

Teaching mode design in mechanical engineering major courses integrating intelligent manufacturing

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Abstract: With the continuous application of artificial intelligence technology in diversified industries, mechanical engineering as a discipline closely related to manufacturing industry, is facing the demand of comprehensive transformation and upgrading. Under the background of intelligent manufacturing, the teaching of mechanical engineering needs to pay more attention to the combination of theory and practice in order to cultivate compound innovative talents to meet the needs of modern manufacturing industry. This study actively explores new teaching mode under the background of intelligent manufacturing to stimulate students' enthusiasm for learning complex theoretical knowledge through diversified teaching links. Then a balanced communication and effective feedback mechanism between teachers and students will be enhanced, and a new situation can be created in which students change from passively accepting course content to actively exploring the latest knowledge in the field of mechanical manufacturing. Relying on the trinity of pre-class independent preview, in-class interaction between students and teachers, and post-class knowledge reconstruction in the teaching process, students' initiative to learn mechanical engineering courses can be strengthened, and thus engineering practice ability and innovation ability of students for intelligent manufacturing are improved.

1. Introduction

As a critical part in the new round of industrial revolution, intelligent manufacturing is profoundly changing the production mode and development direction of the global manufacturing industry. It takes the IoTs, big data, artificial intelligence, cloud computing and robotics as the core supports, and realizes the digitalization, networking and intelligence of the production process. This change not only promotes the transformation and upgrading of the traditional manufacturing industry, but also puts forward new challenges and requirements for the mechanical engineering discipline which is closely related to it. Major countries in the world are looking for a breakthrough in manufacturing intelligence to seize the opportunity for future economic and technological development. The United States has put forward national strategic plans for advanced manufacturing to improve intelligence and innovation policies in manufacturing. Germany has

released the Industry 4.0 strategy to form the fourth industrial revolution led by intelligent manufacturing [1]. China points out that intelligent manufacturing is an important driver of the transformation from a manufacturer of quantity to one of quality, which is also the core content of the transformation of the manufacturing industry. Through the research and formulations of intelligent manufacturing, the development of intelligent manufacturing equipment and products can be accelerated, and industrial upgrading and transformation in the wave of information technology will be promoted, which lead to the lift of the intelligent level in the manufacturing processes.

Under this circumstance, colleges and universities, as the main position of talent cultivation, must actively respond to this trend and carry out comprehensive innovation in the curriculum design, teaching methods and practice mode of mechanical engineering, in order to meet the needs of intelligent manufacturing. As a basic subject of manufacturing industry, mechanical engineering has been providing theoretical guidance and technical support for industrial production. However, in the context of intelligent manufacturing, the traditional mechanical engineering education mode has exposed some limitations. For example, the content of the course mainly focuses on traditional knowledge such as mechanical design and processing technology, while lacks systematic explanation of intelligent technology. The teaching method is mainly based on theory indoctrination, and the cultivation of students' practical ability and innovative ability is relatively weak [2,3]. There is a certain disconnect between the equipment used in practical teaching and the actual needs of the intelligent manufacturing industry. These problems make it difficult for some mechanical engineering graduates to fully adapt to the needs of high-quality composite talents in the era of intelligent manufacturing [4].

Therefore, the course teaching mode of mechanical engineering needs to be redesigned. Under the background of intelligent manufacturing to meet the new requirements of talent cultivation in the new era. Modern intelligent manufacturing emphasizes interdisciplinary knowledge integration and technology application, which requires students not only to master the basic knowledge of traditional mechanical disciplines, but also to have intelligent technology application ability, innovative design ability and comprehensive ability to solve complex engineering problems. Therefore, the design of teaching mode needs to break the boundaries of traditional disciplines, and organically combines mechanical engineering with information technology, automation technology, data analysis, to provide students with a comprehensive knowledge system of intelligent manufacturing. Meanwhile, the essence of intelligent manufacturing lies in achieving higher efficiency and quality through data-driven production methods, which requires the mechanical engineering course to make full use of intelligent tools in the teaching process and adopt more diversified and innovative teaching methods [5, 6]. For example, with the help of modern teaching methods such as virtual simulation and online education platforms, students can intuitively feel the operation logic of intelligent manufacturing systems. Through the project-driven approach, students are able to develop practical skills and a sense of teamwork in the process of completing practical engineering problems.

2. Analysis of teaching difficulties

Mechanical engineering education is facing a full range of challenges under the impact of new intelligent manufacturing technologies and applications. The teaching content, teaching mode and practice of the course need to be deeply reformed to meet the training needs of high-quality compound talents. The following is an analysis of the main difficulties in the course teaching of mechanical engineering under the background of intelligent manufacturing from three aspects: course content, teaching methods and practice links.

2.1. Integration and update of course contents

Intelligent manufacturing integrates multi-disciplinary knowledge such as mechanical engineering, information technology, automation, artificial intelligence, and the Internet of Things. However, traditional mechanical engineering courses mainly focus on mechanical design and manufacturing processes, and less on information technology, big data, artificial intelligence and other content. This kind of simple knowledge system is difficult to meet the requirements of intelligent manufacturing for interdisciplinary comprehensive ability. In the course design, how to integrate the multidisciplinary knowledge effectively, not only to avoid the course content too scattered, but also to ensure the coherence and integrity of the knowledge system has become one of the major difficulties.

In addition to the wide variety of disciplines involved, some intelligent technologies are developing rapidly, with new concepts, new methods and new tools, such as digital twins, edge computing and artificial intelligence. However, the curriculum update cycle of colleges and universities is long, and the course content is difficult to reflect the latest technological development in time, resulting in the teaching content lagging behind the actual needs of the industry.

2.2. Innovation and implementation of teaching methods

At present, the teaching mode of mechanical engineering mainly focuses on classroom teaching, and the teaching process is highly one-sided. Students often accept knowledge passively in the learning process, while lack active exploration and innovative thinking. Intelligent manufacturing requires students to be able to solve complex engineering problems, which is difficult to meet with a single classroom teaching. Although innovative teaching methods such as project-driven teaching, case teaching and flipped classroom have good application prospects in intelligent manufacturing teaching, these methods put forward high requirements on teachers' teaching design ability and students' autonomous learning ability. On the one hand, teachers need to design challenging and practical teaching projects; on the other hand, students also need to have strong self-learning ability to cope with complex problem situations in the class.

Besides, intelligent manufacturing teaching involves machinery, information, programming and other aspects of content. However, the basic level of students in these areas is uneven. Some students may perform well in traditional mechanical courses, but have insufficient knowledge of information technology or programming techniques, which poses additional difficulties for the implementation of teaching.

2.3. Design and implementation of practice links

Some related equipment in intelligent manufacturing, such as industrial robots, flexible manufacturing systems, digital twin systems, etc., have high costs for university laboratory construction funds. Some universities find it difficult to purchase advanced equipment or update experimental facilities due to funding constraints, resulting in a disconnect between students' practice conditions and the actual needs of the intelligent manufacturing industry. Therefore, some universities use virtual simulation experiments to replace some actual experiments. However, although the virtual experiment is economical and efficient, the students lack the actual operation experience of the equipment, and it is difficult to fully grasp the operation characteristics and complexity of the equipment, which weakens the effect of practical teaching to a certain extent.

Meanwhile, traditional experimental courses usually focus on a single device or local process due to the limited time of practical teaching, and lack the experience of the overall production system. Students have insufficient opportunities to operate on real equipment, which also limits the

improvement of practical ability.

3. Analysis and design of teaching mode

Training high-quality engineering talents to meet the needs of intelligent manufacturing has become an important goal in mechanical engineering education reform. Combined with the analysis of the teaching difficulties of mechanical engineering courses under the background of intelligent manufacturing in the previous section, the design progress of the teaching mode is systematically discussed from five aspects: determination of teaching objectives, integration of curriculum system, innovation of teaching methods, optimization of practice links and improvement of evaluation mechanism.

3.1. Determination of teaching objective

Intelligent manufacturing has put forward multi-level demands for mechanical engineering talents, so the first step of teaching mode design is to determine cultivate complex and innovative engineering talents as the core teaching objectives.

In terms of knowledge objectives, students need to master both traditional mechanical engineering knowledge and intelligent manufacturing knowledge, including mechanical design and manufacturing, information technology, big data analysis, industrial robots, flexible manufacturing systems, etc. In terms of ability goals, students are trained to integrate interdisciplinary knowledge, design intelligent production systems, and analyze and solve engineering problems. In terms of quality objectives, students' innovation awareness, teamwork ability and ability to adapt to complex engineering environment need to be enhanced. Therefore, based on the above goals, the teaching model needs to be designed from three aspects, namely knowledge imparting, ability training and comprehensive quality improvement.

3.2. Integration of curriculum system

While retaining the core contents in the courses of mechanical engineering, the knowledge related to intelligent manufacturing can be integrated into them. For example, the design methods of intelligent equipment can be added to the content related to mechanical design, while the additive manufacturing and flexible manufacturing technology can be introduced in the basic contents of mechanical manufacturing technology.

According to the hierarchy and relevance of knowledge and skills, the curriculum is divided into basic module, professional module and extended module. The basic module includes theoretical knowledge of mechanical manufacturing, design, principles, etc. The professional module includes advanced knowledge of artificial intelligent technology, automation control, big data, cloud computing, etc. The extended module includes practical knowledge such as project management and enterprise digital manufacturing that is applied in industrial field. The modular design enables students to make personalized choices according to their own interests and development direction, and improve the learning effect.

3.3. Innovation of teaching method

The teaching methods are no longer based on traditional classroom teaching, but are oriented to the practical engineering problems. Students are asked to complete projects through teamwork by giving project tasks. For example, sensor-based intelligent detection equipment can be designed by the students in the related content learning of mechanical design, robotic handling or assembly

systems can be developed in content learning related to flexible manufacturing systems. This method can improve students' practical ability and comprehensive application ability.

In actual teaching, typical intelligent manufacturing cases can be selected, such as Industry 4.0 practice in Germany and Intelligent manufacturing strategy in China, for analysis and discussion, so that students can deeply understand the practical application scenarios of intelligent manufacturing. During this process, the flipped classroom model can be used. After the teacher proposes the project objectives and tasks, students can learn the basic knowledge through online resources in advance, and the class time is used for practice, discussion and question-answering, which improves students' ability to master the professional knowledge of intelligent manufacturing.

3.4. Optimization of practice link

The practice links of intelligent manufacturing courses depend on the laboratory construction work in colleges and universities. Robot programming, motion control and intelligent production line operation can be simulated through the industrial robot laboratory. Digital twin technology can be used to simulate complex manufacturing systems by virtual simulation experiment platform.

Teachers can implement multi-level practical teaching, including basic practice such as parts machining, equipment operation and comprehensive practice of small intelligent production line construction. On this basis, a comprehensive project practice can be designed according to the actual needs of enterprises. Through the design and implementation of an intelligent manufacturing solution, the whole process from design, manufacturing to production scheduling in an enterprise can be simulated, so that students can accumulate practical experience in a real environment.

3.5. Improvement of evaluation mechanism

Curriculum evaluation can be expanded from a single theoretical examination to multi-dimensional evaluation, including traditional theoretical knowledge test, innovation ability evaluation, practical ability assessment and team cooperation ability assessment. Among them, the innovation ability evaluation tests the students' ability to transform intelligent manufacturing technology, the practical ability assessment evaluates the students' ability to apply intelligent manufacturing technology in the real application, and the team cooperation ability evaluates the students' ability to communicate with others in the process of project execution.

Meanwhile, process evaluation is also introduced to continuously evaluate students' learning process through project progress reports, class participation, online learning records, etc., in order to enhance the attention to students' comprehensive performance.

4. Application and practice of teaching mode

According to the above analysis results, we have carried out the preliminary application and practice in the mechanical professional course Intelligent Manufacturing Technology. Based on mechanical design and manufacturing related courses, this course is aimed at third-year undergraduate students majoring in mechanical engineering and teaches the core topics related to intelligent manufacturing technology and its relationship with various research directions in the field of mechanical engineering. It mainly involves the connotation, characteristics and technical system of intelligent manufacturing technology, including professional knowledge in the fields of intelligent design, intelligent processing, intelligent monitoring and control of processing process, intelligent manufacturing system and equipment. Through the study of the course, students can master the basic common knowledge and key technologies of intelligent manufacturing, and understand the cutting-edge technology of modern intelligent manufacturing. In addition, students

can accurately grasp the intelligent development direction of the research field of this major, understand the application scenarios and practical significance of intelligent technology in various fields of mechanical engineering, and use intelligent manufacturing technology to solve related manufacturing problems.

4.1. Pre-class preparation

Intelligent manufacturing is the product of the integration of mechanical engineering, electrical engineering, computer science and other disciplines. If the key knowledge points of the course are not prepared in advance, it is easy for students to get lost in the grand conceptual category of intelligent manufacturing technology. Therefore, teachers need to set teaching objectives online before each class, supplemented by multimedia materials related to the intelligent manufacturing industry, so that students can be well prepared for in-class learning.

For example, during the teaching of Chapter 6 in the Intelligent Manufacturing Technology course, the learning background and objectives of the section on intelligent manufacturing equipment are released online before class to help students understand the teaching objectives and the prerequisite knowledge needed for the course. Then, video resources related to this chapter are released, allowing students to have a preliminary understanding of the functions and applications of machine tools, the key technologies and difficulties of precision machining with intelligent technology. Through pre-class study of diverse learning resources, students can become familiar with the ways in which machine tools can achieve high precision processing, as well as the intelligent numerical control technology, intelligent sensing technology, and intelligent control technology required for intelligent machine tools. It enables them to understand the functions and application scope of these technologies during classroom instruction.

4.2. In-class study

During the in-class study, different knowledge points of intelligent manufacturing are given in the form of pictures or videos, and the key technologies of intelligent manufacturing and their engineering application cases are taught to students. This enables them to understand the relevant theoretical knowledge and combine with other professional mechanical courses, which can further improve the understanding of intelligent manufacturing process for students.

Taking the intelligent design technology in Chapter 2 of the Intelligent Manufacturing Technology course as an example, when introducing the development process of intelligent design, the undertakers of intelligent design are classified as human experts, design expert systems, and human-machine intelligent design systems according to different stages. Illustrations are respectively provided for these three key knowledge points. For instance, the structure of an aircraft is designed through 3D design software like SolidWorks and CATIA, thereby extending to the case of the early independent research and development process of the domestic large aircraft C919. A comparison is also made between the current method of virtual design for aero-engines using human-machine intelligent design systems, enabling students to profoundly recognize the gap between domestic intelligent manufacturing technology and the advanced levels abroad, which reinforces students' belief in strengthening the country through science and technology as well as their motivation to study diligently.

4.3. Post-class evaluation

The diversified homework is published through an online teaching platform, and use animation, video and other ways to show the dynamic process of intelligent manufacturing. Through the visual

understanding of intelligent manufacturing mode, students make full use of the knowledge learned in the class, and realize the review and consolidation of the theoretical basis of intelligent manufacturing. Teachers can grasp students' understanding of knowledge points through online performance analysis, and adjust and optimize teaching links according to the analysis results.

Taking intelligent processing technology as an example in the Chapter 3 of Intelligent Manufacturing Technology course, after introducing the intelligent prediction method of manufacturing process in class teaching, video homework is assigned and students are required to briefly describe the source, detection and suppression methods of vibration in milling processing after watching the video. According to the intelligent processing knowledge learned in class, combined with the content of other professional courses, students complete the work by writing, mind mapping, graphic description and other forms, and submit the electronic or paper version of the work online. Based on the statistics of homework results in the online learning platform, teachers can know the degree of students' mastery of intelligent manufacturing knowledge content and give reasonable evaluation.

5. Conclusions

Based on the background of intelligent manufacturing, this study discusses the exploration of the new teaching mode according to the teaching characteristics of mechanical engineering courses. Through the design of a variety of teaching links, students' learning enthusiasm can be mobilized, and their online interaction can be enhanced. The teaching methods that combine the basic theory of mechanical manufacturing with intelligent manufacturing cases are adopted to gradually change the situation of students from passive learning to active participation in teaching activities. Relying on the statistical data provided by the online learning platform, teachers can deeply integrate teaching and assessment. While enabling students to know their own learning status, teachers can use big data to grasp students' learning situation, analyze and optimize teaching plans, and integrate teaching resources. Therefore, students can more deeply master the theoretical knowledge content and application practice ability of mechanical engineering courses, so as to pay attention to the bottleneck problems in the field of mechanical manufacturing, and lay a solid theoretical and practical foundation for the needs of intelligent manufacturing industries.

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