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Research on the Training Program Design of Interdisciplinary Engineering Talents Based on Outcome Based Education

-Take intelligent manufacturing system engineering major as an example

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***Abstract*—To meet the requirements of interdisciplinary and compound talents from the new industrial revolution, China's higher engineering education is reforming towards new model. Taking the new major named "intelligent manufacturing system engineering" as an example, basing on outcome-based education model, using "T" type, "project-based learning" methods, this paper tries to explore the design and realization of training program and curriculum system.**

Keywords—New engineering; OBE; "T" type; PBL; intelligent manufacturing

I. THE TRADITIONAL ENGINEERING EDUCATION MODEL IS CHALLENGED UNDER THE NEW ENGINEERING BACKGROUND

The quality of talent training is directly related to the improvement of the country's core competitiveness and the realization of strategic goals, which is highly valued by all countries. In 2007, the World Bank pointed out in the annualreport of *Building Knowledge Economy* that the education system has become the most critical long-term influencing factor in social development that is increasingly focused on competition and innovation [1]. In response to the new industrial revolution marked by high digitization, networking and self-organization of machines in Production. Major developed countries around the world are actively exploring new engineering education models. Focusing on interdisciplinary, teamwork and other comprehensive capabilities, focusing on creativity and international perspective and emphasizing that return to engineering practice are the common directions of engineering education reform in the United States, the European Union, Japan, South Korea and any other countries and regions [2].

China's higher engineering education is still subject-oriented. The cultivated graduates have poor practical ability, innovative ability and team ability. High-skilled compound talents and innovative export-oriented talents are seriously lacking. On February 18, 2017, the Chinese Ministry of Education and related universities reached the “Fudan Consensus” to accelerate the construction and development of new engineering. Accelerate the construction and development of new engineering. Compared with the traditional engineering education, the new engineering construction pays more attention to inter-industry docking, cross-disciplinary, the construction of innovation and entrepreneurship education system, taking students as the center, global vision, and the feelings of home-country [3]. These concepts are in line with the development trend of international engineering education. However, how to use this concept to guide the determination of a specific professional training goal, the design of the curriculum system, curriculum content and the choice of teaching methods need further exploration.

With the extensive application of modern information technologies such as mobile Internet, Internet of Things, big data and cloud computing, traditional manufacturing industries are gradually moving towards smart manufacturing. And this will be at the core of manufacturing strategy upgrades in countries such as China, the United States, Germany and any other countries. To this end, this paper is based on the undergraduate major of “Intelligent Manufacturing System Engineering” proposed by Tongji University to explore the realization of the new engineering construction concept at the level of professional training programs.

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II. ESTABLISH THE MAIN PRINCIPLES OF THE TRAINING PROGRAM

A. Focus on the Ability and Outcome of Students

We are in a "flowing modern society" where information and knowledge are ubiquitous and rapid changed [4]. So both educators and educated people will face enormous challenges. In its report *The Future of Work: Employment, Skills, and Workforce Strategies for the Fourth Industrial Revolution*, the World Economic Forum pointed out in 2016 that 50% of the knowledge acquired by college freshmen was outdated when they graduated [5] .

In 2004, the Engineering Education Committee of the National Academy of Engineering (NAE) released the research report of *engineer 2020: Engineering Vision for the New Century* which predicted the 10 capabilities that engineering graduates should have in the future: strong analytical ability, ability to find problems and solve problems, creativity, good communication skills, mastery of business management principles, leadership principles, high humanistic quality, strong professionalism, rapid resilience and learning ability, awareness of lifelong learning [6]. Judging from the degree of relevance to the profession, 9 of the above 10 abilities do not involve specific professional knowledge and skills, and belong to the interdisciplinary category of comprehensive ability.

In 2014, The American Society of Mechanical Engineers (ASME) and the German Society of Mechanical Engineers (VDI) conducted a joint study [7], which is about the impact of future manufacturing development on factory employees, arguing that from a technical perspective, IT, information and data processing analysis, awareness of organization and process, human-computer interaction are most necessary in the future. From the point of view of the individual's literacy, it will be more important to be “communicative” rather than “specialized”. That is to say, social ability, teamwork, ability to adapt to change and self-management are more important. With the sense of continuous improvement and life-long learning will help them develop better.

It can be seen that training modernized composite talents who have a wide range of knowledge, high degree of blending of knowledge, wide thinking radiation, strong social adaptability, mastery of the basic knowledge of two or more majors or subject areas and ability of scientific analysis, insight and business management capabilities has become an important content and direction for the higher engineering education in the future.

B. Focus on Interdisciplinary Training

For the manufacturing industry, as the digitalization process continues to deepen, the comprehensive positions of skills related to intelligent manufacturing, information technology, data analysis, and system integration will usher in greater demand. Especially for smart manufacturing is important. Because production technology of smart manufacturing presents cooperative features, the smooth implementation of products and production processes requires complex and efficient coordination between various mechanical, hydraulic, electronic and software components. Therefore, the industry needs more “system architects and system engineers” with comprehensive management capabilities such as broad-based and complex knowledge structure, and overall ability, creativity and sustainable learning ability. Such talents need to be trained on an interdisciplinary platform. The current education model is formulated to cope with the gradual refinement of the social division of labor in the industrial era. It is still a training model that is divided into disciplines and sub-specialties, which can no longer meet the needs of social development.

In his famous book *The Third Industrial Revolution*, American scholar Jeremy Rifkin put forward the idea of setting up a "decentralized cooperative classroom" for "flattening" teaching. Training in a large class of disciplines, designing a modular curriculum system, and implementing a cross-disciplinary teaching model will be an important way to train interdisciplinary talents in the new industrial revolution era. In the *National Medium- and Long-Term Plan for Science and Technology Development* (2006-2020), emphasis is also placed on “strengthening basic science and cutting-edge technology research, especially interdisciplinary research.”

C. Focus on Engineering Practice and Innovation

Engineering is a system with a holistic nature. Re-emphasizing the emphasis on practicality is the general development trend of international higher engineering education. In recent years, theoretical research on engineering education has found that arrangements outside the classroom and outside the curriculum are helpful for the development of personality development, social skills and social participation awareness of undergraduate. “Engineering 2020” program of The US also places great emphasis on the importance of extracurricular activities. Although such projects or practical activities occur outside the classes or outside the school in time or form and they are independent of the formal school curriculum, they are intrinsically linked to the teaching system and training program. The students trained in engineering education in Germany have strong practical ability, which has proved to be an important factor for the continued strong growth of manufacturing industry of German. Because one of an important feature is that Germany's engineering education has a long-standing tradition of cooperation with industry. Therefore, the deep cooperation between schools and enterprises will become a very important way to improve students' practical ability. In the face of the diversified needs of the future industry, the standardized training programs in the past can have very limited results and establish direct dialogue with the manufacturing industry to provide personalized training content will be even more important in the future. Moreover, while paying attention to practical ability [8].

It is still necessary to pay attention to the cultivation of innovative ability. With the extensive application of technologies such as Internet of Things, cloud computing, big data, 3D printing and so on, and the strengthening of networked collaboration, the engineering field has reduced the suppression of creativity, which can release the creation instinct. It will pay more attention to innovation and synergy to achieve system effectiveness in the future. In the *Creator: New Industrial Revolution*, Chris Anderson pointed out that innovation plays an important role in the new industrial revolution. As the main technology innovator and entrepreneur, engineers will play a greater role in promoting human society into a new era of knowledge economy driven by Technological innovation.

III. THE MAIN THEORIES AND METHODS FOR THE DESIGN OF TRAINING PROGRAM

A. Output-Based Education Model

Outcome-based education (OBE) is an engineering education model actively adopted by all major developed countries in the world. In essence, OBE focuses on the main line of "defining expected learning outcomes—achieving expected learning outcomes—assessing learning outcomes." First, we should conceptualize the abilities and levels that students should achieve when they graduate, Then seek to design appropriate education methods to ensure the realization of the expected goals, and attach great importance to the student's output evaluation. This method also triggered the emphasis on certification in engineering education in Europe and the United States that began in the last century. Generally, the "results-oriented" certification standards were adopted, and the promotion of professional continuous improvement was the ultimate goal of certification [9]. At present, there are six "*international recognition system for international engineers*" agreements, the most authoritative of which is the *Washington Agreement*. On June 2, 2016, China became the 18th official member of the *Washington Agreement*. It indicates that focusing on students' ability output, cultivating engineers according to international standards and assessing teaching quality will play an important role in China's higher engineering education reform.

B. "T" Structural Talents

Spoher and Kwan of IBM in the United States put forward the concept of "T" talent training as early as 2009. According to the differences in knowledge and abilities that graduates need to solve problems and communicate with other people, the training of talents is divided into "I" and "T" types to cultivate and strengthen the competitiveness of the breadth of engineering graduates [10]. "I" talents are generally only competitive in one field. In addition to having a deeper professional skills, "T" talents have broad interdisciplinary skills to help them better move into the workplace. The concept is shown in the figure below.

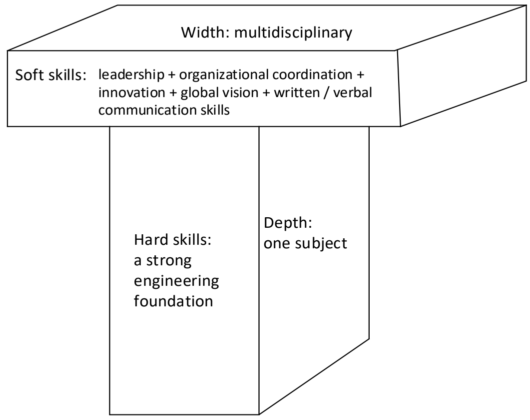

Fig. 1. Schematic diagram of the "T" talent capability structure

C. Project-Based Learning

"Project-Based Learning" (PBL) is a new research-based learning method to effectively enhance students' practical ability and innovative ability. And it is highly praised by domestic and foreign educational circles. The method is student-centered, supported by the concept and principle of the discipline, and is driven by problems arising from actual needs. The method is student-centered, supported by the concept and principle of the discipline. And it is driven by problems arising from actual needs. By guiding students to solve these real problems within a certain period of time to develop the learning and practical ability, problem solving ability, innovation ability and teamwork ability of relevant knowledge of students. In recent years, PBL researchers have further developed a "P Cube"-based learning method (P3BL), which is guided by problems, projects, and products.

IV. DESIGN OF OUTPUT-BASED TRAINING PROGRAM

A. Clarify Professional Training Objectives and Implementation Paths

In summary, we found that higher engineering education should be based on student ability as the main output, cultivate in an interdisciplinary or interdisciplinary model and focus on increasing the proportion of outside the classroom or practice. These concepts are to be solidified and implemented through the design of training programs and curriculum systems.

An important concept of OBE is to conduct teaching activities around Intended Learning Outcomes (ILOs). To this end, we must first clearly define the learning ability output. In the stage of demonstration of professional establishment, on the basis of systematic theoretical research, experts and scholars from teaching, scientific research and enterprises are invited to carry out multiple rounds of brainstorming. Then, according to the needs of the community for the post group, the layers should be decomposed to obtain the ability of the graduates. Then, according to the needs of the community for the post group, the layers should be decomposed to obtain the ability of the graduates. Secondly, based on the ability outcomes "reverse design" curriculum system and teaching method, So that the ability of graduates can be organically introduced into the curriculum system, then the contribution of each course is clearly defined for the realization of student ILOs. Finally, a seamless matching matrix is formed. Some similar curriculum systems have become more common in engineering education in other countries.

B. "T" Concept Guide Course Architecture

With the "T" type talents to cultivate design guiding ideology, the training program should be a balance between breadth and depth. On the one hand, the students who are trained need to have a wide range of professional knowledge and can communicate between different disciplines. That is to say, there is a certain degree of "soft skills" in the "horizontal direction" to help them learn quickly and respond to changes that may occur at any time. On the other hand, it must have a considerable depth in a certain field, that is, "vertical" professional academic ability. Therefore, in the first three years, the "width" was mainly expanded by public basic courses and professional basic courses. In the fourth year, the "depth" was promoted by the professional characteristic courses. This kind of curriculum design can essentially remove the barriers between various disciplines and connect them with bridges [11].

C. PBL Teaching Method Enhances Students' Practical Ability

Based on the PBL teaching method, this paper starts with the four elements of content, activities, situations and results, and designs a project-based learning program that runs through the 2-3 years of university study. The main design ideas are shown in the following figure. The series of "projects" in the picture are intrinsically related and belong to different courses or disciplines in the initial stage. But as the compulsory and elective courses of the students are carried out, they are mutually constituent elements and integrated into smart products or overall solutions in the graduation design or thesis stage. This idea integrates interdisciplinary training into an organic system that can effectively improve students' hands-on ability and ability to solve practical engineering problems.

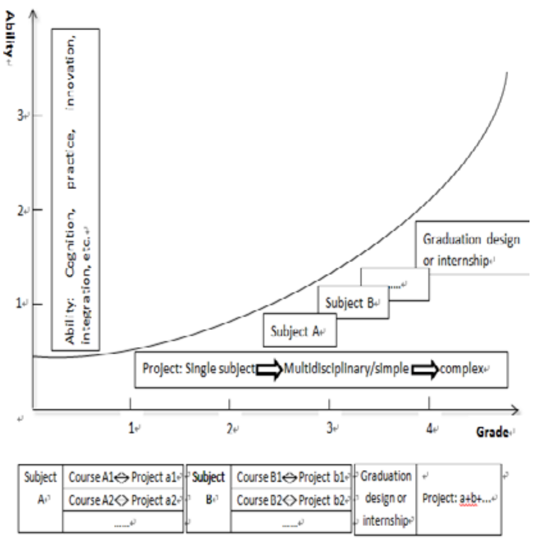

Fig. 2. PBL-based practical learning

V. CONCLUSION

At present, a new round of engineering reforms with interdisciplinary and practical practice has formed a consensus in the domestic higher engineering education community. This paper explores the design of taking the concept of "new engineering" to guide a specific professional training program, curriculum system and teaching method. Through the "reverse design" training program to ensure that the curriculum is matched with the student's ability; through the "T" design of the curriculum architecture to achieve the matching of students' professional depth and interdisciplinary ability; Through the design of project-based learning that combines single course practice and comprehensive training to systematically enhance students' cross-scientific cognitive, practical, and integrated abilities. Then complete the training of system engineers who can harness the increasingly complex manufacturing system of the future.

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