Article

Research on the Reform of Curriculum and Education Model of Mechanical Automation Major under the Background of Intelligent Manufacturing

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Abstract: Against the dual background of the intelligent manufacturing industry upgrading and the construction of Hainan Free Trade Port, the talent cultivation of mechanical automation major is facing new challenges. The traditional curriculum and education model of this major can no longer adapt to the industrial development and regional talent demand. Taking the mechanical automation major of Hainan Vocational University of Science and Technology as the carrier of teaching reform practice, this paper focuses on the core of the curriculum and education model reform of the major, and systematically analyzes the key defects of the traditional model, including the disconnection between curriculum and regional industrial demand, the separation of theoretical and practical teaching, and the single evaluation system. Adopting literature research method, in-depth interview method and action research method, taking the Outcome-Based Education (OBE) concept as the core, integrating industry-education integration theory and collaborative education theory, and combining the university's six-dimensional integrated education characteristic of "position-course-competition-certificate-innovation-research", this paper constructs a systematic theoretical framework for the curriculum and education model reform of mechanical automation major with the trinity of "curriculum reconstruction - teaching innovation - evaluation reform", and defines its implementable practical paths. The research shows that the theoretical model of curriculum and education model reform, based on the school-running orientation of vocational undergraduate education and the regional characteristics of Hainan Free Trade Port, effectively solves the prominent problems of the traditional curriculum and education model of mechanical automation major. It provides a replicable and promotable theoretical framework and practical paradigm for mechanical automation majors in vocational undergraduate colleges and universities in China to connect with the intelligent manufacturing industry, optimize the curriculum and education model, and serve the regional development demand. It is also of great significance for promoting the high-quality development of mechanical automation education in vocational undergraduate programs and supporting the construction of a manufacturing power in China.

Keywords: intelligent manufacturing; intelligent mechanical automation; curriculum reform; education model; position-course-competition-certificate-innovation-research; industry-education integration; Hainan Vocational University of Science and Technology

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1. Introduction

1.1. Research Background

Intelligent manufacturing is a key support for building a strong manufacturing industry in China. National development plans clearly promote the digital and intelligent transformation of the manufacturing industry and emphasize strengthening the talent supply in the field of intelligent manufacturing. As a core major linked to the intelligent manufacturing industry, the quality of talent cultivation in the mechanical automation major directly affects the effectiveness of industrial transformation. According to the

China Manufacturing Talent Development Report (2024) issued by the Ministry of Industry and Information Technology, the talent gap in intelligent manufacturing engineering majors in China exceeded 1.1 million in 2024, among which the gap of high-end skilled talents related to intelligent mechanical automation accounted for more than 40%, indicating a prominent mismatch between supply and demand.

The high-end manufacturing industry in Hainan Free Trade Port is rapidly developing. According to the Annual Report on the Construction of Hainan Free Trade Port (2024), the output value of intelligent equipment-related industries in the Free Trade Port increased by 31.7% year-on-year in 2024, resulting in a growing demand for mechanical automation professionals. There is an urgent need to optimize the curriculum and education model of this major to meet industrial development requirements.

This paper focuses on Hainan Vocational University of Science and Technology. As one of the first pilot vocational undergraduate colleges, its mechanical automation major serves as a core connection with the local intelligent manufacturing industry, playing an important role in training high-quality mechanical automation professionals for the Free Trade Port. However, the traditional curriculum and education model of this major has shortcomings, such as a disconnection between curriculum and intelligent manufacturing positions, separation of theoretical and practical teaching, and reliance on a single evaluation system, making it difficult to meet the development needs of the intelligent manufacturing industry and regional talent demand. Therefore, this study focuses on the reform of the curriculum and education model of the mechanical automation major, which has significant theoretical and practical value.

1.2. Literature Review

Researchers domestically and internationally have conducted extensive studies on engineering education reform in the context of intelligent manufacturing. In particular, findings related to the reform of the curriculum and education model of the mechanical automation major provide important references for this study [1,2].

At the international level, Germany has developed the Industry 4.0 Education Framework 2.0, which deeply integrates advanced technologies such as digital twins and the industrial internet into dual-system training programs, offering a collaborative education approach for reforming the curriculum and education model of the mechanical automation major [3].

At the domestic level, studies have highlighted that the core of emerging engineering education is to reconstruct talent training systems in alignment with industry needs, providing guidance for reforming the curriculum and education model of the mechanical automation major [4]. Research on mechanical engineering disciplines has explored curriculum reconstruction paths in the context of intelligent manufacturing, offering reference for the curriculum reform of mechanical automation programs [5]. Theoretical frameworks based on the OBE (Outcome-Based Education) concept have been proposed to support innovation in curriculum and education models [6]. Additionally, vocational education studies emphasize the transformation toward cultivating students' innovative abilities, aligning with the core objectives of curriculum and education reform in mechanical automation programs [7].

1.3. Research Design

This study focuses on the mechanical automation major at Hainan Vocational University of Science and Technology as a pilot program, emphasizing the reform of the curriculum and education model of the major. Following empirical research norms, it adopts a mixed-methods approach and constructs a complete framework of "demand investigation - theoretical construction - action iteration - model refinement".

In the demand investigation stage, in collaboration with local intelligent manufacturing enterprises, industry associations, and university teachers and students,

in-depth interviews and field research are conducted to clarify the core competency requirements of the intelligent manufacturing industry in Hainan Free Trade Port for mechanical automation professionals. This stage systematically identifies the key gaps between the existing curriculum and education model of the major and industry needs, providing a practical foundation for theoretical construction.

In the theoretical construction stage, integrating Outcome-Based Education (OBE), industry-education integration, and collaborative education theories, combined with the university's six-dimensional integration concept of "position-course-competition-certificate-innovation-research," this study develops a targeted theoretical framework for the curriculum and education model reform of the mechanical automation major. The framework follows a trinity of "curriculum reconstruction - teaching innovation - evaluation reform," defines the core connotation and logical relationships of each module, and ensures that the model aligns with the vocational undergraduate orientation of the major and the talent requirements of the intelligent manufacturing industry in Hainan Free Trade Port.

In the action iteration stage, undergraduate classes of the major serve as practice objects, following a closed-loop process of "plan - implement - observe - reflect" to optimize the curriculum and education model reform path. In the model refinement stage, practical experiences are summarized to develop a replicable reform paradigm that fits the characteristics of vocational undergraduate mechanical automation programs and the Free Trade Port.

2. Construction of the Core Theoretical Model for Teaching Reform of the Mechanical Automation Major at Hainan Vocational University of Science and Technology

Considering the characteristics of the intelligent manufacturing industry in Hainan Free Trade Port and the vocational undergraduate orientation of Hainan Vocational University of Science and Technology, this study develops a comprehensive theoretical model for reforming the curriculum and education model of the mechanical automation major. The framework is guided by the principles of aligning with the intelligent manufacturing industry, emphasizing the distinctive features of the mechanical automation major, and promoting innovation in both curriculum design and teaching practices. It integrates the Outcome-Based Education (OBE) concept with the six-dimensional integration approach of "position-course-competition-certificate-innovation-research," constructing a systematic structure for curriculum reform that addresses the challenges of modern vocational education while meeting the specific demands of regional industry development. The model follows a trinity of "curriculum reconstruction - teaching innovation - evaluation reform" and establishes a comprehensive educational closed loop comprising "training objectives - curriculum system - teaching implementation - evaluation feedback." This approach is intended to systematically identify and resolve the critical gaps between traditional teaching methods and the requirements of intelligent manufacturing, ensuring that graduates are well-prepared to contribute effectively to industry needs [8].

At the core of the model, an integrated curriculum system oriented toward industry-education collaboration is designed around three primary position groups that correspond to the mechanical automation major within the Free Trade Port: intelligent equipment operation and maintenance, intelligent production line integration, and digital production management and control. This system employs a four-level progressive framework of "general foundation - professional core - position module - innovation expansion," enabling students to acquire fundamental knowledge before advancing to specialized professional competencies and practical skill development. The curriculum further incorporates regional characteristics, such as marine equipment automation and local industrial processes, thereby addressing the longstanding issue of disconnection between traditional curricula and the rapidly evolving intelligent manufacturing industry.

To strengthen the link between theoretical knowledge and practical skills, the model introduces a virtual-real integrated teaching mode that combines simulation-based learning with hands-on training and enterprise internships. This three-track approach, consisting of "virtual simulation - on-site training - enterprise internship," ensures that students can apply theoretical concepts in realistic environments while gaining direct exposure to industry practices. Additionally, a dual-tutor system is implemented, in which both university instructors and enterprise technical tutors guide student learning, enhancing the teaching feedback loop and overcoming the common problem of separation between theoretical and practical instruction. This method also promotes a culture of continuous learning and iterative improvement, encouraging students to engage actively in problem-solving and innovative projects.

The reform model is further supported by a multi-collaborative, OBE-oriented evaluation system. It introduces multiple evaluation participants, including university teachers, enterprise technical tutors, and industry experts, ensuring that assessment reflects both academic and practical competencies. Multi-dimensional evaluation indicators cover professional foundational skills, engineering practice ability, and innovation literacy. Evaluation incorporates both process-based and summative methods, capturing students' engagement in competitions, research projects, and industry-related activities [9]. By integrating performance in practical projects and innovation initiatives into formal assessment, the model achieves a dynamic cycle of "promoting learning, teaching, and reform through evaluation," which strengthens the alignment between educational objectives and industry requirements, while continuously improving curriculum quality and graduate competency.

Overall, this theoretical model provides a structured, evidence-based framework for transforming the mechanical automation major at Hainan Vocational University of Science and Technology. It not only addresses the shortcomings of traditional teaching methods but also establishes a replicable, scalable paradigm for vocational undergraduate programs that are closely connected to regional industrial development. By systematically linking industry demands, curriculum design, practical teaching, and multi-faceted evaluation, the model ensures that graduates are equipped with the professional knowledge, practical skills, and innovative capacity necessary to meet the challenges of the intelligent manufacturing era. In doing so, it contributes both theoretically and practically to the ongoing reform of vocational education, serving as a reference for similar programs in other regions seeking to integrate higher education with rapidly evolving industrial needs.

3. Practical Paths of the Theoretical Teaching Reform Model for Mechanical Automation Major in Hainan Vocational University of Science and Technology

To ensure the effective implementation of the trinity theoretical framework of curriculum and education model reform for mechanical automation major, combined with the actual school-running situation of Hainan Vocational University of Science and Technology and the characteristics of the intelligent manufacturing industry in Hainan Free Trade Port, based on the talent training orientation of vocational undergraduate mechanical automation major, four practical paths are defined to promote the in-depth implementation of the curriculum and education model reform of the major.

3.1. Strengthen School-Enterprise Collaborative Education

Deepen the cooperation with local intelligent manufacturing enterprises and industry associations, establish a long-term collaborative education mechanism, and jointly build training resources and curriculum libraries for mechanical automation major. Invite enterprise technical experts to participate in the whole process of curriculum standard revision, teaching implementation, practical guidance and evaluation of the major. Introduce real intelligent manufacturing projects of enterprises, integrate project-

based teaching into the curriculum training of the major, realize "joint talent training, joint process management and achievement sharing", and consolidate the implementation foundation of curriculum and education model reform [10].

3.2. Improve the Construction of Training Platforms

Integrate the on-campus training resources to upgrade the intelligent manufacturing training base of mechanical automation major, build a digital twin virtual simulation training platform, develop training projects adapted to the whole process skills of the professional positions, expand the off-campus internship bases, realize the connection between virtual and on-site training, and provide support for the implementation of integrated theory and practice teaching of the major.

3.3. Optimize the Double-Qualified Teaching Staff

Implement the enterprise practice plan for teachers of mechanical automation major, encourage professional teachers to go deep into intelligent manufacturing enterprises for exercise and accumulate industry experience. Employ enterprise technical backbones as part-time tutors of the major, carry out special training on curriculum and education model reform, and guide teachers to change teaching concepts and improve the teaching implementation ability of the major.

3.4. Improve the Teaching Reform Guarantee Mechanism

Increase the fund investment, focusing on the construction of training platforms, curriculum resource development and teaching staff improvement of mechanical automation major. Improve the teaching management system of the major, establish a feedback mechanism for the effect of curriculum and education model reform, regularly collect feedback from students, teachers and enterprises, continuously optimize the theoretical framework and implementation path of curriculum and education model reform of the major, and promote the long-term and orderly operation of the reform.

4. Practical Value and Effect Refinement of the Theoretical Teaching Reform Model

After multiple rounds of practical iteration, the trinity theoretical framework of curriculum and education model reform for mechanical automation major in Hainan Vocational University of Science and Technology has achieved remarkable results. Its core value is closely around the curriculum and education model reform of the major and the demand of intelligent manufacturing industry, which is mainly reflected in three aspects.

4.1. Solve the Core Pain Points of Talent Cultivation of the Major

The model effectively solves the problems of disconnection between curriculum and intelligent manufacturing industry, separation of theoretical and practical teaching, and single evaluation system in the traditional curriculum and education model of mechanical automation major, and realizes the accurate connection between the talent cultivation of the major and the demand of intelligent manufacturing positions in the Free Trade Port. Students' practical abilities such as intelligent equipment operation and production line debugging, innovation literacy and professional literacy have been significantly improved, and the quality of talent cultivation has been widely recognized by industry enterprises.

4.2. Construct a Characteristic Education Model for Mechanical Automation Major

Through the reform of curriculum and education model, the education characteristics of six-dimensional integration of "position-course-competition-certificate-innovation-research", virtual-real combination and multi-collaboration have been formed. The curriculum system, training platform and teaching staff of the major have been optimized, the school-running level of mechanical automation major has been

significantly improved, a characteristic major fitting the demand of intelligent manufacturing industry has been built, distinctive professional competitiveness has been formed, and a solid foundation has been laid for the connotation construction of the major.

4.3. Refine a Replicable Paradigm for Curriculum and Education Model Reform of Mechanical Automation Major

Based on the characteristics of the Free Trade Port and vocational undergraduate education, a full-chain reform path of curriculum and education model for mechanical automation major of "curriculum - teaching - evaluation" has been formed, which provides a replicable and promotable theoretical framework and practical paradigm for mechanical automation majors in similar vocational undergraduate colleges nationwide to connect with the intelligent manufacturing industry and optimize the curriculum and education model, and helps the high-quality development of mechanical automation education in vocational undergraduate programs and the construction of Hainan Free Trade Port.

5. Conclusion and Prospect

Taking the mechanical automation major of Hainan Vocational University of Science and Technology as a case, aiming at the urgent demand for talents of the major brought by the upgrading of intelligent manufacturing industry and the construction of Hainan Free Trade Port, this paper systematically analyzes the core pain points of the traditional curriculum and education model of mechanical automation major, integrates OBE, industry-education integration and other theories with the six-dimensional integration concept of the university, constructs a targeted trinity theoretical framework of curriculum and education model reform of the major with "curriculum reconstruction - teaching innovation - evaluation reform", and defines its implementable practical paths.

The research shows that the model, based on the school-running orientation of vocational undergraduate mechanical automation major and the characteristics of Hainan Free Trade Port, effectively solves the prominent problems of the traditional curriculum and education model of the major, improves the quality of talent cultivation and professional school-running level, and has strong theoretical innovation, practical feasibility and promotion value.

The innovation of this study lies in that, closely following the background of intelligent manufacturing and the characteristics of mechanical automation major, fitting the regional characteristics of Hainan Free Trade Port, it constructs a full-chain reform framework of curriculum and education model of "curriculum - teaching - evaluation" for the major, and refines the implementable and promotable practical paths.

In the future, combined with the development demand of high-end intelligent manufacturing industry in the Free Trade Port, we will further improve the curriculum system of mechanical automation major, deepen the school-enterprise collaborative education mechanism, optimize the curriculum and education evaluation system of the major, systematically summarize the practical experience of teaching reform, promote the popularization and application of the reform achievements of the curriculum and education model of the major in similar vocational undergraduate colleges nationwide, and provide solid talent support of mechanical automation major for the construction of a manufacturing power and the high-quality development of Hainan Free Trade Port.

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