Research on the Training Mode of Emerging Engineering Education Driven by Complex Engineering Problems

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Abstract The training of new engineering professionals in higher institutions complies with the new economic development's demand for high quality engineering and technology talents, and plays a model and lead role in our higher engineering education reform. Complex engineering problems are characterized by complexity, engineering and innovation, and the ability to solve complex engineering problems is a basic requirement of our undergraduate engineering education. Aiming at the existing problems in the current new engineering training mode, this paper takes the major of Internet of Things engineering as an example, takes the new engineering concept as the guidance, combines the new engineering major and analyzes the characteristics of complex engineering problems from the perspective of talents cultivation and ability development. Based on this, the ability framework and ability model based on the characteristics and connotation of complex engineering problems are constructed. With the cultivation of the ability to solve complex engineering problems as the core, new ways to improve the quality of talent training under the background of new engineering construction are explored and practiced.

Keywords Emerging engineering education; Training mode; Complex engineering problems

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1. Introduction

Engineering education professional certification is an internationally accepted engineering education quality assurance system, which is also an important basis for international mutual recognition of engineering education and engineer qualifications. China's engineering education certification began in 2006. Since China joined the Washington Agreement, domestic universities have begun to cultivate students' ability to solve complex engineering problems to carry out engineering education certification work, including eight graduation requirements of certification standards to fully reflect the ability of undergraduates to analyze, solve and evaluate complex engineering problems.

In the process of new engineering construction, domestic colleges and universities have carried out a lot of research and practice on the connotation and cultivation methods of the ability to solve complex engineering problems, including curriculum system construction, practical course teaching case design, curriculum design and engineering thinking cultivation of graduation design, etc. However, there is still insufficient discussion on the cultivation system of students' ability to solve complex engineering problems. Training students' ability to solve complex engineering problems is a systematic and overall work for all majors. Improving the ability to solve complex engineering problems is not a matter of a day, and relevant countermeasures need to be implemented comprehensively in the process of talent training. It reflects the whole process in the time dimension, that is, from admission education to graduation design; In the space dimension, it reflects the full range, namely, theory course, practice course, discipline competition, social practice, etc., through multi-dimensional integration to form a teaching and training system, and conscientiously implement it. Facing the interdisciplinary integration, the reform ideas of cultivating target-driven, diversified talent training, three-dimensional curriculum system, learning results-oriented and open quality management, the ability to solve complex projects is cultivated and carried out in the whole process of talent training. [1]

All countries in the world have reached a consensus on the importance of the quality of higher education, and set up special institutions responsible for supervising and ensuring the improvement of the quality of education. The same is true for engineering education certification, which not only has a set of accreditation standards, but also has a dedicated body responsible for it. The Accreditation Board for Engineering and Technology in the United States, ABET, The Canadian Engineering Accreditation Board and the Engineering Council UK, etc. In order to establish a set of mutual recognition mechanism and platform for the certification systems of various countries, the engineering education accreditation bodies of Australia, New Zealand, Canada, the United States, Ireland and the United Kingdom jointly signed the Washington Accord (WA) in 1989. Its main spirit is that on the premise of substantially equivalent, each signatory member States can recognize their certified degrees each other, and thus substantially enable graduates from these countries to work in the member States involved in the agreement or obtain the license of practicing engineering science and technology, thus achieving the goal of international interoperability. Greater emphasis will be placed on accountability for performance in higher education, with particular emphasis on the evaluation of student learning outcomes, as well as the transparency of evaluation results and information. From the degree standards of various countries or professional training programs, the quality and level of higher education are also indicated by the learning results. It is the most reasonable and appropriate to use the learning results of students to examine the quality of higher education. Therefore, in the quality assurance mechanism, the evaluation

of students' learning effect is paid much attention to, and it is the current trend.[2]

2. The curriculum system of the ability to solve complex engineering problems

2.1 Connotation of the ability to solve complex engineering problems

In recent years, ABET has put forward many innovative and pragmatic educational reform plans for engineering education, among which one of the most important is to develop the ability of the department to solve complex engineering problems, that is, the ability and knowledge that students have when they graduate, including: the ability to apply mathematics, science and engineering knowledge; The ability to design and execute experiments, analyze and interpret data; The ability to design systems, components, or programs to meet specific needs; Ability to function in a cross-domain team; Ability to identify, articulate and solve engineering problems; Awareness of professional and ethical responsibilities; The ability to communicate effectively; The breadth of education needed to understand the impact of engineering solutions in a global and social context; Recognition of the need for lifelong learning and the ability to implement it; Knowledge relevant to contemporary issues; The techniques, skills and application of modern engineering required to carry out engineering business. These 11 competencies outline the quality standards for a bachelor's degree in engineering in the United States. [3,4]

The graduation requirements stipulated by China's engineering education certification are the specific description of the knowledge and ability that students should master when they graduate, including the knowledge, skills and qualities that students have mastered through the study of this major. There are twelve standards, including: the ability to use the knowledge of mathematics, science and engineering; Design and execution of experiments, as well as the ability to analyze and interpret data; The skills, techniques and use of modern tools required to solve complex engineering problems; The ability to design engineering systems, components, or programming; Project management, effective communication, domain integration and teamwork skills; Ability to explore, analyze and apply research results and solve complex engineering problems; Understand the environmental, social and global impact of engineering technology, and develop the habit and ability of continuous learning; To understand and apply professional ethics, and to recognize social responsibility[5]. The competence structure is shown in Figure 1.

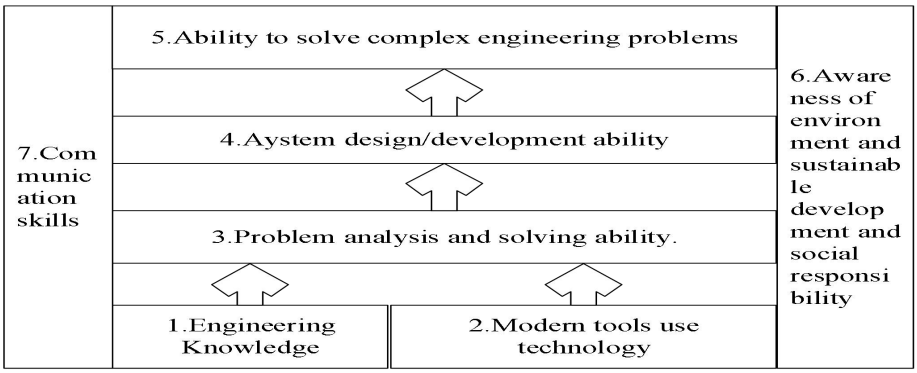

Figure 1. Capability structure for solving complex engineering problems.

2. 2 Hierarchical curriculum system and complex engineering ability cultivation

On the premise of solid basic scientific knowledge, professional courses are divided into professional core courses, professional extension courses and professional application courses. Through the progressive learning of the three modules, students will continuously enhance their professional abilities, and be able to innovatively research, design, develop, evaluate and have the ability to solve complex engineering problems. The development of this core competency is a gradual process. First, students learn the knowledge of major courses to solve complex engineering problems, such as sensor principle, network protocol, Internet of things system, etc. Secondly, students will learn the latest scientific and technological knowledge, such as edge computing technology, big data technology, artificial intelligence course group, etc., in the extended major courses. Finally, in the course of professional application module, students can initially use professional methods to solve the problems of complex Internet of Things engineering design and implementation, and use professional knowledge to propose solutions to the problems. A hierarchical ability cultivation system is formed, as shown in Table 1.

Table 1. Hierarchical curriculum system and complex engineering ability cultivation

Academic Year	Curriculum theory and practice	Development of ability to solve complex engineering problems
Freshman year	Basic subject courses, basic experiments	Ability to apply theoretical knowledge
Sophomore year	Major basic course, major basic experiment	The ability to apply theoretical knowledge
Junior year	Major core classes, major experiments	Application of theoretical knowledge analysis to solve professional problems, comprehensive problems
Senior year	Professional orientation class, innovative experiments	Apply theoretical knowledge to analyze and solve complex engineering problems

According to the characteristics of complex engineering problems, knowledge learning should focus on application rather than mastering. The application of engineering principles to solve complex engineering problems requires a wide range of basic knowledge and cross-integration of professional knowledge. The curriculum setting of Internet of Things engineering should fully reflect the above characteristics. The characteristics of the universal standards for graduation requirements are clear, open, measurable, and full coverage. The standards are incorporated into the professional development program and must be known and understood by both teachers and students. The standards will be broken down into indicators, effectively implemented into the curriculum, and their achievement will be judged in an objective and reasonable way. The twelve general standards are the minimum requirements, graduates, in the degree of knowledge, skills, literacy need to be higher than the general standards, able to solve complex engineering problems, to achieve the professional training objectives.

3. Measures to improve the ability to solve complex engineering problems

The above has made an in-depth analysis of the current situation, influencing factors and reasons of the ability of new engineering students to solve complex engineering problems. The following are three aspects: improving learning methods to achieve self-improvement, giving full play to teachers' initiative to change classroom mode and building teaching practice platform to help students improve their ability. [6]

3.1 Improve learning methods to achieve self-improvement

Faced with the challenges of the global new industrial revolution, the deep integration of higher engineering education and Industry 4.0, the cultivation of specialized talents based on the law of knowledge activities, and the enhancement of the ability to serve the society based on internal and external cooperation should become the common choice of different types of universities. The key to the integration and symbiosis of university talent training and industry 4.0 is to form a dynamic balance mechanism of self-organizing ability and external adaptability around the main line of knowledge activities.

Solving engineering problems is a basic thinking skill that engineering students need to have. The constant evaluation index at the technical level is innovation, which has two dimensions: the scope of processing and the complexity of the problem. Germany's "scope" dimension is below the European average, while its "complexity of problems" is above it. It should be noted that the complexity of the problem is much more important than the scope of the problem. Learning through innovation exists in work organizations that promote learning, and solving complex engineering problems is our main goal. I believe there is nothing more rewarding than students solving a practical problem by themselves.

3.2 Give full play to teachers' initiative to change the classroom model

In order to improve students' ability to solve complex projects, teachers should track and evaluate students' performance in the whole learning process, and ensure that students meet graduation requirements through formative evaluation. Each main teaching link has clear quality requirements, and the realization of graduation requirements is promoted through teaching link, process monitoring and quality evaluation. Regular curriculum system setting and teaching quality evaluation. Teachers have sufficient teaching ability, professional level, engineering experience, communication ability and career development ability, and can provide guidance to complex engineering problems in combination with new engineering majors. On the basis of course teaching, teachers can create opportunities for students to "solve practical problems", test students' practical ability, and promote students to display their talents through reasonable grading. To cultivate graduates who meet training objectives, graduation requirements and have the ability to solve complex engineering problems.

3.3 Build a teaching practice platform to help students improve their abilities

Under the new requirement of cultivating new engineering talents, the aim of engineering practice teaching reform is to cultivate excellent engineering innovative talents. Engineering training practice is an important carrier to cultivate the innovative practical ability of new talents. It is necessary to reconstruct, integrate and innovate the existing engineering training curriculum system. To establish a practical teaching system of hierarchical and modular engineering training platform that meets the

requirements of modern industry, has perfect connotation and pays attention to the cultivation of comprehensive application ability, and goes deep into the construction of engineering culture to establish the central cultural concept of "real engineering environment, cultivating modern industrial spirit".

4. Conclusions and Suggestions

This paper studies and analyzes the connotation of training students' ability to solve complex engineering problems, hierarchical curriculum system and engineering ability training system, understands the indicators of students' ability to solve complex engineering problems, and puts forward some useful suggestions for evaluating the ability to solve complex engineering problems. The core concept of engineering education professional certification is "student-centered, result-oriented and continuous improvement". This concept has fundamentally changed the concept and practice of school teaching and management, promoted the optimization of talent training programs for new engineering majors, and promoted the reform of classroom teaching mode.

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Conflicts of Interest

There is no conflict of interest.

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