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Exploration and Practice of the Integration of Industry and Education in High-Level Research Universities and Local Application-Oriented Universities in China

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Abstract. Facing the rapid process of technological revolution and industrial transformation, higher engineering education urgently needs to cultivate excellent engineering and technical talents. The integration of industry and education is one of the effective ways of talent cultivation. Many high-level research universities and local application-oriented universities have adopted this approach according to their positioning and subject characteristics. The two types of universities mainly explore and practice the industry-education integration mode of engineering education through their directly related enterprises (such as China Pingmei Shenma Group, Hualan Biological Engineering Co. Ltd., etc.). They adopt "multi-path" school-enterprise collaborative training models such as project-based on-the-job internships, collective internships, and the joint construction of training bases and R&D centers. The validity of the model has been confirmed by follow-up investigations. According to their positioning and talent training goals, universities have built a model of industry-education integration and school-enterprise collaborative education that suits their own characteristics, effectively and comprehensively improving the quality of talent training by cultivating outstanding engineering and technical talents with strong engineering practice and innovation ability. They are expected to meet the needs of enterprises at different levels. This study provides empirical evidence for talent cultivation models that adapt to technological progress and industrial development in China and beyond.

Keywords: Engineering education · outstanding engineers · industry-education integration · school-enterprise collaboration · education mode

1 Introduction

The new technological revolution and industrial transformation are advancing by leaps and bounds. As the breadth, depth, speed, and precision of scientific and technological innovation have improved significantly, the means to solving major global problems

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through scientific and technological innovation are explored to meet the challenges of the times [1, 2]. This has brought severe challenges to engineering education, and higher engineering education urgently needs to cultivate outstanding engineering and scientific talents to solve worldwide problems. With the increasing number of global challenges, engineering talents should not only possess strong engineering ability, innovation ability, and the ability to solve complex engineering problems, but also possess qualities such as entrepreneurial spirit and professional sensitivity, such as mastering skilled technologies and extensive knowledge. All these require university students to establish lifelong learning and thinking abilities. Therefore, the focus of engineering education is not on the improvement of teaching content, but on building a new talent training model that matches the contemporary learning environment, and enhancing students' ability to discover problems, build problem frames, and formulate effective solutions, so as to realize the role change from the receiver of knowledge to the producer of new knowledge [3].

Therefore, in response to the ever-changing talent needs of the international scientific and technological revolution, China's implementation of the "Education and Training Plan for Distinguished Engineers" is a major measure to promote transformation in engineering education from a major country to a strong country. The aim is to cultivate a large number of high-quality engineering and technical talents with strong innovation capabilities, adapt to the needs of economic and social development, take a new path of industrialization [4], and serve the national strategies of building an innovative country and strengthening the country with talents. According to the training objectives of the excellent engineer program [5], to promote the research, practice, and reform of engineering education, many colleges and universities have worked to establish an industry-education integration [6] and school-enterprise collaborative education mechanism[7, 8] based on the requirements of cultivating innovative, application-oriented, and compound talents and guided by industrial demand.

Beijing Institute of Technology (BIT) is a high-level research university focusing on polymer materials, while Henan Institute of Science and Technology (HIST) is an ordinary local application-oriented university targeting bioengineering. Both universities have tried to adopt the talent cultivation mode of industry-education integration and achieved practical results over the years. Based on practice, the implementation effect of the industry-education integration education mode for engineering talent cultivation in this project is analyzed, providing examples for exploring engineering talent training models for global high-quality development.

2 Exploration of Industry-Education Integration Mode

The background of the new era and the social environment call for outstanding engineering talents with strong comprehensive quality. They can not only have a high level of professional and theoretical knowledge and practical skills, but also can effectively deal with various problems in learning and practice, and have certain professional ethics.

The macromolecular material major of BIT adheres to whole-chain education, which breaks the traditional barriers between theoretical teaching and practical teaching. It explores a talent training model aimed at improving students' engineering practice ability, a means of school-enterprise collaborative education, and a blueprint for composite engineering talent training. This model cultivates outstanding talents engaged in cutting-edge theoretical research, technology research and development, and technology management in the field of polymer materials and engineering.

The bioengineering major of HIST closely combines the needs of enterprises, markets, and society, increases cooperation with enterprises in teaching, and explores a school-enterprise collaborative education model with local characteristics. This model cultivates outstanding senior engineering talents in bioengineering with strong practicability, innovative awareness, innovation ability, international vision, and strong development potential.

2.1 Optimization of Professional Training Model

The macromolecular material major of BIT explores the multi-path talent training model of "general education + general specialty foundation + specialty + X." Through the implementation of the project-driven undergraduate tutorial system, a gradual training system of "knowledge-based, academic-oriented, practice-driven, and entrepreneurship and innovation leading" is built. A talent training model of "value shaping, knowledge cultivation, and practical ability" is established. It cultivates students' mass entrepreneurship and innovation character of scientific exploration, critical innovation, and pursuit of excellence, unity, and cooperation. According to the characteristics of polymer materials professional courses and the needs of students' training objectives, talent training is more industry-oriented and application-oriented, and research direction is more interdisciplinary, so as to promote the close integration of teaching and research content to meet the needs of enterprises.

From the beginning of enrollment, undergraduates continue to carry out practical teaching, such as experiential teaching, study visits, production practice, and project cooperation. Students are cultivated from "learning knowledge to creating knowledge," "technology frontier to the front line of production," from "finding problems to solving problems," and "campus learning to lifelong learning," and realize the seamless connection of "university talent training to high-end industry talent." The trinity talent training model cultivates "innovative, skilled and complex" excellent engineering talents that adapt to global scientific and technological progress and industrial development.

Taking advantage of local characteristics, HIST explores the talent cultivation mode of "general education + discipline foundation + professional education + practical education" according to the requirements for training outstanding engineering talents. This model allows students to master the basic theory, professional knowledge and skills of bioengineering, foster certain scientific thinking and practical innovation ability, and cultivate the basic ability to manufacture, develop and solve problems related to bioengineering products to realize the comprehensive and coordinated development of knowledge, ability and quality.

2.2 Design of School-Enterprise Collaborative Education Mode

The focus of the industry-education integration is to educate students through school-enterprises cooperation. According to the needs of both schools and enterprises, they jointly participate in talent training, mainly including the joint development of cooperative research and development projects and internship programs, joint guidance of the internship process, and joint evaluation of student internships. Currently, the "multi-path" education mode of school-enterprise collaborative education is mainly based on project-based, replacement-job internship, collective production practice, etc.

In the project-based collaborative education model, students participate in the mentor's industry-university-research cooperation project on the one hand. Students participate in design or engineering practice and under the guidance of their mentors. On the other hand, students' innovation and entrepreneurship practice can be combined with the needs of enterprises. Students take part in the research of the school in their spare time. They go to cooperative enterprises to carry out production practices irregularly during holidays and participate in technological innovation and engineering research and development of enterprises. They bring problems to the production enterprises to seek solutions and combine the actual production of enterprises to complete the project content.

The replacement-job internship is to select some excellent undergraduates from senior students to practice in cooperative enterprises for 6–12 months. They participate in the whole enterprise production process and learn enterprise culture, product design, production equipment, production process, and enterprise operation management.

In the collective production practice mode, students are organized and assigned by the university to different enterprises for 1–2 months of production practice. The school instructors lead the students to the enterprise, and the enterprise sends engineering and technical personnel to provide training and practice guidance for those undergraduates. This allows the students to experience the production process and operation of the enterprise and understand the entire life cycle process of enterprise product design, manufacturing, assembly, use, and maintenance.

These different forms of practice activities are carried out on the basis of maintaining the systematic and rigorous learning of subject knowledge and truly realize the combination of theory and practice. Through different enterprise production practice models, university students are cultivated to have a broad academic foundation, a strong sense of social responsibility, outstanding practical innovation ability, positive team spirit, as well as knowledge application, technical innovation, project management and professional ethics.

2.3 Build a Production-Education Integration Base

The two surveyed universities deepened their ties with related enterprises and cooperated with state-owned enterprises, industry leaders, and local characteristic enterprises to jointly build school-enterprise collaborative education demonstration bases and R&D centers and carry out talent training through industry-university-research cooperation projects. Every year, the enterprise accepts university students and graduate students for different forms of production practice (Fig. 1). Through the functions of the teaching base and R&D center, students can experience and learn first-class technologies and operating skills, which can not only improve their practical ability through engineering practice, but also ensure the development direction of their practical application. The ability matches the needs of enterprises so that the cultivated talents can fill the talent gap of enterprises and lead the development of the industry. The technical problems encountered by relevant enterprises in production can be entrusted to universities to solve, forming a

Fig. 1. Student production practice base on-site production follow-up

benign contact and communication channel. School-enterprise cooperation can jointly promote technological innovation and progress. At the same time, enterprises can also obtain a high-quality young labor force from it, expand their influence, and absorb excellent talents who meet the company's requirements during this period to achieve a win-win goal.

3 Implementation Effect

Since the macromolecular material major of BIT launched the industry-education integration and school-enterprise collaborative education, the university has successively established several joint training bases and R&D centers in cooperation with central enterprises, leading enterprises in science and technology, key private enterprises, and local governments such as China Pingmei Shenma Group, Kailong Chemical Co., Ltd., and Huasong Beili Intelligent Technology Co., Ltd. Teaching of professional courses, visiting study, production practice, and project cooperation are carried out in these centers.

The operation and practice results of the "multi-path" school-enterprise collaborative training mode (including project-based undergraduate tutors, post-placement practice, and group practice) prove that the trained undergraduates have been comprehensively improved in terms of knowledge acquisition, ability improvement, and professional quality-building, especially in terms of engineering and technical ability improvement and professional quality building. The ability to cope with the development and changes of international science and technology has also been trained.

Joint training practice bases and R&D centers have been established between HIST and national high-tech enterprises and large private enterprises, such as Hualan Biological Engineering, Inc., Budweiser Beer, and Xinxiang Tuoxin Pharmaceutical Co., Ltd. These centers provide undergraduates with production practice and an understanding of the industrial development paths and places. The school-enterprise collaborative education mode, with "replacement-job internship and collective production practice" as the focus, cultivates students' ability to combine theory with industrial production practice and adapt to society, so that students can acquire good engineering practice ability, organization and management ability, as well as communication and team cooperation ability.

A questionnaire was designed according to the basic quality requirements of employers' needs for engineering talents for material specialty and the evaluation standards for

Table 1. Design of the questionnaire

Items	Content	Options			
Student information	In school or graduated	In grade four at the university		Graduated	
	University	Beijing Institute of Technology		Henan Institute of Science and Technology	
	Major	Macromolecular materials specialty		Bioengineering	
	Practical learning form	Research project	Replacement-job internship	Collective production practices	
Post-graduation careers	Government department	Go to graduate school	State-owned enterprise	Private enterprise	
Knowledge acquisition and skill mastery	Interdisciplinary knowledge learning	Poor	General	Satisfied	Very satisfied
	Acquisition of cutting-edge knowledge				
	Mastery of cutting-edge technology				
	Industry recognition				
	Understanding of enterprise operation mode				
Engineering capacity improvement	Apply knowledge and technical ability	No exercise	Get exercise	Improved	Great improvement
	Technological innovation capability				
	Ability to find problems				
	Problem-solving ability				
	Ability to handle complex problems				
Professional ethics cultivation	Social responsibility	Not strong	General	Increased	Very strong
	Sense of mission				
	Entrepreneurship				
	Innovation and entrepreneurship				
	Team spirit				

engineering students proposed by the research unit. A questionnaire survey was conducted on students' professional qualities from three dimensions, i.e., "cognitive learning of subject knowledge and professional skills," "knowledge application, technical innovation, engineering design and production operation," and "entrepreneurship, professional ethics, and team spirit" (see Table 1). The effectiveness of the industry-education integration and school-enterprise collaborative education model was examined. The survey objects were senior undergraduates and graduates majoring in macromolecular material.

A total of 600 questionnaires were distributed, and 586 valid questionnaires were returned (including 352 graduates and 234 seniors). There are certain differences in the employment directions of graduates from the two universities (Fig. 2). In total, 70% of

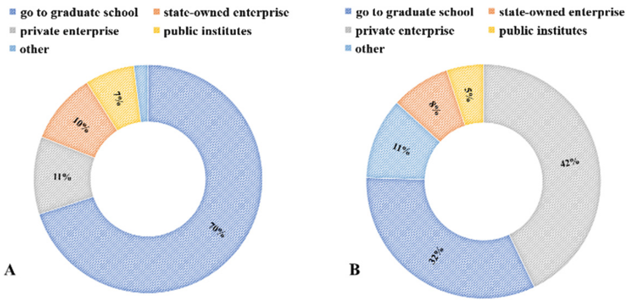

Fig. 2. The student percentage of graduates' employment destination. Note: A represents the macromolecular material major of BIT, and B represents the bioengineering major of HIST.

the students majoring in macromolecular material were admitted to graduate schools; 21% of the students went to state-owned enterprises or large private enterprises; 7% of the students went to the government or public institutions for employment. By contrast, 32% of bioengineering graduates passed the master's degree, 52% entered private enterprises, and 11% had flexible employment.

These results show that due to the difference in training directions, in high-level research universities, most of the trained students hope to make greater contributions after further studies, and the rest are almost all trained by state-owned enterprises and large private enterprises as high-end backbone engineering talents. After graduation, the students trained by local application-oriented universities mainly serve the local economic development, which meets the goal of their universities.

3.1 Increasing Innovation and Entrepreneurship Awareness with the Production-Education Integration Model

The demand for engineering innovation of enterprises facing global challenges is reflected in the two major ability requirements for engineers: cutting-edge insight and technology development, and creative thinking and original innovation. The results of whether to participate in different forms of enterprise practice show that 98% of the students participated in enterprise production practice. There were 427 students who had participated in the tutorial research project, accounting for 73% of the subjects (including about 30% who needed to study in enterprises). There were 132 students who participated in enterprise internships, accounting for 23%. 98% of the students participated in collaborative practice activities.

The survey found that students are highly motivated to participate in innovation and entrepreneurship competitions. An average of 41% of the students participated in innovation and entrepreneurship competitions, 36% had participated in the tutor research project, 35% had participated in the internship, and less than 20% had only participated in the collective production practices internship. These results show that students who participated in in-depth research projects have a strong sense of innovation, entrepreneurship, and enthusiasm to participate in various competitions.

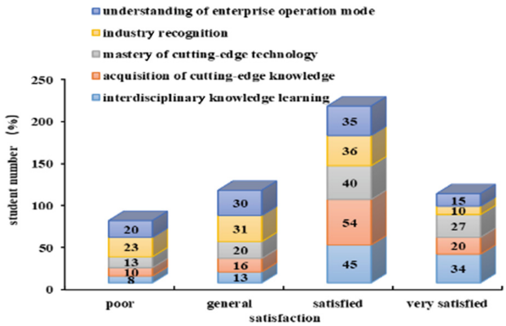

Fig. 3. Results of students' satisfaction with knowledge acquisition and skill training.

3.2 Improving Students' Initiative to Acquire Knowledge and Skills with the Production-Education Integration Model

Under the uncertainty of industrial development, there is no experience in technology as a reference. This requires engineering talents to have strong self-motivation, continuous learning, innovation, and growth, the courage to challenge, to try and to make mistakes, the ability to quickly adapt to changing environments, and maintain a solid theoretical foundation for coping with technological changes.

This study investigates students' knowledge acquisition and skill mastery abilities. The results are shown in Fig. 3. Through participating in scientific research projects and enterprise practice, more than 90% of the students are satisfied with the acquisition of interdisciplinary and cutting-edge knowledge, and more than 89% are satisfied with the mastery of front-end technology. Especially the students involved in project research and enterprise practice are more aware of the importance of expanding knowledge. The school-enterprise collaborative model cultivated their awareness and ability to acquire knowledge and skills more actively. The number of students who are satisfied with the understanding of the industry and the enterprise production mode reaches 74%, indicating that the school-enterprise collaborative education has expanded the students' awareness of the industry, production enterprises, and their operation and management models to varying degrees.

3.3 Improving Students' Comprehensive Ability of Engineering Management with the Production-Education Integration Model

Engineers with cross-border integration capabilities are the most valued and needed by enterprises [9]. Enterprises pay more attention to the improvement of comprehensive engineering management capabilities (i.e., the overall understanding of the industry and application scenarios, the application skills of the learned professional knowledge, the ability of technological innovation and cross-border integration to solve complex problems), and other comprehensive engineering management capabilities. Figure 4 shows the survey results of students' satisfaction with knowledge and technology application, technological innovation, problem discovery, problem-solving, and complex problem-solving.

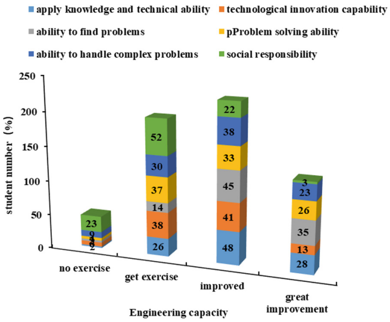

Fig. 4. Results of students' satisfaction with engineering ability improvement.

It can be seen from Fig. 4 that the ability of most students to find and solve problems has been greatly improved, especially the ability to solve complex problems has been greatly improved, and the satisfaction rate has reached 91%. A small number of students have also cultivated their industry-leading ability; however, only 3% have improved their industry-leading ability, indicating that Chinese enterprises have not paid enough attention to the transformation from technology catch-up to innovation-leading, and students have not received enough training in the process of production practice.

3.4 Improving Students' Professional Ethics with the Production-Education Integration Model

The integration of production and education and the school-enterprise collaborative education model provide students with opportunities to participate in project research and production practice, increase students' love for their majors, and make students feel the challenge and importance of solving practical problems. The practice on the production lines enables students to have a deeper understanding of the latest advanced technology and management and operation mode of modern industry, improve students' scientific exploration ability, and understand the development trend of the industry. 76% of the students enhanced their sense of social responsibility and mission (Fig. 5). 58% of the students strengthened their entrepreneurial spirit and realized that to become a high-end engineering and technical talent, they must not only understand technology, but also be able to manage. 78% of the students strengthened innovation and entrepreneurship. In the process of project research and production practice, students need to communicate and cooperate with teachers, classmates, enterprise technicians, and managers [10]. 87% of the students think their openness, cooperation, and communication skills have improved greatly. The above results show that the school-enterprise cooperation model has improved students' professional ethics at multiple levels and in an all-around way.

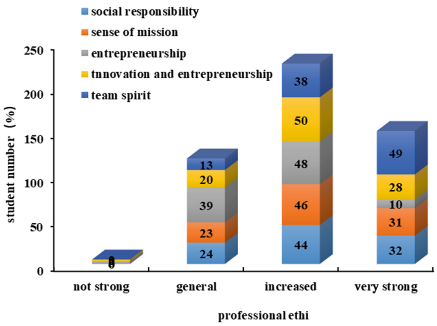

Fig. 5. Results of satisfaction with professional quality shaping

4 Conclusion

Driven by the scientific and technological revolution and industrial transformation, engineering education is gradually entering the stage of comprehensive innovation. Cultivating outstanding innovative talents who can face future challenges is the focus of engineering education. Both BIT and HIST have paid attention to close cooperation with key industrial enterprises and deepened the long-term mechanism of industry-education integration base construction and joint training. They focus on cultivating high-quality engineering talents with outstanding technological innovation capabilities and good at solving complex engineering problems.

According to their respective professional positioning and advantages, the two universities explored “different paths” of professional talent training models of “project-based, post-placement practice and collective practice” that suit their respective majors. It has enhanced the attractiveness and enthusiasm of enterprises to participate in school engineering education, effectively promoted the close integration of talent cultivation and industry, achieved good implementation results, and provided an empirical basis for promoting the excellent engineering talent cultivation model to adapt to global technological challenges.

Although the implementation of the above-mentioned industry-education integration and school-enterprise collaborative education model has achieved good results, this research uses the method of student self-evaluation, and there may be a gap between their subjective feelings and the real situation. Therefore, the scientificity and rigor of engineering talent training quality evaluation must be improved. Furthermore, how the school-enterprise collaborative education model of industry-education integration can exert a more profound effect requires in-depth thinking and research.

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