



Innovation in research and engineering education:
key factors for global competitiveness

*Innovación en investigación y educación en ingeniería:
factores claves para la competitividad global*

PETOE: ESTABLISHING A NEW JOINT TALENT TRAINING MECHANISM FOR UNIVERSITIES AND INDUSTRIAL ENTERPRISES

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Abstract

As a serve to China national strategy, PETOE, the Plan for Educating and Training Outstanding Engineers, is a national action in China's higher education reform and development with the leading, innovation and breakthrough property. PETOE mainly puts forward five key tasks, among which "establishing a new joint talent training mechanism for universities and industry enterprises" is the core one. The task includes four aspects: firstly, setting up a coordination mechanism for multi government departments in the implementation of PETOE; secondly, establishing a guidance mechanism for industry to participate in the implementation of PETOE; thirdly, building a talent training mechanism for university-industry cooperation; fourthly, studying and formulating relevant policies to establish college students practice system in China's characteristic socialism market economy. The goals of the task are to transfer the supply and demand relationship between universities and enterprises into a collaboration one, emphasize the pertinence and adaptability of engineering talent training, and establish the cooperation mechanism between universities and enterprises. This paper discussed the above content with focuses on the progress introduction, the results obtained and problems faced, and the general standards required in talent training, etc.

Keywords: PETOE; university-industry collaboration; engineer training

Resumen

Como un servicio a la estrategia nacional de China, PETOE, el Plan para la educación y formación de los ingenieros en circulación, es una acción nacional en la reforma de la educación superior de China y el desarrollo del liderazgo, la innovación y el avance inmobiliario. PETOE pone principalmente hacia delante cinco tareas clave, entre las que "el establecimiento de un nuevo mecanismo de formación de talento conjunta de las universidades y de las empresas de la industria" es el núcleo. La tarea incluye cuatro aspectos: en primer lugar, la creación de un mecanismo de coordinación de los departamentos gubernamentales de varios en la aplicación de PETOE, en segundo lugar, establecer un mecanismo de

orientación para la industria a participar en la ejecución de PETOE , en tercer lugar , la creación de un mecanismo de formación de talento para la universidad- industria cooperación, en cuarto lugar , el estudio y la formulación de las políticas pertinentes para establecer el sistema universitario a los estudiantes en la práctica característica de la economía de mercado socialista de china. Los objetivos de la misión son la transferencia de la oferta y la demanda relación entre las universidades y las empresas en una colaboración de uno, hacen hincapié en la pertinencia y la capacidad de adaptación de la formación de talento de ingeniería, y establecer el mecanismo de cooperación entre las universidades y las empresas. En este trabajo se analizó el contenido de arriba con se centra en la introducción de los avances, los resultados obtenidos y se enfrentaban a problemas, etc.

Palabras clave: *PETOE; colaboración universidad-empresa; formación de ingenieros*

1. The Overview of PETOE

China has defined three national strategies as taking a New Industrialization Path with Chinese characteristics, constructing an Innovative Country and Country's Reinvigoration based on Human Resources Development. These strategies have proposed emerging demands on engineering education. As a major educational reform, "The Plan for Educating and Training Outstanding Engineers " (PETOE), which was proposed in The National Plan for Medium and Long-Term Education Reform and Development (2010-2020), was launched on June 23, 2010.

PETOE was an important measure of China's higher engineering education which provides an initiative service to national development strategies during the new period in China. It was committed to cultivating a large number of engineering and technical personnel with high quality and innovative abilities to meet the needs of economic and social development, so as to provide a solid human resource foundation in the process of industrialization and modernization, and enhance national core competitiveness and comprehensive power.

PETOE was oriented by the following statements: "towards Industry Modernization, towards Globalization and towards Future Construction." The first means that PETOE will try to meet the needs of the industrial sector serve the new industrialization with Chinese characteristics, and maintain the country's economic and social sustainable development. The second notes that PETOE will serve to the "Going-global" strategy to exploit the international market for industry and provide a steady stream of engineering technical personnel with international competitive abilities. The third emphasizes that PETOE should be steered by a strategic foresight to train and reserve candidate engineers to lead engineering development in the future.

China is a genuine power of engineering education for its large number and ratio of undergraduate and graduate students in engineering programs. In the past 60 years, China has cultivated more than 15 million bachelor's degree and junior college engineering students, and 0.58 million graduate engineering students. Since 1978, China's engineering education has output a large number of engineering and technical personnel who supported the rapid economic growth for more than 20 years and some of whom played a central role in the remarkable engineering projects in China. At present, China has 1015 universities, 90% of the total institutions, having science and engineering programs. Among them, 572 universities grant engineering master's degrees and 269 grant engineering doctoral degrees. By the starting of PETOE in 2010, 3.71 million undergraduate and 0.47 million graduate students are majoring in science and engineering programs, accounting for 32% of total on-campus undergraduate and graduate students.

China has already formed a relatively rational system on engineering education. The structure of educational hierarchy tends to be reasonable, the talent cultivation and quality assurance system are gradually improved. However, there are still problems in China's engineering talent cultivation system, which can be summed up as internal and external ones. Internal problems include: the lack of engineering practice; the rigid pattern in training engineers, the scientific-oriented engineering education; the lack of creative training, the lack of faculty's engineering experiences. External problems include: the absence of engineer qualification system in most industry professions; the inadequate industry guidance and support to engineering education; the lack of policy and law support in university-industry collaboration, the lack of participation of enterprise in university talent cultivation process, and the low social recognition of engineering profession. These problems show that there are big gap between teaching and practice in engineering education. It is a critical time to change and meet the industrial needs.

In the context mentioned above, PETOE keeps close touch in the Chinese industrial development and the international trend of higher engineering education. It acts as a breakthrough point to accelerate the comprehensive reform of higher engineering education. Its final missions are to improve the quality of Chinese engineering education, build a modern higher engineering education system with a world level and Chinese characteristic, and promote China's engineering education from a grand power for its quantity to a great power for its quality.

The basic principles of PETOE are: industry-oriented, university-enterprise collaboration, respective implementation and diversity mode. The principle of industry-oriented emphasizes industrial sectors' participation in the process of talent training. The principle of university-enterprise collaboration refers to establish the mechanism of joint training talents in engineering education. The principle of respective implementation means to support different types of colleges and universities to participate in the plan. Different educational institutions should focus on training different types of talents. . The principle of diversity mode refers to give full consideration to the diversity of industry professions and their demands for engineering talents and to cultivate engineers in various ways.

PETOE contains five key tasks: establishing a new joint talent training mechanism for universities and industry enterprises; innovating the talent training mode; improving the quality of engineering faculties; expanding the opening of engineering education to the world; identifying the engineering talent training standards. Meanwhile, some specific measures are proposed: establishing a Multi-sector Coordination Mechanism, setting up national education centers for engineering practice, reforming the engineering faculty employment, assessment and training system, formulating supportive policies to encourage universities and enterprises to participate in PETOE.

The fields of PETOE involve both traditional industries and emerging industries of strategic importance. It is necessary to pay special attention to the talent demands in the period of national industrial update and train relevant talents in advance. PETOE programs will train the field engineers, design engineers and R&D engineers for the future at levels of bachelor's degree, master's degree and doctoral degree. It would be implemented from 2010 to 2020. Based on the principle of voluntary, about 20% colleges and universities which have engineering programs will participate in the plan. More than 10% full-time engineering undergraduates and 50% full-time engineering graduate students will join the plan.

Among the five tasks, the essential one is to establish a new joint talent training mechanism for universities and industrial enterprises. The task includes setting up a coordination mechanism for multiple sectors;

establishing a guidance mechanism for industry to participate; building a talent training mechanism for university-industry cooperation; formulating relevant policies and exploring the establishment college students practice system under China's characteristic socialism market economy condition.

2. Multi-sector Coordination Mechanism in PETOE

2.1 The needs for establishing a multi-sector coordination mechanism

Coordination plays a critical role in PETOE since central & local government, various industry ministries, hundreds of universities, tens of thousands large and medium enterprises have joint this broader partnership.

On the one hand, PETOE needs the powerful support from national policy-making departments. For instance, in order to encourage the industrial enterprises to participate in PETOE, some incentives are necessary such as tax privileges and cost- and risk-sharing policies to protect students' security during their practice in enterprises. These policies will encourage enterprises to participate in the PETOE and relieve their worries essentially. This process involves relevant industrial ministries of the State Council: the Ministry of Industry and Information Technology, the Ministry of Human Resources and Social Security, the Ministry of Housing and Urban-Rural Development, the Ministry of Transport, the State-owned Assets Supervision and Administration, the State Administration of Taxation, the State Administration of Work Safety, the Civil Aviation Administration of China, the State Bureau of Surveying and Mapping Geographic Information, the State Oceanic Administration, the Chinese Academy of Engineering, and so on.

On the other hand, PETOE requires the cooperation between industries for the following three reasons. First, cross-discipline have become an unstoppable trend in academic and technology development. To formulate the industrial training standards, it is necessary to enhance the communication between different sectors which had common professional requirements. Second, the experiences on engineer training from an industry would benefit the others. Better communication between industries can promote the best practice sharing. Third, the supports from local governmental policies are critical for local universities and colleges. Members of PETOE are not only central ministries' universities but provincial universities and city colleges. So except for the supportive policy at the national level, municipal and provincial policies are also very critical.

2.2 Organizational Structure of PETOE

An effective and well-established organization system is indispensable for realizing the vision of PETOE. The organizations of PETOE include the leading agency, academic committee, the coordinating bodies, the expert groups and the executive system.

(1) The leading agency and academic committee. "PETOE Committee" was set up by the Ministry of Education together with the relevant ministries of the State Council. Its responsibilities are to steer the plan, formulate the supportive policies and make decisions. Its daily works, assigned to the Higher Education Division of the Ministry of Education, include drafting working proposal, calling for industrial enterprises, association and expert groups to devote to the PETOE. The Higher Education Division is also responsible to implement the plan. "PETOE Academic Committee " was jointly set up by the Ministry of Education and Chinese Academy of Engineering. It's made up of 21 academicians from the Chinese Academy of Sciences (CAS) and Chinese Academy of Engineering (CAE). The Committee guides the overall academic directions of PETOE.

(2) Coordinating body. The Ministry of Education and relevant industry departments jointly set up a coordinating team which is mainly composed of department or division directors from the Ministry of Education and the industry departments. The leader of the team is selected from industry departments. It is responsible for coordinating the industrial participants, planning, implementing and evaluating the PETOE; formulating the industry criteria on talent training; suggesting the industry policies and measures; and organizing PETOE in the specific industries.

(3) The expert groups. Together with industry departments, the Ministry of Education invited distinguished industrial and educational experts to join the expert groups which are led by industrial experts. The industrial experts are commonly in-service or recently retired senior engineers and technicians; the educational experts should generally have senior professional titles and wealthy teaching experiences. The groups are responsible for directing PETOE implementation, developing the industry criteria, and demonstrating the professional training proposals.

At present, the Ministry of Education has cooperated with the Ministry of Housing and Urban-Rural Development, the State Administration of Work Safety, the Civil Aviation Administration of China, the State Bureau of Surveying and Mapping Geographic Information and other ministries to set up working teams and expert groups.

(4) The executive system. In the PETOE, universities and cooperative enterprises jointly form university-enterprise collaboration agencies which are responsible for the specific talents training process. In addition, the enterprises should establish "Engineering Education Centre" for students to conduct engineering practice for one year.

3 Industrial guidance Mechanisms of PETOE

3.1 Why - the requirements of market economy

Under the planned economy environment, the industries steered the talent cultivation directly. In the bureaucracy system at that time, the central government set up a ministry for each industry to make development plan and macro-control the industries. Even as for the talent training level and types, these ministries made the specific plans, requirements and guidance. Meanwhile, those industrial departments established universities and colleges to train engineers and technicians following their own industrial plan. This system made the universities affiliated to the industries closely. Additionally this system required industrial colleges to cultivate available talents according to the industrial needs. During this period, the government, industry and universities had a close relationship.

Since 1978, a market economy environment was gradually established in China. However the linkage between industries and universities become weaker. Along with the reform of government departments in 1998, most of the industry departments were revoked and replaced by various industrial associations. These associations mainly focused on the guidance, communication and coordination in their own industrial development. Meanwhile, a majority of the industrial colleges, except for a few that was placed under the Ministry of Education, were decentralized to provincial governments. The Associations have no executive powers of government ministries, nor industrial financial resources and responsibilities to directly affect the talents training as before. This was a new issue arise under the environment of market economy. The big gap between universities and industries made a direct result so-called structural imbalance in China's

engineering education. A large number of college graduates could not be employed easily while a great amount of enterprises were desired to find the right employees. This context makes PETOE to consider a new mechanism in market economy environment. There are emerging needs to reestablish the industrial participations in training engineers.

3.2 How – establish the institutionalized links between education and industry

The industries and industry departments have good understanding of the technological frontier, the development trends of industry and the demands of employers. PETOE plans to gradually set up an institutionalized link between industry and education to enable the education sector train future engineering personnel according to the industrial needs and timely adjust personnel training objectives, structure, levels and types. This change will make education accelerate the economic and social development. To date, the guidance from industrial sector is mainly reflected in the following two ways.

(1) Directing the formulation of industrial training criteria to meet the industrial requirements for engineering professional qualifications. The industrial training criteria will be jointly issued by both industrial and educational departments. The expert groups whose members come from industry departments, industrial associations and educational institutions firstly identify the core professional standard system and the critical and related fields in the professions development. Secondly, these groups will draft the industrial training criteria based on PETOE general professional criteria. These industrial training criteria are set at levels of bachelor's degree, master's degree and doctoral degree and cover all the industrial fields and engineering programs. If an engineer can work in various industries and needs to be trained across multiple industries, the professional criteria should be developed in every industry. Now The Association for Mechanical Engineering has developed the Mechanical Engineers Training Criteria in PETOE at three levels. In accordance with the criteria, an undergraduate student could be certificated as mechanical trainee engineer if he attained abilities the standard requires. Similarly if a graduate student achieves the master's degree criteria and finishes additional two-year engineering practice, he/she could be certificated as mechanical engineer and is eligible to practice in the mechanical engineering profession. In this way, the training at school connects with the professional qualification. Now various industrial work teams and expert groups have been organized for demonstrating the universities' education programs, developing industrial criteria and considering the incentives policies.

(2) Participating in evaluating the quality of education. With reference to international practice, the industry departments and associations together with the Ministry of Education establish a quality evaluation system of PETOE to assess the educational outcome in accordance with the training criteria. Industrial quality evaluation mainly include three aspects: reviewing the training programs of universities to decide whether they could join PETOE; guiding and reviewing the key elements in training process; participating in a PETOE graduates' follow-up survey after their graduation a year later. If a degree program failed the evaluation, it should be withdraw from PETOE.

4 University-enterprise collaboration systems in training engineer

4.1 Universities-enterprises collaboration is the key to success in PETOE

As mentioned above, with the overhaul of ministries, most of the large state-owned enterprises are charged by the "State-owned Assets Supervision and Administration Commission" of the State Council and go far away from those traditional industrial colleges. The links between both sides has become loose in the market economy. Pursuits of profit become main goals of state-owned enterprises, since they should win the market competition. Those state-owned enterprises have no time and obligation to provide venues,

resources and services to universities' engineering education. Similarly those non-state-owned or restructuring enterprises which developed under the environment of market economy also regard profit and development as their priority. The lack of strategic foresight and social responsibilities of these enterprises make them pay little attention on training talents for future. So there is no active cooperation with universities in training engineers.

We cannot imagine a university can train excellent engineers without a real engineering practice environment. Compared with universities, industrial enterprises hold the most of advanced equipment and technology. Meanwhile, the enterprises have many experienced engineers. The innovative abilities of engineering students would be promoted greatly under their teaching and supervising. It is beyond all doubts that engineering education should go toward real engineering practice of enterprises, who should be encouraged join the process of talent training.

4.2 The model of university-enterprise collaboration in PETOE

In PETOE, every level of engineering personnel training is divided into two phases: on-campus learning and on-site learning in enterprises. They are equally important. The latter requires students to learn in enterprises for about a year during their whole learning process. Except for learning advanced technology, the students should learn corporate culture, combine the graduate design with actual production, and participate in technological innovation and engineering development. The students should also be taught the professionalism and ethics during the practice.

The joint training relies on the Engineering Education Centers, the integrated training platform established in enterprises. These centers are built on the basis of the previous practice bases with expanded functions. The main tasks of these centers include: drafting training proposal together with cooperative universities; constructing the Curriculum system especially on the enterprises learning and practice; arranging the one-year practice learning. Now a batch of such centers has already been put into use. Till now 194 universities participating in PETOE have combined with leading enterprises to establish 980 Engineering Education Centers. Together with 23 ministries of the State Council, the Ministry of Education has preliminarily select 654 as State-level candidate centers.

By the end of 2012, the enterprises which join PETOE had reached 6,155. 3,779 of them are large enterprises and 2,983 are high-tech enterprises. Details are in Table 1.

Table 1. The enterprises who contracted with PETOE

Universities	Large enterprises	High-tech enterprises	Sum up
"985" Project Universities	1613	1387	2078
"211" Project Universities	780	640	1448
Undergraduate Universities	1232	804	2273
Newly-Established Universities	154	152	356

Sum up	3779	2983	6155
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Meanwhile, from its launching in 2010 till 2012, 11,487 part-time faculties from enterprises have involved in PETOE's teaching and 4,972 full-time faculties from colleges and universities were sent to enterprises. Table 2 shows the specific data.

Table 2. The exchange of full-time and part-time faculty in PETOE (2010.6-2012.12)

Universities	Enterprises' part-time faculty	Curriculums enterprises' faculty involved	Teaching hours of enterprises' faculty	Weeks of graduate design supervised by enterprises' faculty	university faculty sent to enterprises
"985" Project Universities	3860	1694	44612	8617	1496
"211" Project Universities	3026	855	57266	3387	1233
Undergraduate Universities	4204	1730	53154	15657	1917
Newly-established Universities	397	161	6093	465	326
Sum up	11487	4440	161125	28126	4972

5. Supportive policies and institutions

In order to support and ensure PETOE's development, the Ministry of Education and related industry departments have formulated relevant policies. These policies will be discussed briefly as below.

5.1 Policies issued by the Ministry of Education

In January 2011, the Ministry of Education issued the Guideline of PETOE which includes:

(1) Giving priority to develop professional degree program and distribute more recommended quota to engineering master's degree program to supply excellent students for PETOE; Suggesting flexible enrollment management in PETOE programs to retain admission qualification for those students who would like to practice or work in enterprises for 1-2 year before beginning the graduate program.

(2) Supporting colleges and universities to reform the engineering faculty appointment criteria, assessment and training approaches; Evaluating engineering faculties from focusing on theory research and published papers to engineering project design, patents, industry-university cooperation and technical services.

(3) Giving priority to those programs on new strategic industries.

(4) Supporting students in PETOE universities for international exchange. It will include government funded overseas study, internship, exchange learning; Giving priority to fund the youth faculties' academic exchange in multinationals enterprises; Giving priority of government scholarship to fund foreign students to finish engineering education in china; increasing government scholarship quota to independent

recruitment program in PETOE; giving priority to PETOE universities to develop Chinese-foreign cooperative education programs.

(5) Supporting the engineers in PETOE enterprises' for continuing education; supporting their on- job training, improving the in-service engineers' theoretical level and helping them to master new technologies and new equipment; Supporting the enterprises which established national and provincial centers to enhance their in-service engineers' qualification level, giving priority to admit the in-service engineers in these enterprises to take part in in-services professional engineering master's degree program; encouraging those enterprises which established the national Engineering Education Center to develop in-services doctoral program with cooperative universities; giving privileges to those universities at the graduate-level engineering education for PETOE enterprises in enrollment policies.

(6) Giving the employed priority to those students who graduate from PETOE programs.

5.2 Policies issued by industry departments

The industry departments and associations have developed specific policies to encourage the enterprises to join in PETOE. These policies include part-time faculty incentives and incident assurance polices. For example, together with the Ministry of Education, the Ministry OF Housing has issued the guideline policy to strengthen the students' practice in enterprises. Together with the Ministry of Education, the Ministry of Transport issued the supportive policy in maritime education and founded the joint mechanisms of navigation engineering education. The Ministry of Treasury is conducting survey and formulating preferential tax policy in accepting internships. The Ministry of Land and Resources, and the China Earthquake Administration have put PETOE tasks into the industrial talent development plan.

6. General standards of PETOE

In order to ensure the quality of training, PETOE formulated the general standards at undergraduate, master's and doctoral level. These standards are the national benchmarking for training the future outstanding engineers. These standards should be followed by any university who join in the PETOE. The following is the 11 general standards at undergraduate level:

- (1) With a good engineering ethics, the pursuit of excellence, professionalism and patriotism, a stronger senses of social responsibility and humanistic quality;
- (2) With deeper concern about environment, occupational health, safety, and social service;
- (3) With engineering-related knowledge of mathematics and natural science, knowledge of economic, management and the other humanities and social sciences;
- (4) With basic knowledge in engineering and fundamental theories in the field for solid works, a good understanding of producing processes, equipment and manufacturing systems, and a good understanding of professional development status and trends;
- (5) With an understanding of the technical standards, policies, laws and regulations in the field and relevant industry;
- (6) With learning abilities to access to information and professional development;
- (7) With integrated abilities to utilize scientific theories, analysis and problem-solving methods and technical means to solve practical problems; with an ability to participate in the design of producing and operational systems, and with an ability to operate and maintain these systems;

- (8) With a stronger sense of innovation and product development and initial capacity of design, technology and innovation;
- (9) With necessary skills to manage, communicate, and collaborate in a team and abilities to adapt to the environments;
- (10) With initial capacity of response to crisis and emergencies;
- (11) With a certain degree of communication, competition and cooperation under the circumstance of international exposure and cross-culture.

7. Concluding remarks

According to statistics, 7,678 students registered in PETOE program in 2008, 13,599 in 2009, 25,953 in 2010, 38,634 in 2011 and 44377 in 2012. The total students have reached 130,241, including 112,640 four-year undergraduate, 16,485 master's and 1116 doctoral.

PETOE has powerfully pushed forward the engineering education in the past three years. The new joint talent training mechanism becomes a model in higher education in China. Based on this mode the Ministry of Education launched other five similar plans: "The Outstanding Doctor Training Plan", "The Outstanding Legal Talent Training Plan", "The Outstanding Teacher Training Plan", "The Outstanding Forestry and Agricultural Talent Training Plan" and "The Outstanding News Media Talent Training Plan".

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