Experiences, Issues and Reflections of School-Enterprise Joint Training in Chinese Mainland under the Vision of PETOE Strategy: An Empirical Study Based on Small-N Cases

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Abstract

The Plan for Educating and Training Outstanding Engineers Plan (PETOE) is one of the major reform projects initiated by the Ministry of Education of China, as well as one of the major initiatives to promote Chinese mainland transform from a “great power nation” of engineering education to a “powerful nation” of engineering education. From the perspective of global comparison, this research conducts an empirical study based on small-N cases of the practical experiences of school-enterprise joint training in Chinese mainland. The research indicates: during the implementation process of PETOE over the past decade, significant progresses have been made in establishing school-enterprise joint training mechanisms, reforming school-enterprise joint training models, establishing school-enterprise joint training organizations and improving school-enterprise joint training teachers; at the same time, some key issues appear, including how to deepen the connotation, how to create the benefits and how to sustainably develop school-enterprise joint training. In the context of promoting a new round of PETOE strategy, it is urgent to communicate and coordinate with relevant stakeholders such as policymakers, industry and business sectors, and institutions of higher learning, and take active and steady measures to jointly promote engineering education reform in Chinese mainland.

Key words: the Plan for Educating and Training Outstanding Engineers Plan, higher engineering education, school-enterprise joint training, Chinese mainland, small-N cases

1. Introduction

On June 23, 2010, the Ministry of Education of China held a kick-off meeting for the Plan for Educating and Training Outstanding Engineers[1] (hereinafter referred to as “Outstanding Engineers Plan”) in Tianjin City. The Outstanding Engineers Plan is to implement the strategic deployment of the 17th National Congress of the Communist Party of China to take the road of new industrialization with Chinese characteristics, build an innovative country with strong human resources, and implement the Outline of the National Medium and Long-term Education Reform and Development Plan (2010-2020) [2]. In addition, it is also a key measure to promote China from “a nation with great power” in engineering education to

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1) The data shows that the number of enrollment, registration and graduates of engineering majors in China’s colleges and universities is more than that of other countries in the world, ranking first in the world, and approximate 3-5 times higher than that of Russia, the United States. At present, there are more than 1,100 colleges and universities in China implementing engineering education, more than 19,000 engineering majors, about 5.5 million enrolled students, and more than 1.2 million graduates. China has formed the world’s largest engineering education system. In this sense, China has become a country with great power in engineering education.
The implementation period of the Outstanding Engineers Plan is from 2010 to 2020, involving a large number of pilot colleges and universities as well as a wide range of specialized disciplines covering levels of undergraduate, master and doctoral degrees, and has strengthened the integration of government, universities, research institutes, and industry enterprises. The joint participation of many stakeholders has brought a large-scale, multi-layered and comprehensive educational reform. The Outstanding Engineers Plan has a very important role as a model and guidance for higher education in cultivating talents to meet social needs, adjusting the structure of talent cultivation, improving the quality of talents cultivation, promoting educational reform, and enhancing graduates’ employability.

One important feature of the Outstanding Engineers Plan is “in-depth participation of industries and companies in the whole educating and training process”. The Outstanding Engineers Plan regards school-enterprise cooperation as the key to successfully cultivating Outstanding Engineers, and puts forward the implementation principles of being under the guidance of industry, strengthening school-enterprise cooperation, considering the different classifications of colleges and universities, and promoting with various models, which requires colleges and universities to integrate the school-enterprise relationship, and shift from the paradigm of “on-campus cultivating” to the paradigm of “open school-enterprise cooperation training”.

Therefore, an in-depth study of school-enterprise joint training of the Outstanding Engineers Plan will broaden the depth and breadth of the Outstanding Engineers Plan education research at the theoretical level, improve the quality of the Outstanding Engineers Plan, and deepen the reform of school-enterprise joint training. It can also provide Chinese experience and solutions for the training of engineering and technology talents, and provide references for other countries and regions to facilitate international comparison and exchange.

2. Research Questions

Judging from the policy documents issued by relevant ministries and commissions of Chinese mainland over the past decade, the focus of the policies has gradually shifted from “establishing” school-enterprise joint training mechanism to “innovating” school-enterprise joint training mechanism.

On January 8, 2011, the Ministry of Education issued Several Opinions of the Ministry of Education on the Implementation of the Educational Training Plan for Excellent Engineers (hereinafter referred to as “Opinions”). The Opinions acclaimed the establishment of school-enterprise joint training mechanism. “The connotation of school-enterprise joint

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① The transformation from a nation with great power in engineering education to a powerful nation in engineering education is basically an improvement from quantity to quality. It is the goal of China’s engineering education in the new era and an important foundation for China to realize a socialist modernized country.
training mechanism is to jointly formulate training goals, develop curricula and teaching content, implement training process, and evaluate the quality of training. Undergraduate and graduate students should have about one cumulative year to study in enterprises, learn advanced technologies and corporate culture, conduct in-depth engineering practices, and participate in the technological innovation and engineering development of enterprises, so as to cultivate the professionalism and engineering ethics of students[3].” The training of Outstanding Engineers is a realistic and urgent demand for improving the quality of higher engineering education. The cultivation of professional spirit and ethics requires students to deeply study the advanced technologies and corporate culture of enterprises, conduct engineering practice in depth, and participate in the technological innovation and engineering development of enterprises.

On September 17, 2018, the Ministry of Education, the Ministry of Industry and Information Technology, and the Chinese Academy of Engineering jointly issued the *Opinions on Accelerating the Construction and Development of New Engineering and Implementing the PETOE 2.0*, which proposed improving the multi-agent collaborative educational mechanism [4]. Education policies are often driven by educational reform or play a strategic leading role in the latter. The shift from “establishing” to “innovating” is not an irrational and subjective choice, but the result of prudent and scientific decision. In order to make better use of the cooperative education mechanism, the academia needs to urgently look back and sort out the basic experience and main issues of the school-enterprise joint training from a rational perspective, put forward policy recommendations to promote the sustainable development of school-enterprise joint training.

3. Literature Review

At the preliminary and middle phases of the Outstanding Engineers Plan, the academia of Chinese mainland conducted empirical research in order to grasp the situation and diagnose issues. Some studies specifically focused on the issues of school-enterprise joint training, while some other discussed the issues of school-enterprise joint training when discussing the progress of the Outstanding Engineers Plan.

For example, Cai Jing (2011) conducted research on the progress in some pilot colleges and universities more than a year after the Outstanding Engineers Plan through online survey and interview survey. The research found that: new mechanisms have been launched from the perspective of industry and enterprises, but still confronted with some problems and challenges [5]. Lei Qing, Wang Min, Li Ming, etc. (2013) combined with the *Report on Working Progress of Outstanding Engineers Plan* of some pilot colleges and universities released on the website of the Higher Education Department of the Ministry of Education, specifically combed the *Progress of School-Enterprise Joint Training* [6]. The *Report on the Progress of the Outstanding Engineers Plan* (2013) is a compilation of the progress of the school-enterprise cooperation in training Outstanding Engineers [7]. Lin Jian (2013) showed the main achievements, pointed out the existing issues, and put forward measures and suggestions on the basis of a general overview of the Outstanding Engineers Plan progress [8].
Lv Liangxue and Xu Zhigang (2015) summarized the school-enterprise cooperation process of selected “985 Project” colleges and universities, “211 Project” colleges and universities, provincial colleges and universities, and local colleges and universities cultivating applied-type undergraduates, based on the progress reports on the Outstanding Engineers Plan of pilot colleges and universities released by the Ministry of Education in 2013, especially based on the analysis and research of typical cases of colleges and universities [9]. Zhu Xiumin (2016) reviewed the implementation after one cycle of the Outstanding Engineers Plan, based on interviews, questionnaires and data review, found that “the lack of school-enterprise cooperation” was the most prominent issue in the first implementation cycle of the Outstanding Engineers Plan, and analyzed the objective reasons behind it [10]. Wang Sunyu, Xie Zheping, Zhang Yu, etc. (2016) summarized and combed the effectiveness and issues of school-enterprise cooperation of the Outstanding Engineers Plan based on the cases study of colleges and universities [11].

In general, the existing research is worthy of reference in terms of research method and research content. The research methods used in related studies show diversity, mainly involving online surveys, interview surveys, case studies, questionnaire surveys, etc., which help to draw scientific and explanatory conclusions. In terms of research content, related studies can basically reflect the progress of the Outstanding Engineers Plan at different phases, raise key issues, and propose corresponding policy recommendations. However, the researches on the progress of school-enterprise joint training still have limitations. The related researches mainly focused on the initial stage or the first implementation cycle of the Outstanding Engineers Plan, but not reviewed and sorted out from a nearly ten years long period, which cannot fully reflect the progress of the Outstanding Engineers Plan, especially the latest development in the Outstanding Engineers Plan.

4. Research Methods

4.1 Literature analysis

The research intends to comprehensively collect and review the literature materials about school-enterprise joint training, analyze and discuss the historical background, implementation and issues of school-enterprise joint training in engineering education. Specifically, the research selects representative colleges and universities in China, collects policy text and regulations, summary report, meeting materials, policy text of educational authorities. In order to comprehensively and objectively reflect the school-enterprise joint training of the Outstanding Engineers Plan, this research relies on the Report on Working Progress of the Outstanding Engineers Plan of pilot colleges and universities released by the Ministry of Education in 2011 and 2014, related research literature (including relevant research papers, research reports from 2010 to 2020, etc.), data from the official website of colleges and universities, news reports, and selected representative pilot colleges and universities.

4.2 Small-N case study
In order to improve the explanatory power and persuasiveness, this research mainly adopts the Small-N case study method. Small-N case study is an important method of educational research, and is good at using constructive or demonstrative explanatory theories to compare the similarities and differences between different cases. The method is divided into four models, e.g., individualized comparison, generalized comparison, inclusive comparison and diversified comparison. They have their own characteristics in terms of comparison goals, case determination, and theoretical interest. The theory of interpretation based on the comparison of multiple cases has the characteristics of narrative and openness, which has implications for higher education research.

As an important method in the field of social sciences, the Small-N case studies method does not focus on isolated cases. Instead, multiple cases are selected for in-depth analysis. Through repeated comparison of multiple cases, the causal mechanism of social phenomena is revealed to construct an interpretive theory. The multi-case comparison method has great implications for higher education research in terms of theoretical construction, research topics, and research methods. It has a broad application space and is helpful to enhance the theoretical depth and explanatory power of research. It is suitable for exploring macro-level or meso-level educational issues such as educational system, organization and policy. It helps to improve the methodological quality of case studies and the theoretical depth of higher education research.

5. School-Enterprise Joint Training Experience of the Outstanding Engineers Plan

After the implementation of the Outstanding Engineers Plan, three batches of colleges and universities have participated in: 61 in the first batch, 133 in the second batch, and 160 in the third batch [12]. According to the demonstration of the Outstanding Engineers Plan expert group, the first batch approved 462 undergraduate specialties or pilot classes, and 293 graduate-level discipline areas [13]; the second batch approved 362 undergraduate specialties or specialty categories, 95 graduate-level discipline areas [14]; the third batch approved 433 undergraduate specialties, 126 graduate-level discipline areas [15], involving a total of 1,257 undergraduate specialties or specialty categories, or pilot classes in 354 colleges and universities, and 514 graduate-level discipline areas.

Related research indicates that more than one year after implementation of the Outstanding Engineers Plan, some pilot colleges and universities have begun to explore, gradually shifting from the paradigm of closed on-campus cultivation to the paradigm of open school-enterprise cooperation training, and actively invited enterprises to participate in the Outstanding Engineers Plan.

Additionally, the pilot colleges and universities have attached great importance to the industry-academy-research value, and attained some progress in actively building school-enterprise cooperation platform, establishing talent cultivating mechanisms with organic combination inside and outside the school; signed joint substantive training agreement; jointly formulated and improved the training standards of related specialties;
given full play to the advantages of the industry-academy-research combination, and vigorously promoted the cooperative education [16].

With the in-depth advancement of the Outstanding Engineers Plan, important progress has been made in building school-enterprise joint training mechanisms, reforming the school-enterprise joint training models, establishing school-enterprise joint training organizations, and improving school-enterprise joint training teachers.

5.1 Establishment of school-enterprise joint training mechanisms

The establishment of school-enterprise joint training mechanisms requires enterprises shift from employing units to joint training units. In general, the training mechanisms mainly include organizational and operational mechanisms.

For the organizational mechanisms, each pilot college or university has successively established an Outstanding Engineers Plan leadership committee, established an expert group composed of professors and corporate tutors, explored a working mechanism for joint discussions and exchanges, and continuously improved the management system, so as to ensure the effective implementation of the Outstanding Engineers Plan.

For example, Beijing Institute of Technology and the counterpart enterprises have jointly established Teaching Steering Committee which is responsible for consulting and guiding the plan development and evaluation, training model, standard and process, for researching, developing and reviewing relevant standards, and providing guidance [17].

Beijing Institute of Petrochemical Technology has established a “School-enterprise Engineering Education Steering Committee” in cooperation with Yanshan Petrochemical. Senior engineers of the enterprise and university experts jointly discussed the school’s talent cultivating goals and industry’s talent requirements, discussed and formulated personnel training standards and training programs, developed the curricula, organizational model and operating mechanisms, etc., and formulated the implementation programs of school-enterprise cooperation, quality assurance measures, student safety guarantee regulations, etc.[18]

For the operational mechanisms, the Ministry of Education encourages pilot colleges and universities to generally divide the four-year training phase into a three-year on-campus training phase and a one-year enterprise training phase. At the on-campus training phase, colleges and universities mainly focus on strengthening engineering practice ability, engineering design ability and engineering innovation ability, restructuring the curricula and teaching content, strengthening the cultivating of interdisciplinary and interdisciplinary talents, promoting a variety of research-based learning methods such as problem-based learning, project-based learning and case-based learning, and strengthening students’ innovative ability training.
At the enterprise training phase, students mainly learn the advanced technologies and corporate culture of the enterprises, carry out in-depth engineering practice, conduct graduation design in combination with the actual production, participate in technological innovation and engineering development, and form professional spirit and ethics. The cumulative study at the enterprise training phase should reach one year, including student production internship, graduation internship etc., so that the internship and practice are no longer a trick, and students can be integrated into the engineering scene. Especially, students can conduct designs at the phase of graduation design, with the guidance of school and corporate tutors, by combining with the actual production problems of enterprises, and even help enterprises solve some practical problems.

For example, China University of Petroleum (East China) has combined the discipline advantages of exploration technology and engineering with the rich experiences of Shengli Oilfield in the petroleum geophysical prospecting industry, proposed to build a student training platform led by full real data processing. It mainly sets up major modules of seismic data collection, processing and interpretation for the Outstanding Engineers Plan Class; build an integrated multi-level engineering training platform which integrates theoretical knowledge, practical simulation and engineering practice with chemical process design; closely connects with Zhongyuan Oilfield, and divides the training platform into four modules: reservoir engineering, drilling and completion engineering, oil production engineering, and surface engineering, dominated by oilfield development process training [19].

5.2 Reform of school-enterprise joint training models

At the beginning of the 20th century, Schneider, the dean of the School of Engineering of the University of Cincinnati, put forward the concept of “cooperative education”. Driven by Schneider, the University of Cincinnati collaborated with local companies to train engineering and technical personnel. The university and the companies jointly formulated teaching plans and were jointly responsible for teaching implementation. The students’ theoretical teaching, engineering skills training, and practical production work were combined to cultivate suitable talent required by engineering practice. This model has also been widely used internationally. In addition to the United States, school-enterprise cooperative education has also been developed in many countries, especially in the field of vocational education, such as the “dual system” model in Germany and the “TAFE” model in Australia [20].

A number of typical school-enterprise joint training models have been formed internationally, including the “cooperative education” model represented by the United States, the “corporate teaching” or “enterprise visit” model represented by Japan, the “dual system” model represented by Germany, the “sandwich” model represented by the United Kingdom, the “work-study” or “apprentice training center” model represented by Canada and France, the “teaching factory” model represented by Singapore, and the “TAFE” model represented by Australia.
Currently, Chinese mainland has also formed several common school-enterprise joint training models which adapt to the national conditions and educational systems, including enterprise customization model, internship base training model, and industry-academy-research training model. There are differences in the three training models in curricula development, time schedule and corporate tasks [21]. “The school-enterprise joint training is a two-way selection process. Schools and enterprises should do well in finding common interests and establishing diverse cooperation platforms. The cooperation between schools and enterprises can complement each other’s advantages and achieve win-win cooperation. Based on the Outstanding Engineers Plan, the school-enterprise joint training model can reduce the shortage of practical resources in colleges and universities. Enterprises can evaluate and select suitable talents through cooperative training channels to reserve human resources for enterprise development. Schools can provide consulting services of technology research and development for enterprises to enhance their independent R&D and innovation capabilities [22].”

After the launch of the Outstanding Engineers Plan, the Chinese academia has actively carried out research and proposed a variety of training models. For example, Lin Jian suggests that the optional models of school-enterprise joint training may include: systematic and comprehensive cooperation model, modular cooperation model, project-based cooperation model, order-based cooperation model, post-employment internship model, study-work alternative model, course replacement cooperation model [23]; Shen Jiajun, Ling Daijian, and Deng Shejun suggest that the optional models of school-enterprise joint training may include: dual-tutor training model, order-based training model, and the integrated industry-academy-research training model [24]; Tan Lu suggests that the optional models of school-enterprise joint training may include: CDIO-based model, order-based model, module-based model, industry-academy-research integrated model, post-employment model [25].

The pilot colleges and universities have attached great importance to and actively carried out school-enterprise cooperation to train Outstanding Engineers. Different types of pilot colleges and universities, on the basis of the original school-enterprise cooperation, have given full play to their advantages, created school-enterprise cooperation models, and carried out in-depth cooperation with various types of enterprises. For example, Shantou University has attracted top international luxury goods companies, such as Italy’s Luxentica Group and Hong Kong VTech Group, to take the initiative to develop school-enterprise joint engineering talent training with them. In the past three years of school-enterprise cooperation, the two parties have jointly designed corporate engineering practices such as corporate cultural experience, theoretical and technological courses, practical training operations, and graduation design aimed at the actual product development of enterprise; conducted ten-month full-time guidance of engineers and school teachers, and graduation design in a real corporate environment, which have been well evaluated by enterprises and students. Students who ever participated in corporate development have grown into the backbone in less than two years.
With the in-depth promotion of the Outstanding Engineers Plan, pilot colleges and universities have explored more school-enterprise joint training models in practice, such as centralized model and decentralized model [26]; project-driven model [27]; tri-dimensional model [28]; strategic alliance-based model; base plus laboratory model [29]; task-oriented model [30]; model based on the CDIO concept [31]; elite class model [32], etc. (as shown in Table 1) Establishing a long-term mechanism of school-enterprise cooperation can not only achieve the deep integration of schools and enterprises, improve the quality of talent training, achieve the complementary advantages of schools and enterprises, but also ensure the smooth implementation of the Outstanding Engineers Plan and serve for the construction of innovative country. There are a variety of school-enterprise joint training models, and the application of each model must be combined with the needs of the school's own development. Schools and enterprises should jointly seek a cooperation model that maximizes the interests of both parties.

Table 1 Selected School-Enterprise Joint Training Models in Practice

<table>
<thead>
<tr>
<th>Title of Model</th>
<th>Connation of Model</th>
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<tbody>
<tr>
<td>Centralized Model and Decentralized Model</td>
<td>The “centralized” model refers to the establishment of national or provincial engineering practice education centers by universities to implement the Outstanding Engineers Plan, and the Ministry of Education’s Administrative Measures for National Engineering Practice Education Centers (Trial) defines the main responsibilities of the national engineering practice education center; “decentralized”, as a supplementary form of “centralized” model, means that colleges and universities make full use of the existing school-enterprise cooperation foundation and various resources, in addition to establishing a “center”.</td>
</tr>
<tr>
<td>Project-Driven Model</td>
<td>This model means that the school-enterprise joint training is not a training model based on the curriculum system, but a training model based on project-based competence training. This is to break the school’s usual curriculum-based training model, but based on enterprise projects, which needs to carry out training, by choosing different projects according to the different levels of ability requirements of the training objectives.</td>
</tr>
<tr>
<td>Tri-Dimensional Model</td>
<td>This model refers to a new type of school-enterprise cooperation training model in the training of outstanding engineers, which involves the enterprises’ entire process, in-depth, and all-round participation. This model is a systematic training model that enables school-enterprise cooperation training to change from the traditional two training subjects to united training subjects.</td>
</tr>
<tr>
<td>Strategic Alliance-Based Model</td>
<td>Relying on the strategic alliance of industrial technology innovation, the colleges and universities work together to solve technical problems in the industry, exchange teaching and scientific personnel, jointly build and share</td>
</tr>
</tbody>
</table>
high-quality resources, and jointly carry out personnel training to form a dynamic and stable school-enterprise relationship.

5.3 Establishment of school-enterprise joint training organizations

The Outstanding Engineers Plan divides the training process of Outstanding Engineers into two phases: on-campus learning and corporate learning. In order to guarantee the completion of the main tasks at the enterprise learning stage at the organizational level, the Ministry of Education encourages the pilot colleges and universities to participate in the establishment of engineering practice education centers in counterpart enterprises. The engineering practice education center is a comprehensive platform for the pilot colleges and universities to closely cooperate with enterprises to cultivate engineering talents. Based on the original off-site practice base, the pilot colleges and universities further strengthen management, expand functions, jointly build a large number of engineering practice education centers with counterpart enterprises to undertake the training tasks of students at the enterprise learning phase, and take full responsibility for students’ study in the enterprises for about a year.

The main task of the center is to organize industry and enterprise experts to participate in the formulation of professional training programs, formulate training goals, build curriculum system and teaching content, especially formulate training programs during the corporate learning phase; implement various teaching arrangements for students during corporate learning; build a team of corporate guidance teachers, organize technical staff and senior management personnel with senior professional titles to serve as part-time teachers in pilot colleges and universities, set up corporate courses, guide students’ internship and training, graduation design; participate in the assessment and evaluation of students, formulate the training standards and assessment requirements at the enterprise learning phase, and evaluate the training quality of students.

Comprehensive pilot universities have given full play to the advantages of complete disciplines and high school running level, so as to establish off-campus bases such as engineering practice education centers. For example, Tsinghua University has leveraged its advantages in the field of engineering education to have a wide range of disciplines, a wide range of specialties and high quality personnel training, jointly established national-level engineering practice education center with 14 units, involving architecture, civil engineering, water conservancy, environment, machinery, precision instruments, thermal energy, industrial engineering, automotive, aerospace, motors, computers, automation, software, etc., almost all engineering colleges and departments. 12 national-level engineering practice education centers led by Tsinghua University have successively signed tripartite co-construction agreements, formulated student training programs at the enterprise learning phase, established organization and management systems, and specified job responsibilities.

Pilot colleges and universities with industry backgrounds have given full play to the advantages of the industry background, so as to establish off-campus bases such as engineering practice education centers. For example, Southwest Jiaotong University has
selected state-owned large and medium-sized enterprises related to rail transit for the pilot specialties of the Outstanding Engineers Plan, and established 18 school-level engineering practice education centers which basically covered all engineering colleges and departments of the university; on this basis, further established 12 national-level engineering practice education centers; meanwhile, established a number of graduate joint training bases with major research institutes and well-known enterprises in the field of rail transit.

As of 2012, 194 pilot colleges and universities of the Outstanding Engineers Plan have established more than 980 school-level engineering education centers in enterprises, in cooperation with leading or large enterprises in various industries. Among them, 654 centers have been selected as the first batch of national-level engineering practice education centers which carry out construction work and are conferred with formal recognition after 1-2 years of construction. In addition to national-level centers, many provincial-level governments represented by Liaoning province have also established a number of provincial-level engineering practice education centers. The Ministry of Education will actively promote some provinces, cities or districts with qualifications to establish engineering practice education centers in succession, gradually build a system of engineering practice education centers at school, provincial and national levels.

5.4 Improvement of school-enterprise joint training teachers

The Outstanding Engineers Plan focuses on the construction of teaching team which consists of professors from colleges and universities, professional tutors and managers from enterprises and research institutions.

For the construction of full-time teachers in the school, pilot colleges and universities of Outstanding Engineers Plan have attached great importance to the improvement of engineering practice ability of full-time teachers, formulated a clear plan for achieving standards, and formulated policies and measures from aspects such as teacher evaluation and assessment, and teacher engineering experience training. For example, Tsinghua University has encouraged colleges and departments to build full-time and part-time teachers of engineering education during the “Twelfth Five-Year Plan” period, strengthened the engineering practice background of teachers, and recruited a group of truly talented people from the industry and enterprises to become full-time teachers in the school [33]. Shanghai Jiao tong University has reformed the teacher evaluation system, adopted related measures on teacher appointment and evaluation, encouraged in-service teachers to go to enterprises to experience engineering practice or advanced studies, understand enterprise needs, and participate in curriculum reform and engineering project development [34].

For the construction of part-time teachers in enterprises, the Outstanding Engineers Plan has focused on building part-time teachers, by encouraging participation of university professors in enterprises, supporting technicians and managers with senior titles to serve as part-time teachers in colleges and universities. From 2013 to 2014, the number of part-time teachers who undertook teaching tasks in pilot colleges and universities reached 17,920, while the
number of teachers who participated in on-the-job learning in enterprises reached 7044 [35](as shown in Table 2). At the same time, pilot colleges and universities have actively introduced teachers with engineering practice experience, actively introduced technical backbones of enterprises, improved the system of teacher training and on-the-job training, and encouraged teachers to undertake actual corporate tasks. The enterprises have actively recommended the backbone of technology and related research institutes to apply for part-time teacher qualification, and undertake the teaching task of corresponding specialties. Pilot colleges and universities have taken effective measures to mobilize the enthusiasm of teachers; carried out the training of teachers, and continuously improved the overall level of teacher team. At present, the national-level engineering practice education centers have already opened corporate teaching courses, and accepted teachers to enter the enterprise for further training.

Table 2 Status of Teachers Participating in the Outstanding Engineers Plan

<table>
<thead>
<tr>
<th>Classification</th>
<th>Amount of corporate teachers undertaking teaching tasks</th>
<th>Amount of courses offered by corporate teachers</th>
<th>Total academic hours of theoretical or practical courses undertaken by corporate teachers</th>
<th>Amount of college teachers sent to enterprises for on-the-job learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colleges and universities directly under the Ministry of Education</td>
<td>7506</td>
<td>2466</td>
<td>111897</td>
<td>2878</td>
</tr>
<tr>
<td>Colleges and universities affiliated to other central departments</td>
<td>955</td>
<td>291</td>
<td>12830</td>
<td>304</td>
</tr>
<tr>
<td>Local colleges</td>
<td>9459</td>
<td>3647</td>
<td>141248</td>
<td>3862</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17920</strong></td>
<td><strong>6404</strong></td>
<td><strong>265974</strong></td>
<td><strong>7044</strong></td>
</tr>
</tbody>
</table>

For example, Harbin Institute of Technology’s corporate tutors have accounted for 126 teaching tasks, participated in 34 courses, taken a total of more than 600 hours of theoretical and practical courses, and undertaken graduation design and internship weeks of more than 270 weeks. A total of 70 young teachers has been sent to the off-site practice bases for short-term studies; more than 150 enterprise experts have been hired to host forums, lectures to train teachers for engineering education [36]. Jiangnan University’s National-level Engineering Practice Education Center has 34 corporate tutors participating in teaching, 17 corporate teaching courses, and a total of 29 teachers attending corporate training [37].

5.5 Achievement of school-enterprise joint training
According to statistics, institutional cooperation links between industry sectors and educational sectors have been gradually established. 21 industry sectors and 7 industry associations have jointly participated in the Outstanding Engineers Plan as of 2014. The situation of enterprises participating in talent training has initially taken shape. More than 6,000 companies have signed contracts with universities to participate in talent training. 980 enterprises and public institutions\(^1\) have jointly applied for establishing national engineering practice education centers with colleges and universities which have participated in the Outstanding Engineers Plan. 626 enterprises and public institutions have been approved as the first batch of construction units for national-level engineering practice education centers, in order to undertake the training task of students at the enterprise learning stage. The situation of gathering resources from all aspects to cultivate talents has initially formed. A total of about RMB 2.2 billion special funds have been invested cumulatively by colleges and universities, and about RMB 420 million have been invested by the contracted enterprises. More than 11,000 part-time teachers have been engaged in teaching tasks. More than 4,400 courses have been developed by corporate teachers, receiving nearly 5,000 on-campus teachers studying in the enterprises [38]. As of 2014, there were 10,145 companies contracted to implement the Outstanding Engineers Plan, including 5,359 large enterprises and 4,379 high-tech enterprises [39](as shown in Table 3).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Amount of Enterprises Contracted to the Outstanding Engineers Plan</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Large Enterprises</td>
</tr>
<tr>
<td>Colleges and universities directly under the Ministry of Education</td>
<td>2411</td>
</tr>
<tr>
<td>Colleges and universities affiliated to other central departments</td>
<td>169</td>
</tr>
<tr>
<td>Local colleges</td>
<td>2779</td>
</tr>
<tr>
<td>Total</td>
<td>5359</td>
</tr>
</tbody>
</table>

6. School-Enterprise Joint Training Issues of the Outstanding Engineers Plan

\(^1\)In Chinese Mainland, *public institutions* refer to social service organizations established by the government using state-owned assets and engaged in education, science, technology, culture, and health.
6.1 Issues of deepening the connotation of school-enterprise joint training

Although pilot colleges and universities as well as Chinese academia have actively explored school-enterprise joint training models, there are currently some misconceptions in the models [40]. The first issue is the simple equivalent of school-enterprise joint training to the order-based training model. Order-based training model appeared as early as the 1990s and has a wide range of coverage in higher vocational colleges. It has played a positive role in improving the employment rate of graduates in vocational colleges and providing the talents required for jobs. Order-based training requires the school’s employment training agreement signed with the employer according to the needs of employer. Students will enter the enterprises providing orders directly after graduation. However, the school-enterprise joint training in the Outstanding Engineers Plan cannot be simply understood as the training of senior technicians in a certain position of the enterprise. If the school-enterprise joint training is simply understood as an order-based training, it will completely depart from the original intention of the Outstanding Engineers Plan [41].

The second issue is the simple understanding of the “3+1” training model of the Outstanding Engineers Plan. Many pilot colleges and universities have proposed the “3+1” training model for undergraduate education, but a few simply believe that the students will study in the school for 3 years, while practice in the enterprise and complete the graduation design in the last year, artificially dividing the theoretical and practical phases. School-enterprise joint training must guarantee the time of practical internships, which doesn’t mean that the Outstanding Engineers Plan condenses 4 years of undergraduate study to 3 years and sends students into the enterprise one year in advance [42]. According to Lin Jian, “segmented implementation” model can achieve better corporate learning results compared with “centralized implementation” model. This is because “from the principles of knowledge learning and mastery, capacity development and improvement, the ‘segmented implementation’ model can better benefit mutual promotion of theory and practice, and gradual improvement of ability and quality [43].”

The third issue is that the content and connotation of school-enterprise joint training need to be further expanded. At the early phase of the Outstanding Engineers Plan, due to the lack of time and awareness, some pilot colleges and universities had expanded the content and connotation of engineering talents through school-enterprise cooperation. For example, in addition to restoring the previously simplified and fancy corporate internships to substantive internships including recognition internships, production internships, graduation internships and other links, corporate engineers have also been invited to make on-site special reports, corporate tutors have been arranged to guide students’ graduation design. However, the connotation of school-enterprise cooperation is much more than that. The place of school-enterprise cooperation cannot be limited to enterprises.

6.2 Issues of creating benefits of school-enterprise joint training

The government, schools, enterprises and students are the participants and stakeholders of school-enterprise cooperation. In the process of in-depth school-enterprise cooperation, the
absence of relevant stakeholders’ functions has affected the Outstanding Engineers Plan to bring greater benefits [44]. The relevant stakeholders participating in the Outstanding Engineers Plan fail to meet the requirements of school-enterprise cooperation in many aspects, affecting the formation of a win-win situation.

The first issue is that the government’s function in advancing the Outstanding Engineers Plan has not been fully realized. The relevant governments of Chinese mainland have not made enough efforts to formulate relevant policies and regulations. They prescribe more standards from the macro perspective and lack targeted guidance by industry and enterprises. The provincial governments have made less effort in supervision and evaluation. As a result, the ability to adjust relevant policies and regulations on the basis of summing up experience is weak, and the pushing power of further deepening school-enterprise cooperation is insufficient. The governments’ funding investment is insufficient. The preferential and compensatory measures for participating enterprises are relatively insufficient, which has affected the enthusiasm of enterprises for deeply participating in talent training.

The second issue is that the guarantee measures of schools in the process of the Outstanding Engineers Plan are insufficient. The funding for school-enterprise cooperation is insufficient, which makes many projects difficult to implement. The school tutors and corporate tutors have less communication with each other, and mainly communicate through the participating students, which is not conducive to the deep and efficient promotion of cooperation. At the same time, some colleges and universities lack corresponding supporting management mechanisms, which cause the low enthusiasm of related teachers, and the low tacit understanding with the enterprise, ultimately affecting the teaching quality.

The third issue is that the enthusiasm of enterprises participating in school-enterprise cooperation is not high. On the one hand, it is due to the low level of enterprises development: the development of small enterprises is highly dependent on the market instead of human capital; and the level of competitiveness has not risen to the competition of talents, therefore, the small demand for high-level talents has caused insufficient motivation to participate in the Outstanding Engineers Plan. On the other hand, some enterprises pay more attention to their own economic benefits, rather than strictly implement the responsibility of enterprises in accordance with mutual agreements.

The fourth issue is that there are deviations between students and enterprises in meeting each other’s needs. Due to the for-profit nature, enterprises pay more attention to the benefits brought by students in the Outstanding Engineers Plan, while the students are not yet capable of creating more capital for the enterprises. Therefore, the energy and financial resources invested by enterprises in training students are not high, and the training content is broad and shallow. Some students are often unable to improve their theoretical knowledge and practical ability as expected at the enterprise learning phase.

6.3 The issues of sustainable development of school-enterprise joint training
The first issue is that some pilot colleges and universities have been encountered difficulties in finding suitable cooperative enterprises, establishing long-term and stable cooperative relationships. Although the pilot colleges and universities have made encouraging progress in school-enterprise cooperation, it is found that many pilot colleges and universities rely on individual elements such as alumni relations, teacher-student relations, and leadership exchanges. Personnel changes in these relations can easily affect school-enterprise cooperation.

The second issue is that new school-enterprise cooperation models still need to be explored. At present, there are various models of school-enterprise cooperation. Among them, it is recommended that such models as pre-employment model is adopted considering the enterprise’s need for engineering talents. This model is not only related to the direct interests of the enterprise, can improve the enterprise’s enthusiasm for school-enterprise cooperation, but also undoubtedly very important to improve the quality of Outstanding Engineers Plan. However, for other students who are not ready to be pre-employed in enterprises, more types of effective school-enterprise cooperation models should be explored [45].

The third issue is that the degree of school-enterprise joint training is insufficient. Research has reviewed the Outstanding Engineers Plan after the first cycle of implementation, and found that the low degree of school-enterprise cooperation can be regarded as the most prominent issue in the first implementation cycle of the Outstanding Engineers Plan [46].

7. Suggestions for School-Enterprise Joint Training of the Outstanding Engineers Plan

7.1 Adhering to the principle of “complementary advantages, mutual benefit and win-win”

In response to the issue of deepening the connotation of school-enterprise joint training, it is recommended that schools and enterprises adhere to the core principle of “complementary advantages, mutual benefit and win-win” [47]. School-enterprise joint training is first and foremost a two-way selection process. Schools and enterprises must do well in solving common points of interest trends, finding mutual cooperation bonds, and establishing diverse cooperation platforms.

There is a potential cooperative relationship of “mutual benefit and win-win” between schools and enterprises. Colleges and universities should use all social resources to actively recommend themselves to enterprises and seek partner enterprises based on their own school positioning and characteristics, professional advantages in disciplines, scientific research and technical capabilities and service levels; consciously choose those enterprises with advanced ideas, superior conditions, mature corporate culture and common values, in accordance with the talent training standards of the Outstanding Engineers Plan and their own requirements in teaching and scientific research; set up a database of enterprises, carry out dynamic management, and be able to use various channels to establish a wide network of industries and enterprises.

The two-way choice between schools and enterprises requires in-depth exchanges and
communication, and clear necessary information related to cooperation, including why cooperation, what are the starting points and goals of cooperation, what are their advantages and disadvantages, and how to carry out in-depth cooperation, its operating conditions and external conditions support. On this basis, schools and enterprises sign a school-enterprise joint training agreement based on the principle of “complementary advantages, mutual benefit and win-win”; formulate the rights and obligations of both parties under the premise of promoting the common development of schools and enterprises, in order to establish new mechanisms of enterprises’ participating in the Outstanding Engineers Plan.

7.2 Strengthening the macro-level guidance of governments and the support from all stakeholders

In response to the issue of creating effectiveness of school-enterprise joint training, it is recommended that the Ministry of Education cooperate with relevant industry authorities to introduce supporting policies to fully mobilize the enthusiasm and initiative of enterprises to participate in the Outstanding Engineers Plan [48]. The Ministry of Education should strengthen communication and coordination with industry organizations, and give more active policy assistance through hiring outsiders of the school to take part-time jobs, and promoting teachers’ internships in related enterprises. The government should make cooperative education a corporate obligation and social responsibility through policies and regulations, and formulate preferential and compensation incentives, such as tax reductions, priority support, promotion of professional titles, and teaching subsidies.

For pilot colleges and universities participating in the Outstanding Engineers Plan, the government should encourage them to implement school-enterprise cooperation through formulating special funding policies, establishing cost-sharing mechanisms, establishing school-enterprise cooperation projects, and selecting enterprises to establish practice education bases, and assist colleges and universities to establish off-campus practice bases. Governments, schools and enterprises at all levels should provide support in various aspects including organizational guarantee, system guarantee, policy incentives, funding guarantee, base construction and operation management.

Enterprises should ensure the implementation of the Outstanding Engineers Plan at the enterprise learning phase, formulate a corporate training plan in a modularized manner according to the target function, ensure the strengthening of organizational leadership, the formulation of rules and regulations, the provision of guidance teachers, the implementation of teaching arrangements, and the provision of living conditions during the implementation of the plan. Colleges and universities should attach importance to the construction of bases starting from ideological understanding, functional positioning, institutional setting, service orientation, interdisciplinary, team building, hardware construction, operation management and management systems, etc., so that engineering practice education centers and engineering training centers become a unified body with complementary and coexisting resources.

7.3 Establishing sustainable development school-enterprise joint training mechanisms
In response to the issue of sustainable development of school-enterprise joint training, it is recommended that schools and enterprises establish a virtuous and circular mechanism of sustainable development of school-enterprise joint training [49]. First, it requires establishing an interest-driven mechanism based on the inherent needs of enterprises. Colleges and universities should focus on how to meet the needs of enterprises, explore and use school resources, and truly help enterprises solve the difficulties in production, operation and R & D. Only by continuously entering the enterprises and gradually establishing a profit-driven mechanism based on meeting the internal needs of enterprise can we lay a solid foundation for the school-enterprise joint training.

Secondly, it requires establishing a guarantee mechanism based on the schools-enterprise joint training. The guarantee mechanisms mainly includes funding guarantee, policy incentive and assessment mechanisms. For the funding guarantee mechanism, colleges and universities should establish special funds for school-enterprise cooperation, and guarantee the development of school-enterprise cooperation activities, the construction of talent training bases in accordance with the talent training programs of the Outstanding Engineers Plan. In order to ensure that the special funds can be implemented, it is necessary to carry out a scientific analysis of the composition of the school-enterprise joint training funds, decompose and set out detailed calculation instructions for the expenditure items, budget amounts, and funding guarantees.

For the policy incentive mechanism, colleges and universities should prioritize teachers with corporate engineering experience, teaching responsibility, and high teaching standards to assume teaching tasks of the Outstanding Engineers Class, introduce a series of policies to encourage teachers to engage in various teaching activities such as curriculum integration, teaching and research reform, acquisition of corporate engineering experience, and strengthening of the guidance at the corporate learning phase; students who enter the Outstanding Engineers Class can enjoy various preferential policies given by the school.

For the assessment mechanism, in order to strengthen the assessment, evaluation and feedback of school-enterprise joint training, a monitoring system including time course, teaching task progress and quality feedback should be established according to the implementation of professional characteristics and training programs. The process management and real-time monitoring should be strengthened through student symposiums, questionnaires surveys, on-site inspections of enterprises, inspection of homework design, communication with corporate tutors, and corporate feedback, etc.

Thirdly, it requires establishing a communication mechanism based on the integration of school-enterprise culture. The integration of school-enterprise culture is a lubricant for sustainable development of school-enterprise cooperation. The in-depth school-enterprise cooperation requires a communication mechanism based on the integration of school-enterprise culture, because there are some differences in the school-enterprise cultural background and values. It is necessary to establish organization that promotes long-term win-win cooperation between the two parties, which mainly serves as a bridge to
communicate information, coordinate relationships, and urge inspections. Colleges and universities should consider the enterprises as their own customers, visit each enterprise as much as possible, and establish various connections with the enterprises through various channels such as alumni. The exchange and integration of campus culture and corporate culture should be strengthened to promote mutual communication and understanding, promote the win-win situation between schools and enterprises, absorb each other’s advantages and strengths in school-enterprise cooperation, and especially form common values in the Outstanding Engineers Plan.

8. Conclusions and limitations

8.1 Research conclusions

First, at the initial phase of the implementation of the Outstanding Engineers Plan, some pilot colleges and universities have begun to practice and explore, gradually shifting from the paradigm of closed campus training to the paradigm of open school-enterprise joint training. With the in-depth advancement of the Outstanding Engineers Plan, significant progresses have been made in establishing school-enterprise joint training mechanisms, reforming school-enterprise joint training models, establishing school-enterprise joint training organizations, and improving school-enterprise joint training teachers. The pilot colleges and universities mainly rely on the organizational and operational mechanisms to establish school-enterprise joint training mechanisms; explored many school-enterprise joint training models in practice. Different types of pilot colleges and universities have their respective advantages based on the engineering practice education center, focusing on establish a team of teachers composed of teachers from colleges and universities, professional and technical personnel and managers from enterprises and research institutions.

Secondly, at present, there are some misunderstandings in the school-enterprise joint training models, for example, the school-enterprise joint training of the Outstanding Engineers Plan is a simple equivalent to the order-based training; the contents and connotations of school-enterprise joint training need to be further expanded; the government, schools, enterprises and students are the participants and stakeholders in the school-enterprise cooperation, the absence of relevant stakeholders’ functions has affected the Outstanding Engineers Plan to bring greater benefits; the school-enterprise joint training faces sustainable development issues such as lack of stability in cooperative relationships, single joint training model, and insufficient degree of joint training.

Thirdly, in response to the issue of deepening the connotation of school-enterprise joint training, it is recommended that schools and enterprises adhere to the core principle of “complementary advantages, mutual benefit and win-win”; in response to the issue of creating effectiveness of school-enterprise joint training, it is recommended to strengthen macro-level guidance from governments and support from all stakeholders; in response to the issue of sustainable development of school-enterprise joint training, it is recommended that schools and enterprises establish a virtuous and circular mechanism of sustainable development of school-enterprise joint training.
8.2 Research limitations

The limitations of this research are reflected in the following aspects. First, some questions may not be thorough enough during the interview process because the interviewees don’t provide comprehensive materials due to the consideration of college management restrictions. Secondly, the implementation period of the Outstanding Engineers Plan is relatively long, the data obtained based on the research literature, pilot college and university cases and interviews may not fully reflect the overall progress of the Outstanding Engineers Plan. Thirdly, this research lacks the research on the effectiveness of school-enterprise joint training, simply because the effectiveness of the pilot specialties of the Outstanding Engineers Plan still needs sufficient evidence and a long period of investigation and research.

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