physics, communication and computer technology.

Therefore, compared with the conventional engineering talents, the high-quality interdisciplinary "emerging engineering" talents having strong practical and innovation abilities in order to solve problems in engineering application and maintain international competitiveness to meet future industrial and economic needs. They shall be proficient in a discipline and also have interdisciplinary knowledge. They shall not only apply the knowledge that they have mastered to solving existing issues, but also have the abilities to learn new knowledge and new technologies to solve the issues in the future and play a leading role in future technologies and industries. They not only perform excellently in technology, but also understand economy, society and management with good humanistic qualities.

In the face of new tide of knowledge-based economy and the 4th industrial revolution, Harvard University, Yale University and other

comprehensive universities and colleges restored their school of engineering one after another. For the School of Engineering, Harvard University sets its education objective as training the next-generation world leader. The core principle of engineering education is to train new-generation engineers with innovative thinking. Students need to have a solid foundation in science and technology, know about how matters run and how the world develops, and be able to engage in interdisciplinary and cross-industrial researches and integration.

1.2 Innovative engineering talents oriented to the future

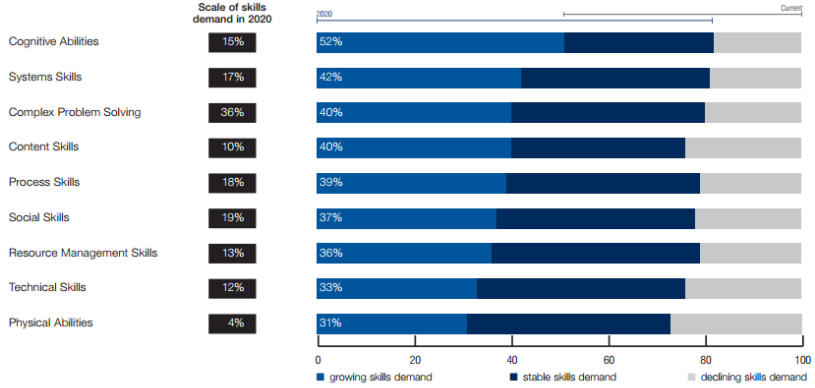
Against the background of the 4th industrial revolution with "integration" as key characteristic, the products and systems in the engineering industry have become increasingly complicated. Increasingly severe energy and environment issues are in urgent need of solution from technological innovations and breakthroughs of the 4th industrial revolution. However, once subversive technologies are applied to production, it will cause dramatic changes to the market and industrial pattern. For example, the economy driven by the internet technology shows the characteristics of cruelty and cycle; online car-hailing and bicycle sharing attracted lots of venture capital in the initial stage of pioneering, but when it's not in anymore, a lot of companies in this field have faded. Thus, talents who want to start a business should have professional skills and seek market return with the following in mind: the innovation cycle becomes shorter with rapidly

emerging new ones; industries are upgrade more frequently; the development modes are more diversified.

Klaus Schwab, founder and executive chairman of the World Economic Forum, said, "The 4th industrial revolution not only shocks the labor forces, but creates the 'labor shortage' of skilled workers. In the face of such a global talent crisis, we must transform the existing education system with a new thinking mode, so as to make it really adapt to the future demands of labor force market."

1.3 Engineering talents oriented to the new industrial system

Industry transformation and upgrading is an inevitable stage for economic development. Internet, artificial intelligence and other new technologies are gradually integrating with the conventional manufacturing in depth. However, the traditional engineering education giving priority to cognition is separated from the development of new industrial system to some extent. The report of the World Economic Forum, the Future of Jobs, pointed out that by 2020, the demand for engineering talents' "abilities of solving complex problems" (36%) would far exceed the demand for "cognitive abilities" (15%) (Figure 1).



Source: Future of Jobs Survey, World Economic Forum.

Figure1 Survey of Future Demands for Skills of Talents

According to the statistics of Adecco, the largest human resources service provider in Europe, 73 million young people are unemployed currently in the world. On the other hand, there are still no suitable candidates for 8 million jobs in the world. Adecco further expected that by 2025, more than a half of young people in the world would engage in brand new jobs which currently do not exist in society. The paradox of surplus and shortage of talents will emerge in the talent market. Marked by “ Made in China 2025”, China’s accelerated effort to develop into a great power in manufacturing, and develop rapidly in eight strategic emerging industrie. However, the shortage of talents in manufacturing is very large, and by 2020, the shortage of talents in the new-generation information technology industry will reach 7.5 million people, while that in the power equipment industry will be 4.1 million people, and the shortage of

talents in new material industry, high-grade numerically-controlled machine tool and robot industry will be about 3 million.

2 Reform practice of countries in the world in engineering talents and China's exploration

2.1 Reform practice of engineering talents of countries

In order to adapt to the technological development against the background of the 4th industrial revolution and the demands of the times, more and more countries realized the great importance of engineering education, and put forward development measures from many perspectives.

2.1.1 Optimizing the engineering education scale and talent training structure

On the one hand, increase the training scale of engineering talents to meet the increasing talent demands of key development industries in respective countries. For example, after the outbreak of financial crisis in 2008, the Alliance for American Manufacturing released the report *Create a better Future for American Manufacturing*, which required the government to take measures regarding trade policies, increase skill training and investment and research and protect manufacturing development. The engineering education of the U.S. actively responded to that strategy. In recent years, the number of person awarded with a bachelor's degree in engineering field has

kept an annual growth rate above 5%; the number of person awarded with a master's degree in engineering field even reached an annual growth rate of 11.11% in 2015. The majors with fast growth in the number of academic degrees are closely related to the internet technology, bio-pharmaceutical, new energy and other emerging industries of which development the U.S. has emphasized in recent years, and agree with the "re-industrialization" strategy put forward by the U.S.

On the other hand, through adjustments of talent training structure, a talent team meeting industrial demands is formed. As shown by the data related to subject setting on the official website of the U.S.'s Classification of Instructional Programs (CIP), the number of set majors of inter-discipline or arts-science integrated disciplines has kept a continuous growth. Harvard University and the University of Michigan founded "Interdisciplinary Expert Committee". Massachusetts Institute of Technology has had nearly 70 multidisciplinary research organizations, research centers, laboratories and project teams. Stanford University promoted the "inter-discipline of biology" research plan. The University of Pennsylvania released the unique "Dual—Title Graduate Degree Programs". The University of Southern California released the "Suggestion on "Interdisciplinary Development and Planning". Besides the "inter-discipline" and "arts-science integrated disciplines", the CIP also set interdisciplinary

majors in other clusters, such as biochemical engineering, engineering chemistry and other subjects under engineering.

2.1.2 Revising the training standards for engineering talents

Directors of education or relevant departments of developed countries took the initiative to revise the training standards for engineering talents. They added innovation abilities, leadership and abilities of coping with complicated problems into the new training standards, further reflecting the requirements of the new industrial revolution for emerging engineering and technical talents.

The National Academy of Engineering (NAE) and the National Science Foundation (NSF) jointly put forward *The Engineer of 2020*, which summarized several key features that a future engineer shall have, including "analysis abilities, practical experience, creativity, communication abilities, business and management abilities, ethics and lifelong learning abilities".

Germany formulated the "German Qualification Framework for Graduation from Universities", laying out overall description of the education that graduates receive, of graduates' abilities and qualities, study results, education level and qualifications for various diplomas. The research institutes and universities founded by the federal government and state governments of Germany have already participated in such jobs as technical development, standard formulation and talent training system of "Industry 4.0" and carried out lots of work in realizing interdisciplinary exchanges and

cooperation and establishing the training partnership between enterprises and universities.

During the process of formulating the standard of The Accreditation of Higher Education Programs (AHEP), the U.K. stipulated that the output of professional learning should include “natural science and foundation of mathematics and associated engineering discipline contents”, “engineering analysis”, “design”, “economic society and environment background” and “engineering practice”.

2.1.3 Implementing various types of engineering education reforms

The governments and universities of all countries promoted various policies and projects and implemented engineering education reforms, so as to enable engineering education to better meet the requirements of future industrial and social development.

Massachusetts Institute of Technology released the *Institute - wide Task Force on the Future of MIT Education* in August, 2014, and started the first round of plan (2017-2020) of engineering reform in August, 2017, i.e. the NEET plan. It stressed that engineering education shall be centered on students and reform students’ study modes and contents, aim to train engineering leaders in future industries and social development, and make the MIT’s engineering talents oriented to the future industry,. At present, it sets two threads themed living machine and autonomous machine, and students will receive a Science Bachelor Degree in the major that they study and a NEET program certificate when they are graduated.

The U.K. implements the training modes of market-oriented application-oriented and competency-based talents in higher education. Compared with the traditional academic elite talent training mode and the U.S.'s general education, it stresses academic autonomy of universities, adjusts the course system according to the market demands, emphasizes students' career and specialty, and stresses the training of their own abilities. The "sandwich" education mode is a talent training mode integrating university students' study and work widely implemented in the higher education of the U.K. Exampled by engineering education, students mainly receive the training of natural science and foundation courses in their freshman year, to widen their horizon of knowledge and pinpoint their strength. In their sophomore years, students mainly focus on the study of foundation courses of specialties, so as to lay a foundation for their future development. In their junior year, students enter enterprises to carry out internship of specialty, so as to integrate theories with practice, learn about the frontier development and improve comprehensive competence. In their senior year, students will return to school, study specialized courses and business administration, and complete their diploma project. The "theory-practice-theory" teaching method stressing the importance of practice enables students to integrate work experience and classroom study and improve market adaptability. Meanwhile, the one-year enterprise internship enables students to walk out of the tower of ivory and

enter society, enhancing the students' comprehensive qualities and understanding of society.

France executes elite education in engineering education, and its comprehensive universities' engineering school and higher specialized institutions are distinctive in system, enrollment and training modes. The education of comprehensive universities is hierarchical, divided into three stages: the first stage is basic education; the second stage is specialized education, to realize specialization through high-level education; the third stage is postgraduate education. Among the higher specialized institutions, most are subordinate to various ministries and commissions of the state, and they mainly engage in researches of applied science and training of engineers. For example, École Centrale de Nantes specially focuses on the training of hard skills and soft skills during the process of course setting. The hard skills mainly include high-level science and technology abilities, the abilities of dealing with complex technical issues, the abilities of constantly adjusting and adapting to new fields, new technology development abilities, the abilities of managing time, budget and team, the abilities of coping with uncertain and rapidly changing external environment and the abilities of dealing with emergencies. The soft skills mainly include learning and predicting human demands, international horizon, critical thinking and innovative thinking, comprehensive personality and wide culture and knowledge background, communication and

teamwork abilities, learning enterprises' work and engineers' professional activities. The biggest characteristic is to break the barriers between disciplines and specialties, to enable students to select study in two specialty fields of engineering, enable students to be able to transfer from one field to the other and adapt to the demands and development in the future.

2.2 Reform and explore China's engineering education

At present, our country has engineering education of the largest scale in the world (Table 1). By 2016, the number of undergraduates of engineering at school had reached 5.21 million; the number of graduates of engineering had reached 1.19 million; the number of specialty points of engineering had reached 17037. The number of undergraduates of engineering at school accounts for about 1/3 of the total number of students of higher education at school. At present and in the near future, our country's engineering education will take improving the training quality of talents as the core, to accelerate our country's moving from a big country of engineering education to a great power of engineering education.

Table1 Statistics of the Number of Students of Major Countries in the World

Country/region/economy	Total number of graduates (2012)	Number of graduates of engineering (2012)	Ratio in the total number of graduates in the country (%)	Ratio in the total number of graduates of engineering in the world (%)
North America	2,404,584	160,066		6.3
Canada	168,183	9,471	5.6	0.4
Mexico	425,754	67,332	15.8	2.7
America	1,810,647	83,263	4.6	3.3
European Union (EU)	2,602,040	193,030		7.6
France	311,026	22,707	7.3	0.9
Germany	386,090	43,818	11.3	1.7
U.K.	389,298	16,435	4.2	0.6
Non-EU	1,518,411	150,015		5.9
Russia	1,406,050	142,806	10.2	5.6
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
World total	20,433,355	2,534,843		

Firstly, develop majors related to strategic emerging industries. In 2010, the State Council released the *Decisions on Accelerating Cultivation and Development of Strategic Emerging Industries*. In order to accelerate the training of talents of strategic emerging industries, by the end of 2016, the number of undergraduate specialties of engineering related to strategic emerging industries arranged by the Ministry of Education had reached 22, and the number of specialty points of engineering had reached 1401 (Table 2). In addition, according to preliminary statistics, the number of undergraduate specialties of electronic information, automation and computer related to IT industry offered in universities has reached 30, and the number of specialty points of engineering has reached 5675 (Table 3). Taken together (no double counting), there are 6271

specialty points, accounting for about 36.8% of the number of undergraduate specialties of engineering.

Table 2 Summary Table of Undergraduate Specialty Points of Engineering Related to Strategic Emerging Industries Set after 2010

Name of specialty	Number of points	Name of specialty	Number of points
New energy science and engineering	87	Intelligent power grid information engineering	20
New energy materials and devices	52	Hydroacoustic engineering	3
Energy chemistry engineering	51	Marine engineering and technology	5
Resource recycling science and engineering	31	Marine resource development technology	10
Environmental protection equipment engineering	10	Building environment and energy application	200
Radiation protection and nuclear safety	8	Bio-pharmaceutical	70
Function materials	35	Data science and big data technology	3
Nanometer materials and technologies	10	Robot engineering	1
Microelectric science and engineering	94	Flight control and information engineering	2
Photoelectric information science and engineering	241	Geographic space information engineering	1
Internet of Things engineering	466	Material design science and engineering	1
Total			1401

Table 3 Summary Table of Undergraduate Program Points Related to IT Industry

Specialty category	Specialty name	Number of points	
Electronic information category	Electric information engineering	675	2324
	Communication engineering	547	
	Electric science and technology	226	
	Microelectric science and engineering	94	
	Photoelectric information science and engineering	241	
	Information engineering	102	
	Broadcasting and television engineering	15	
	Hydroacoustic engineering	3	
	Electronic packaging technology	9	
Electronic information category	Integrated circuit design and integration system	30	2324
	Medical information engineering	32	
	Electromagnetic field and wireless technology	13	
	Radio wave propagation and antenna	4	
	Electronic information science and technology	313	
	Telecommunication engineering and management	4	
	Applied electronic technology education	16	
Automation category	Automation	478	566
	Railway traffic signal and control	87	
	Robot engineering	1	
Computer category	Computer science and technology	974	2785
	Software engineering	561	
	Network engineering	417	
	Information security	98	
	Internet of Things engineering	466	
	Digital media technology	214	
	Intelligent science and engineering	31	
	Spatial information and digital technology	16	
	Electronic and computer engineering	3	
	Data science and big data technology	3	
	Cyberspace security	2	
Total		5675	

Secondly, deeply explore the talent training systems and mechanisms for effective modes integrating production and education in depth. Implementing the Several Opinions on Deepening Integration of Production and Education of the General Office of the State Council, universities actively build the open school-running mode and flexibly set specialty directions according to industrial demands and technological development. Universities and enterprises strengthen cooperation, and jointly formulate training objectives and training programs oriented to market demands and international competitiveness, jointly develop courses, jointly construct laboratories and practical training and practice base, cooperate in cultivating and training teachers and carrying out researches, and explore effective channels to train talents in urgent need. The integration of production and education, as an important measure for promoting the coordinated development of economy and society, is integrated into all links of economic transition and upgrading that run through the whole process of talent development, forming a working pattern coordinately promoted by the government, enterprises, schools, industries and society.

Thirdly, accelerating the training of talents urgently needed in key fields. For the key fields in urgent need of talents, the Ministry of Education and industrial departments jointly take measures and provide key support. In 2007, the Ministry of Education, the National Development and Reform Commission, the Ministry of Finance, the Ministry of Personnel, the Ministry of Science and Technology and the State-owned Assets Supervision and Administration Commission

jointly printed and distributed the "Opinions on Further Strengthening the Work on Training of Talents Urgently Needed in Nationally Key Fields". In 2012, the Ministry of Education and the Ministry of Transport jointly printed and distributed the "Several Opinions on Further Improving Navigation Education Quality". In 2014, the Ministry of Education and the State Administration for Safety Supervision jointly printed and distributed the "Guidance on Strengthening the Work on Training of Chemical Safety Talents", and the Ministry of Education and the Ministry of Commerce jointly printed and distributed the "Opinions on Innovating the Talent Training Mechanism for Service Outsourcing and Improving the Development Ability of Service Outsourcing Industry". In 2015, the Ministry of Education and China Meteorological Administration jointly printed and distributed the "Guidance on Strengthening the Work on Training of Meteorological Talents". In 2016, the Ministry of Education, the Office of the Central Leading Group for Cyberspace Affairs and other departments jointly printed and distributed the "Opinions on Strengthening Network Security Discipline Construction and Talent Training". In 2017, the Ministry of Education, the Ministry of Human Resources and Social Security, and the Ministry of Industry and Information Technology printed and distributed the "Planning Guide for Talent Development in Manufacturing". Such series of documents are based on the cooperative cultivation of talents by the Ministry of Education and relevant industrial departments. They put forward specific measures and supporting policies for optimizing the

specialty structure in relevant fields, reforming the training mechanism, strengthening practice and practical training and strengthening the construction of teaching staff.

3 Emerging Engineering Education: Intelligence guarantee of the 4th industrial revolution

The "Emerging Engineering Education" is not just "emerging engineering", or the engineering of "emerging applied technology". The Emerging Engineering Education (3E) is our country's engineering education reform direction put forward on the basis of new situations of international competition, according to new demands of national strategic development and new requirements of strengthening moral education and cultivating people. After February, 2017, actively promoted by the Ministry of Education, the "Fudan Consensus", "Action of Tianjin University" and "Beijing Guide" were formed one after another. We spared no effort to explore and form Chinese modes and China experience in the global engineering education, so as to strengthen China through powerful national higher education. The efforts provide a brand-new perspective for the reform attempts in global higher engineering education.

3.1 Connotation and characteristics of Emerging Engineering Education

The 4th industrial revolution changed the normal form and mode of engineering, putting forward new challenges and requirements for

various types of talents, including engineering talents. The normal form of the existing engineering education, i.e. "returning to engineering", has failed to meet such requirements any more. Thus, it is imperative to carry out the "Emerging Engineering Education" which satisfies the 4th industrial revolution.

The connotation of Emerging Engineering Education is as follows: Guided by strengthening moral education and cultivating people, it aims to deal with changes and shape the future. By combining coordination and sharing, it will train diversified and innovative engineering talents. The connotation can be understood from three layers:

3.1.1 New idea: Dealing with changes and shaping the future

Idea is the guide of action and the concentrated education of development direction and development ideas. The construction of Emerging Engineering Education shall drive the innovative development of engineering education by taking the lead in reform of idea.

(1) The Emerging Engineering Education puts more emphasis on actively dealing with changes. Innovation is the primary driving force leading development, and the fundamental challenge is to explore the unknown which is constantly changing. Drucker, a famous management scientist, once said that no one could control changes, and the only way was to walk ahead of changes. The Emerging Engineering Education shall actively deal with changes,

lead innovation, explore new ideas, new structures, new modes, new quality and new systems of engineering education under the constantly changing background, and train excellent engineering talents being able to adapt to the changes of the times and the future.

(2) The Emerging Engineering Education places more stress on taking the initiative in shaping the world. Higher education, as an important bonding point of the primary resources of talents, the primary productive force of science and technology and the primary driving force of innovation, is closely related to the development of social and economic development. Engineering education directly relates science and technology to industrial development, and engineering talents and engineering science and technology become important forces changing the world. Thus, the Emerging Engineering Education shall get rid of the cognitive restriction of "adapting to society", and shoulder responsibility of bringing benefit to human and shaping the future, and become revolutionary force driving economic and social development.

3.1.2 New requirements: Train future diversified and innovative excellent engineering talents

As a kind of new engineering education, the Emerging Engineering Education has no difference in the nature of education, but it has changes in the requirements for training of talents.

(1) New talent structure. The engineering talent training structure is required to be diversified. On the one hand, our country's industrial development is unbalanced currently. It experiences both Industry 2.0 and Industry 3.0 simultaneously. It is essential to phase out Industry 2.0, popularize Industry 3.0 and attempt for Industry 4.0, so the demands for engineering talents are complicated and diversified. It is essential to perfect the diversified talent training structure from R&D, design, production and sales to management and service, which connects with the whole industry chain. On the other hand, for engineering education itself, it is essential to re-determine the training objectives and training scale of all levels, including junior college program, undergraduate program, master's program and doctoral program according to the requirements for the qualities and abilities of future engineering talents, and establish the engineering education transformation and upgrading supply mechanism oriented to population change demand and based on industrial adjustment.

(2) New quality standards. The training quality of engineering talents is required to be oriented to the future. At present, there is no unified definition of quality standard for future engineers, but lots of descriptions of the qualities of future engineers reflect the core factors of the quality of future engineering talents to some extent. The report of 2016 World Economic Forum "The Future of Jobs: Employment, Skills and Workforce Strategy for the 4th Industrial Revolution" specially stressed the composite skills including social skills, system

skills, skills of solving complicated issues, resource management skills and technical skills. Based on the international standards and our country's great strategic demands and the actual situations of development, the future engineering talent training standards shall stress the following core competencies: patriotism, innovation and entrepreneurship, interdisciplinary crossing and integration, critical thinking, global vision, independent lifelong learning, communication and negotiation, engineering leadership, environment and sustainable development, and digital literacy.

3.1.3 New channels: carry forward and innovate, inter-disciplines and integration, and coordination and sharing

In a sense, the Emerging Engineering Education reflects the form of the future engineering education, and it is an innovative engineering education program keeping up with the times, and it needs new construction channels.

(1) Carry forward and innovate. The Emerging Engineering Education shall be rooted in historical precipitation and traditional advantages and oriented to the future and speed up reform and innovation. It shall cope with the rapid changes of modern society and uncertain reform challenges in the future through the sublimation of talent training ideas, reform of systems and mechanisms and innovation of training modes. The future engineering leader talents who are good at finding scientific problems in engineering, and able of solving engineering problems by use of scientific principles and

able of solving significant problems in the face of human and national key strategic demands.

(2) Inter-disciplines and integration. Most breakthroughs of key core technologies and major engineering innovative scientific and technological achievements derive from cross-disciplines. The construction of Emerging Engineering Education shall take inter-discipline and integration as the strength of engineering innovative talent training and transform high-level scientific research advantages and industry-university-research resources to education advantages.

(3) Coordination and sharing. To promote the disciplinary structure adjustment of Emerging Engineering Education and talent training quality by coordination. Universities shall develop new majors oriented to the future technologies and industries and form the coordinated education mode through the coordination of the relationship of multiple stakeholders of engineering education. The universities should serve as main body of the mode, which is led by the government, guided by industries and participated by enterprises, and gradually break through the policy barriers, resource barriers and regional barriers restricting the talent training quality of engineering education. Promote the co-construction and sharing of high-quality education resources and education achievements of the Emerging Engineering Education by sharing. The constantly deepening economic globalization and rapidly flowing innovation factors make

cooperation and sharing the common choice for the development of higher engineering education.

3.2 Actions of Emerging Engineering Education

The "Fudan Consensus", "Action of Tianjin University" and "Beijing Guide" constitute a "trilogy" of the construction of Emerging Engineering Education, starting the main theme of talent training and opening up new channels for engineering education reform. With a view to the national strategic goals of "Two Centenary Goals", the construction action route of emerging engineering education puts forward the action plan of "three stages, three tasks and three breakthroughs".

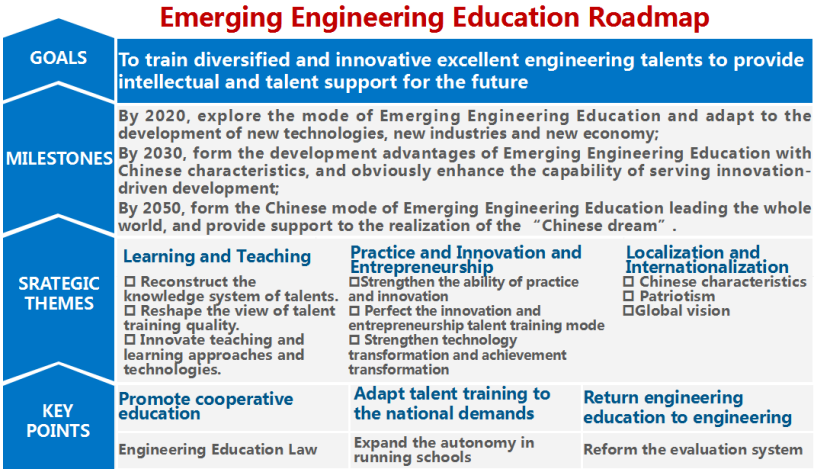


Figure 2 Roadmap for Construction Action of Emerging Engineering Education

3.2.1 Stage goal

By 2020, we should build the mode of Emerging Engineering Education to support the development of new technologies, new industries and new economy. By 2030, we should form advantages of Emerging Engineering Education with Chinese characteristics and obviously enhance the capability of serving innovation-driven development. By 2050, we should form the Chinese mode of Emerging Engineering Education leading the whole world, and provide support to the building of a moderately well-off society in an all-round way and realization of the Chinese dream of the great rejuvenation of the Chinese nation.

3.2.2 Key task

(1) Learning and teaching

Reconstruct the knowledge system of talents. Carry out prospective layout and dynamic adjustments of subject arrangement and major planning around industry chain and innovation chain. Build a batch of emerging discipline and specialty clusters serving the modern industries and speed up the transformation of traditional disciplines and specialties. Accelerate course reform based on the core qualities and competence of excellent engineering talents of the times and the future. Pay more attention to the construction of frontier knowledge and interdisciplinary knowledge systems, to the

construction of practical and innovative course systems and to the construction of general course systems of engineering education.

Reshape the view of talent training quality. To accelerate the core quality system and academic standard system adapting to the lifelong development of students of engineering and the demands of society, we need to improve the "student-centered" training system jointly participated in by students, teachers, employers and alumni and alumnae. We need to improve the continuously improved loop quality system, including learning objectives-training objectives-training program-course outline-evaluation and analysis-course quality report-implementation of improvement plans-learning objectives.

Innovate teaching and learning approaches and technologies. In 2017, the Horizon Report predicted major technologies, key trends and significant challenges in the technology application of higher education in the future five years (see Table 4). We can see that more interactive, intelligent and individualized teaching and learning approaches and technologies will accelerate development. Teaching and learning approaches will be inquiry-based, discussion-based and participative, supported by 3D network environment, augmented reality and virtual reality, artificial intelligence and other information technologies.

Table 4 Comparison between Chinese Higher Education Edition and World Higher Education Edition in the "Horizon Report"

		Chinese edition	World edition
Main technologies	Within one year	Flipped classroom, mobile learning, maker space, massive open online course	Self-adaptive learning technology, mobile learning
	Two to three years	Learning analysis and adaptive learning, augmented reality and virtual reality technologies, virtual and remote laboratories, quantified self	Internet of Things, next-generation learning management system
	Four to five years	Affective computing, stereo display and holographic display, robot technology, machine learning	Artificial intelligence, natural user interface
Key trends	Short-term trend	Apply blended learning design more; open education resources rapidly increase; STEAM learning rises	Blended learning design, collaborative learning method
	Medium-term trend	Rebuilding the learning space, inter-agency collaboration increases day by day, introspection of university running mode	Continuously focusing on and measuring learning, re-building the learning environment
	Long-term trend	Rising of coding literacy, promoting transformation and innovation culture, transferring to in-depth learning approach	Promoting innovation culture, in-depth learning approach
Significant challenges	Difficult challenge	Individualized learning, management issue of the big data of education, popularizing teaching and learning innovation	Achievement difference, digital challenge
	Challenges that can be coped with	Integrating technologies into teacher training, adopting both formal and informal learning, improving digital literacy	Improving digital literacy, integrating formal and informal learning
	Severe challenges	Train the capability of complex thinking, balance connected life and non-connected life, reshape the role of teacher	The management knowledge is out of date, rethink the role of teaching

(2) Practice and innovation and entrepreneurship

Strengthen the ability of practice and innovation and entrepreneurship. Extend the platform for education through practice, and strengthen teaching experiment, scientific practice and internship and practical training. Change engineering practice environment and engineering practice modes and integrate the experience of real world into engineering education through maker mode, 3D printing and other new technologies and new modes. Meanwhile, educators shall receive education first and enhance teachers' practice, innovation and entrepreneurship education and teaching abilities.

Improve the innovation and entrepreneurship talent training mode. Establish the total whole-process and all-around innovation and entrepreneurship talent training mode integrating ideological and political education, interdisciplinary training, industry-university-research cooperation, and innovation and entrepreneurship guidance and service. Improve the engineering education supply system, and break the barriers and boundaries restricting innovation and entrepreneurship talent training.

Strengthen technology transformation and achievement transformation. Adhere to science-education integration and industry-education integration, focus on the great demands of economic development and make breakthroughs in core technologies and cutting-edge technologies supporting strategic emerging industry

development. Improve the system and mechanism and service system for technology transformation and achievement transformation, and accelerate the transformation of innovative achievements of engineering technology into the real power of economic and social development.

(3) Localization and internationalization

China's voice. General Secretary Xi Jinping repeatedly stressed that the building of world-class universities in China must have Chinese characteristics, and it was essential to be rooted in China to run universities. The construction of Emerging Engineering Education must adhere to the orientation to national significant strategic demands and the main battlefield of national economy. Explore the engineering education system and mechanism which better adapt to our country's history, national conditions and culture and are more closely related to the realistic objectives and future direction of our country's development. Serve the people, the Communist Party of China, development of socialist system with Chinese characteristics, the reform and opening-up and socialist modernization construction and make China's voice heard in the world.

Patriotism. Patriotism is profound identification and deep feelings of the country, history and culture, regarding the country as home, having awareness of unexpected development, spirit of responsibility

and patriotic feeling. The Emerging Engineering Education shall adhere to the responsibility and mission of "strengthening the country through running schools". Identify direction in serving the national strategies, define the paths and measures supporting the national economy and society and industrial development, integrate patriotism into the whole process of engineering talent training, train the engineering talents who actively serve society and solve significant problems related to the country development and the people's livelihood, and make contributions to the realization of the Chinese dream of the great rejuvenation of the Chinese nation.

Global vision. Based on "The Belt and Road" and other national overall opening-up strategies, vigorously and actively promote engineering education internationalization, absorb and integrate high-quality international higher engineering education resources, strengthen international academic and talent exchanges, enhance international engineering technology cooperation, and improve the international competitiveness and influences of our country's future-oriented engineering education.

3.2.3 Key points

(1) To promote the legislative work of engineering education, and greatly promote cooperative education. To explore and formulate the *Engineering Education Law*. Legally strengthen the construction of public service system and system guarantee for university students'

innovation and entrepreneurship education. Establish and perfect the system on industrial enterprises' in-depth participation into university students' practice and innovation abilities, thoroughly solve the issue of university students' internship and practical training difficulty, and form the cooperative education system deeply integrating industry, university and research.

(2) Expand the autonomy in running schools and build the new momentum of engineering education development. Expand the autonomy in enrollment, granting academic degrees and discipline setting and adjustment. Implement the "Several Opinions on Deepening the Reform of Streamlining Administration and Delegating Powers to Lower Levels Integrated with Optimization Service in Higher Education Field" issued by five departments of the Ministry of Education to eliminate the system and mechanism obstacles restricting the reform and development of engineering education, and build the momentum of engineering education development.

(3) Reform the education evaluation system. To establish the evaluation system complying with the characteristics of engineering education. The higher engineering education shall take serving the country as primary task, pay attention to the evaluation of the outcome of talent training and the evaluation of the actual contribution of universities to economic and social development.

Engineering changes the world, and science and technology creates the future. The Emerging Engineering Education must put the training of innovative excellent engineering talents of the times and future in a more prominent strategic position, strengthen the research of Emerging Engineering Education construction laws, accelerate our country's engineering education reform by new ideas, new requirements and new channels, and provide intellectual support and talent guarantee for the realization of the "Chinese dream" and complicated and variable world in the future.

3.3 Reform measures for the development of Emerging Engineering Education

3.3.1 Establish specialties based on industrial demands

The discipline, specialty and talent training type structure issue are the core issues of engineering education reform. It is essential to master the latest talent demands and the future development direction of industrial development through strengthening engineering science and technology talents. On the one hand, it is essential to do well in incremental optimization, and take the initiative in layout of the construction of emerging engineering specialties. It is essential to pay attention to perceptiveness of specialty setting, actively set frontier and urgently-needed disciplines and specialties, accelerate the construction and development of emerging engineering education, and lay out and train talents leading the future technology and

industry development in advance. On the other hand, it is essential to do well in stock adjustment, and accelerate the transformation and upgrading of traditional disciplines and specialties. It is essential to guide universities to, in combination with the new demands of social development, new trend of disciplinary intercrossing and integration, and new achievements of scientific researches. Expand the connotation and construction emphases of traditional disciplines and specialties to form a new course system and build the upgrading edition of traditional disciplines and specialties, so as to upgrade iron and steel, petrochemical, machinery, light industry and textile industries and development towards the high end of value chain. It is essential to promote the intercrossing and integration of disciplines and specialties and enhance the composite engineering and technical talent training.

3.3.2 Change the contents based on technological development

Under the background of the new round of industrial revolution, the technological development of enterprises changes with each passing day, and engineering education shall deepen the reform of teaching contents and course system oriented to the industrial demands. It is essential to actively explore comprehensive courses, the courses solving problems from multiple perspectives and interdisciplinary discussion courses and promote the updating of teaching contents by the latest development of the forefront of

disciplines, industries and technologies. It is essential to integrate innovation and entrepreneurship education into the whole process of engineering education, in order to further implement the specific requirements of innovation and entrepreneurship education. Give full play to the advantages of engineering education in teaching staff, practice platform and industrial collaboration and widely set up business incubation base.

3.3.3 Promote reform with schools as the main body

Universities are the main body responsible for the construction of Emerging Engineering Education. From the perspective of historical law, each industrial revolution required transformation of engineering education contents and modes. During the construction of Emerging Engineering Education, universities shall give play to the primary-level pioneering spirit and be bold in practice, perfect the dynamic adjustment and self-renewal mechanism of disciplines and specialties and explore the new normal form of discipline and specialty setting and management. They shall promote the reform of personnel system, perfect the internal incentive mechanism adapting to the characteristics of teaching positions of universities and explore the mechanism for the two-way exchanges between university teachers and industrial talents. They shall follow the industrial reform and innovate training modes, strengthen work-study combination and university-enterprise cooperation, and enable

enterprises to directly participate in the whole process of talent training.

3.3.4 Change approaches according to students' aspiration and interest

In the Internet era, there are no obstacles for knowledge acquirement, but learning motivation and attention become rare resources. It is essential to adjust education and teaching approaches and methods based on students' aspiration and interest and improve teaching efficiency and benefit. The Emerging Engineering Education stresses adhering to and fully implements the student-centered idea. It is essential to respect students' independent choices, promote the reform of credit system of universities, make explorations in the establishment of course setting, student status management, quality monitoring, assessment and evaluation and other teaching management systems. It is essential to strengthen the reform of teaching methods and teaching means by using the latest research results of learning science for reference, enhancing teacher-student interaction and strengthening students' "motivation of learning". It is essential to spare no efforts to promote the in-depth integration of information technology and education and teaching. To establish a group of high-quality online open courses represented by massive online open courses and integrating course application

and teaching service and promote the reform of student-centered teaching approaches and methods.

3.3.5 Create conditions by internal and external resources

In order to promote school development, it is essential to optimize and configure the resources inside schools and actively obtain social resources, so as to create better conditions for talent training. The construction of Emerging Engineering Education shall further promote the experience in implementation of "education and training plan for excellent engineers". Through university-enterprise cooperation and science-education cooperation, we can optimize and configure teaching resources in a larger scope. It is essential to implement the cooperative education projects based on industry-university cooperation, promote the cooperation between universities and industrial enterprises and scientific research institutes, and jointly establish model colleges of national-level industry-university-research cooperation. In light of the demands of industrial development, it is essential to make explorations in the establishment of long-term mechanism for cooperative education based on national-level industry-university-research cooperation. It is essential to build practice bases or engineering innovation training centers of cooperative education and co-construction and sharing, and comprehensively arrange students to carry out internship and practice in practice departments and the front line of production.

3.3.6 Establish standards based on the forefront of the world

In order to realize the fundamental transformation of our country's engineering education, it is essential to consider our talent training based on the forefront of the world, and establish the engineering education system with international competitiveness. The Emerging Engineering Education shall strengthen the research and construction of the training quality standards for engineering talents, and further perfect the professional certification system for engineering education with Chinese characteristics and international effective equivalence. It is essential to focus on the progress in the frontier technologies in the world and the economic transformation strategies of development countries and carry out full competition in the following fields in the future: grapheme technology, full decoding of human brain, recombination of genome, computer being able to learn, solar-powered airplane for commercial use, intelligent airplane, and unceasing space race, and re-establish the country's competitive advantages.

4 Driving force for industrial transformation and innovation

The Emerging Engineering Education stressed international orientation, future orientation and industry orientation. By focusing on industry chain and value chain, it aims to transform traditional specialties and expedite new specialties and provide intellectual support and talent support for economic development.

4.1 Strengthen talents' ability of innovation and entrepreneurship and collaboration to transform traditional industries

The Emerging Engineering Education is combined with the new demands of social development, new trend of disciplinary intercrossing and integration, and new achievements of scientific researches. Through expanding the connotation and construction of traditional disciplines and specialties, it is essential to build the upgrading edition of traditional disciplines and specialties, and upgrade iron and steel, petrochemical, machinery, light industry and textile industries and development towards the high end of value chain.

Firstly, analyze the qualities that future engineering talents shall have, and define the competence system that engineering talents shall have in engineering technology, information technology, economic management, law, culture, ethics and other key fields. To set up modular courses according to the engineering logic. To break disciplinary boundaries, straighten out knowledge points of courses, carry out the course system reconstruction oriented to learning achievements, establish the one-to-one correspondence relationship between competence acquisition and course system, and build the course system following the engineering logic and education laws.

Secondly, design multi-level and multi-stage practice links. Adhere to the CDIO engineering education idea, and the whole life

cycle of products including "conception, design, realization and operation" as carrier. Implement the cooperative education based on industry-education integration, science-education integration, and university-enterprise cooperation, in order to enable students to obtain meaningful comprehensive design experience.

Thirdly, integrate innovation and entrepreneurship education into the whole process of engineering education, and spare no efforts to train students' creative spirit, entrepreneurship awareness and creativity. The innovation cycle becomes shorter and shorter; the boundary between technical development and industrialization becomes blurred day by day; technological updating and achievement transformation become faster and faster; industrial upgrading is continuously accelerated. Such changes require engineering science and technology talents to have innovation and entrepreneurship awareness and abilities. As the core of the new round of technological and industrial revolution, internet has a very strong cross-border penetration capability, which is reflected in the transformation of other industries by a whole set of rules and ideas of internet. The "internet+" industrial innovation mode requires engineering science and technology talents to have trans-disciplinary and cross-industry abilities with professional knowledge about their industry. The Emerging Engineering Education shall give full play to the advantages of engineering education in teaching staff, practice

platform and industrial collaboration, and widely set up business incubation base and entrepreneurship practice base. Create an innovation and entrepreneurship education atmosphere, promote innovation and entrepreneurship education to run through and deeply integrate into specialized education in an all-around way.

4.2 Train talents in emerging fields and lead the development of new industries

The new economy led by new technological revolution and marked by commercial mode and system and mechanism innovation is promoting the new round of transformation of production mode and changes of economic structure. On the one hand, artificial intelligence, mobile internet, cloud computing, big data and other emerging industries and types of business constantly emerge in the new economy, and such fields are short of talents. On the other hand, new technology is the basis of new economy, and it is essential to pay attention to new technologies which may emerge in the future, especially subversive technologies, and carry out talent training layout in advance.

The Emerging Engineering Education provides industrial cluster with specialized groups adapting to it as scientific support and provides powerful professional talents as human resource guarantee. For the emerging engineering talents. It is essential to stress the innovation and entrepreneurship abilities, prospectively lay out the

frontier technology research and development with the global vision, and constantly lead new industries.

Firstly, actively lay out the new specialties oriented to the future technologies and industries. The next 10 years is the key period when the new round of technological revolution and industrial revolution will develop from being ready to start to outburst in groups. The talent training of Emerging Engineering Education is oriented to the future and oriented to the world, and it is essential to take the initiative in layout and play the role of leading the future technology. On the one hand, it is essential to carry out the intercrossing and combination of existing engineering and the intercrossing and combination between engineering and other disciplines to produce new disciplines and specialties. On the other hand, it is essential to extend science, especially applied science, to engineering to generate new technologies and new engineering fields. It is essential to prospectively lay out the frontier technology fields with the global vision, pay high attention to subversive technologies and commercial mode innovation, constantly expedite new industries, make breakthroughs in air-space-ocean, information network, life science, nuclear technology and other core fields, and provide strategic reserve for sustainable development of economy and society and expand strategic space.

Secondly, accelerate the training of talents urgently needed in the current development of new economy. The strategic emerging industry is the key field to cultivate and develop new functions and obtain new advantages in the future competition and the key development direction of new economy. At present, big data, Internet of Things, artificial intelligence, network security, comprehensive health and other new fields are in the face of critical shortage of talents. The Emerging Engineering Education arranges a batch of emerging engineering specialties oriented to new economy and accelerates the training of talents in urgent need. On the one hand, it is essential to popularize the useful experience of demonstration software schools' systems and mechanisms and the reform of talent training mode, break through the organization mode oriented to traditional disciplines, set up demand-oriented industrialized schools, such as robot school, microelectronic school, intelligent manufacturing school, school of the Internet of Things, and deepen the form of mechanisms and systems. On the other hand, it is essential to promote the innovation in talent training mode, further strengthen the cooperative education based on industry-university cooperation, promote the close integration of talent training and industrial demands, and effectively support the in-depth adjustment of our country's economic structure and the continuous transformation of new and old kinetic energy.

4.3 Meet new demands of national strategic development and build new advantages in international competition

The international competition is ultimately the competition of talents and education. In the future, resource scarcity, environmental pollution, energy shortage, climatic change, aging of population and other global difficult problems will constitute severe challenges to the survival of mankind and sustainable development. All developed countries make strategic deployments in emerging technology fields or advanced manufacturing technology fields, reshape the new industrial system have sustainable competitiveness in the future and enhance their comprehensive national strength to contend for dominance in the world. The historical experience of developed countries proves that taking the initiative in adjustment of higher education structure and developing emerging frontier disciplines and specialties are the core factors for promoting the transformation of human capital structure of countries and regions and realizing the transition from traditional economy to new economy.

Our country's technology and industry development are going through the leap to leading positions. In order to have a leading position in technological and industrial fields, it is essential to have sufficient talent support in such fields, train talents needed in the future technologies and industries in advance, and to take the initiative. Though our country has higher engineering education of

the largest scale in the world at present, big data, Internet of Things, artificial intelligence, network security, comprehensive health and other new economy fields are in the face of severe shortage of talents. The World Economic Forum (WEF) released "The Global Human Capital Report 2017-Preparing People for the Future of Work" in September, 2017. The report analyzed the human capital unitization level of 130 economies all over the world in detail and ranked them. Norway, Finland and Switzerland were top three, respectively; China ranked 34th, being at the average level in the Central Asia, and it had a certain gap with Singapore (ranked 11th), Japan (ranked 17th) and the South Korea (ranked 27th).

Currently, the state put forward such key strategies as "Made in China 2025", "internet+" and "artificial intelligence 2.0". It made overall deployments in our country's manufacturing transformation and upgrading and leaping development by adhering to the basic policy of "innovation driving, quality first, green development, structure optimization, and talent-oriented" and to the basic principle of "market-oriented, government-guided, being based on the present", and planned the "three-step" strategic objectives to realize our country's manufacturing transforming from big to strong. In order to respond to the national strategic demands, support the prosperous development of new economy, make breakthroughs in core and key technologies, construct late-mover advantages, and occupy the commanding height of future global innovation ecosystem, it

urgently needs training a large number of emerging engineering science and technology talents having stronger innovation abilities and adaptability, and consequently improve the whole strength and international competitiveness of our country's engineering education.

The Emerging Engineering Education stresses innovative engineering talents, who can take the initiative in shouldering the responsibilities of the era of coping with challenges, benefiting people and shaping the future, to enhance the international competitiveness. In engineering education, adapting to the demands of economic and social development and promoting the all-around development of people shall be regarded as the fundamental standards for evaluating talent training quality. In extension of applied science to engineering, it is essential to promote the intercrossing and integration and crossover integration of disciplines, cultivate new engineering fields, vigorously develop nanometer materials, biomedicine, new energy, environmental governance, electronic information and other emerging disciplines. It is also essential to promote the organic integration of science education, humanistic education and engineering education, train talents with a solid scientific foundation, strong engineering abilities and high comprehensive qualities, comprehensively improve students' sense of social responsibility, creative spirit and practice abilities, and enhance the international competitiveness of our country's engineering talents.

Through the construction of the four-in-one collaborative system integrating "industry, science, education, entrepreneurship and innovation", the Emerging Engineering Education system takes the initiative in connecting with the new economy and new industry. Supported by industry-education integration, science-education integration, entrepreneurship-innovation integration and discipline integration, the system of talent training, scientific innovation, should focus on new industries.

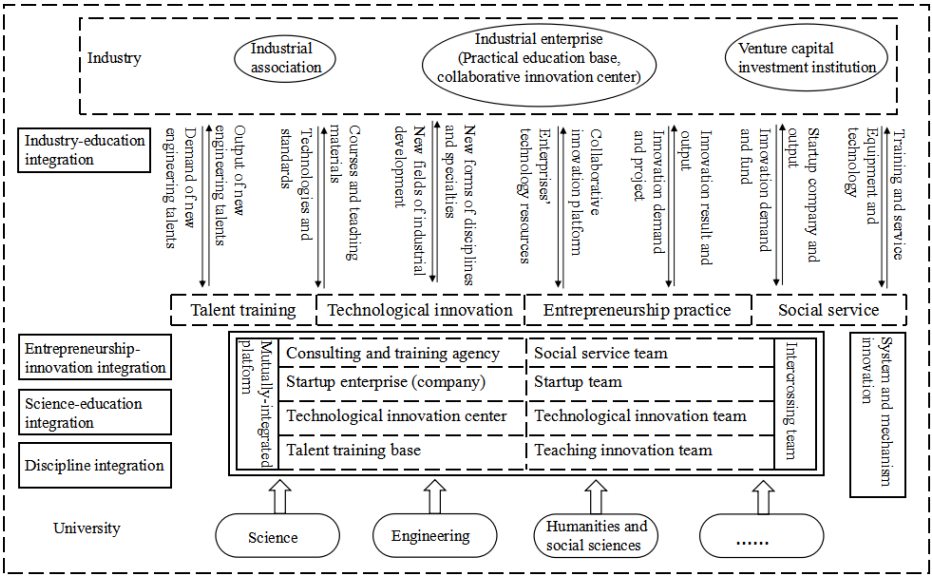


Figure 3 Four-in-one Collaborative System Integrating "Industry, Science, Education and Entrepreneurship" Oriented to the Emerging Engineering

From the perspective of promoting the development of the 4th Industrial Revolution and the development of the new economy, the construction of Emerging Engineering Education is aimed at training talents directly oriented to industries and oriented to economy. In combination with the development laws and the full cycle process of new economy, new industries, new types of business and new technologies, it stresses the training of engineering and technical talents according to the full cycle process and requirements of industry and engineering, actual situations, social development laws, and demands. Based on inheriting the existing achievements in engineering education, it is essential to reform the training ideas, optimize specialty structure, innovate training modes, strengthen the professional certification work, and use the methodology for engineering innovation. Our country's higher engineering education aims to integrate students directly into enterprises' technological innovation when they start their career, so that talents can support the development of new economy, new industries, new types of business and new technologies. If engineering education can lead the development of the 4th Industrial Revolution, new economy, new industries, new types of business and new technologies, Chinese dream of the great rejuvenation can be realized.

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