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Research on Innovative Design and Resource Construction of Comprehensive Experimental Teaching Projects for Materials Forming and Control Engineering Major

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Abstract: As a core supporting major in the manufacturing industry, Materials Forming and Control Engineering undertakes the important mission of cultivating high-quality engineering and technical talents in the new era. Promoting the innovative design and resource construction of comprehensive experimental teaching for this major is an inevitable choice to adapt to industrial transformation, implement national education strategies, and break through teaching difficulties. Firstly, a diversified, intelligent, and virtual-real integrated teaching resource system required for innovative experimental projects is systematically constructed. A group of comprehensive experimental projects that integrate cross-curriculum knowledge, are close to engineering practice, reflect cutting-edge technologies, and stimulate innovative thinking are innovatively designed. Advanced hardware experimental platforms, professional software and simulation tools, a rich digital resource library, and supporting teaching materials are developed. Finally, a multi-dimensional dynamic evaluation system is explored and established.

1. Introduction

The world is currently in a critical period of a new round of scientific and technological revolution and industrial transformation. As the main body of the national economy, the manufacturing industry is undergoing profound digital, networked, and intelligent transformations. In strategic emerging fields, the requirements for materials forming accuracy, performance stability, and production efficiency continue to increase [1]. As a core supporting major in the manufacturing industry, Materials Forming and Control Engineering is directly connected to key production links and undertakes the important mission of cultivating high-quality engineering and technical talents in the new era.

At present, the comprehensive experimental teaching system of the Materials Forming and Control Engineering major is facing severe challenges: Traditional experiments mainly focus on single equipment operation and confirmatory experiments, with insufficient integration of cutting-edge technologies, making it difficult for students to establish systematic thinking; Experimental resources are disconnected from industrial reality, with outdated equipment updates and projects not combined with real production needs. This fails to enable students to accumulate the ability to solve complex engineering problems and meet the needs of modern manufacturing for compound engineering talents [2]. Promoting the innovative design and resource construction of comprehensive experimental teaching for the Materials Forming and Control Engineering major is an inevitable choice to adapt to industrial transformation, implement national education strategies, and break through teaching difficulties [3]. From the perspective of industrial adaptation, it allows students to master core tools in advance and alleviate the pain points of enterprise talent training; From the perspective of education strategy, it is a specific practice in response to the requirements of Emerging Engineering construction, breaking the deadlock of disconnection between theory and practice; From the perspective of talent cultivation, it can cultivate students' innovative thinking and collaborative ability [4]. This work is of great significance. It is not only the key to improving the quality of talent cultivation, but also an important link to promote the coordinated development of engineering education and the manufacturing industry.

Firstly, based on the core knowledge system of the Materials Forming and Control Engineering major, guided by the "outcome-oriented, continuous improvement, and international substantial equivalence" standards of engineering education professional certification [5], and strictly aligning with the core requirement of "graduates must have the ability to solve complex engineering problems" in the certification, the certification indicators are decomposed into specific goals of experimental teaching [6]; Driven by industrial needs, in-depth research is conducted on the technical needs of Materials Forming and Control Engineering talents in fields such as new energy vehicles, aerospace, and high-end equipment, and industrial pain points are transformed into core topics of experimental teaching; With ability cultivation as the core, a three-level experimental project of "basic verification - comprehensive application - innovative exploration" is innovatively designed. Verification experiments consolidate core operation capabilities, comprehensive application experiments strengthen systematic thinking [7], and innovative exploration experiments stimulate innovative capabilities. At the same time, the construction of teaching resources such as the revision of experimental guidelines, the development of virtual simulation resources, the upgrading of experimental equipment, and the construction of school-enterprise co-built experimental case libraries is completed [8].

Secondly, a comprehensive experimental teaching platform with advanced concepts, cutting-edge content, rich resources, efficient operation, and scientific evaluation is built. Through the experimental teaching model of "real project-driven + interdisciplinary team collaboration" [9], students' core capabilities in complex engineering problem analysis, advanced technology application, innovative practice, and team collaboration are significantly improved. At the same time, a replicable experimental teaching reform plan is formed, including a mapping relationship table between courses, experiments, and industrial needs, an experimental resource sharing mechanism, and a capability evaluation index system [10], providing a reference model for experimental teaching reform of similar majors.

2. Reform Content (Mainly Divided into Three Points)

2.1 Innovative Design of Comprehensive Experimental Teaching Content

To consolidate students' professional foundation and cultivate their ability to solve complex engineering problems, a four-module progressive structure of "basic experiments - modern technology - comprehensive innovation - virtual simulation" is adopted to design teaching content. Each module is closely connected to form a complete ability cultivation chain [11].

The basic experiment module focuses on verifying the core principles of metal material forming, setting up projects such as material analysis, performance testing, and traditional process parameter optimization. It is supported by standardized operation manuals and error analysis guidelines to help students proficiently master the operation of basic equipment, deepen their understanding of materials science theories, and lay a solid foundation for advanced learning.

After consolidating the basic module, experiments are further designed in accordance with the latest industry standards. Traditional metal material forming projects are retained to maintain the knowledge system, and cutting-edge technologies such as additive manufacturing and precision forming are introduced to guide students to master the correlation logic between process parameters and product indicators. This achieves seamless connection between experimental content and industry standards, ensuring that technical capabilities match industrial needs.

Relying on the accumulation of basic knowledge and technical foundation, the comprehensive innovation module cultivates systematic thinking through multi-process coupling experiments, requiring students to analyze the key points of process connection and solve cross-link problems; At the same time, the core needs of real enterprise engineering cases are introduced to enable students to improve their problem-solving abilities in simulated R&D scenarios and establish a systematic understanding of "process - structure - performance".

Finally, the virtual simulation module builds a digital twin experimental platform, linking physical equipment and virtual systems. Students can first preview the process and simulate parameter effects through virtual scenarios, and then use virtual schemes to guide physical experiments. This not only lowers the threshold for high-cost experiments, but also cultivates the digital R&D thinking of "virtual - physical - feedback - iteration", providing support for the cultivation of compound engineering and technical talents [12].

2.2 Resource Construction Related to Innovative Teaching Content of Comprehensive Experiments

To ensure the effective implementation of the four modules of the "basic experiments - modern technology - comprehensive innovation - virtual simulation" experimental teaching, it is necessary to systematically plan and construct a hardware resource platform to support comprehensive experimental projects, such as advanced material processing equipment and its intelligent transformation and upgrading devices. This ensures that the hardware configuration accurately matches the technical needs of the experimental modules, which can not only meet the standardized operation of basic experiments, but also support the practical teaching of cutting-edge processes in the modern technology module; Simultaneously, a software resource library is built, covering simulation platforms, data processing tools, standard specification databases, typical case libraries, etc. Among them, the case library needs to dynamically collect the latest industry engineering cases and technological breakthrough achievements, and the standard specification database updates the current national and industry standards in real time to ensure the timeliness and practicality of software resources. Supporting teaching resources are also constructed, including project task books, guidelines, evaluation standards, safety specifications, teaching videos, and virtual simulation modules. Various teaching resources need to be designed hierarchically according to experimental modules. For example, the basic experiment guidelines focus on operating specifications, and the comprehensive innovation module task books highlight problem orientation, ensuring that resources are deeply aligned with teaching goals.

On this basis, further exploration is made into the virtual-real integrated experimental teaching model based on technologies such as virtual simulation. The virtual simulation module is used to first complete the preview and scheme optimization of high-risk and high-cost experiments, and then rely on the physical hardware platform to carry out confirmatory experiments. This forms a closed-loop teaching process of "virtual pre-research - physical verification - data feedback - scheme iteration", effectively expanding the space-time boundary and safety of experimental teaching. Finally, a technologically advanced, cutting-edge, complete, and scientifically evaluated experimental teaching resource ecosystem for the Materials Forming and Control Engineering major is constructed. This ecosystem needs to realize the coordinated linkage of hardware, software, and supporting resources. For example, virtual simulation data can be directly connected to data processing tools, and experimental results can be analyzed against the standard specification database, thereby improving teaching efficiency and effectiveness, and providing strong support for comprehensively enhancing students' ability to solve complex problems and innovative literacy [13].

2.3 Construction of a Multi-Dimensional Dynamic Evaluation System

To accurately measure the effect of experimental teaching and optimize teaching strategies, an intelligent evaluation system for learning behavior analysis is constructed, and a four-dimensional evaluation model of "preview test - experimental process data collection - defense evaluation - project report" is innovatively proposed. This model runs through the entire teaching process, with each dimension assessed independently yet connected, comprehensively reflecting students' knowledge, practical, and innovative abilities.In the preview stage, an adaptive test is used to identify learning blind spots, dynamically adjust questions to locate weak points, and push supplementary learning resources; During the experiment, an intelligent system is used to collect data such as operation specifications and parameter settings, avoiding the emphasis on results over processes and objectively quantifying practical abilities; The defense evaluation introduces stress tests to examine emergency response capabilities and peer evaluation, supplementing evaluation perspectives and improving comprehensiveness; For the project report, text mining technology is used to extract logic, innovation points, etc., conduct quantitative scoring, and identify common problems.

In addition, a feedback closed-loop system is used to optimize teaching strategies. Evaluation data is fed back to teachers in real time to adjust project difficulty and guidance priorities, forming a virtuous cycle of "evaluation - feedback - improvement - re-evaluation" to achieve the dual improvement of teaching quality and students' abilities [14].

3. Feasible Measures

3.1 Preliminary Research and Scheme Design Stage

To ensure the implementation of the comprehensive experimental teaching reform, systematic research is first carried out: On the one hand, research is conducted on the advanced experimental teaching models and resource construction status of Materials Forming and Control Engineering majors in domestic and foreign universities, focusing on analyzing the innovative practices of top universities and enterprise technical talent standards, and clarifying the direction of connection between teaching and industry; On the other hand, the talent cultivation needs of the school's Materials Forming and Control Engineering major, students' foundations, and the shortcomings of existing experimental conditions are analyzed, and a report on "advantages - shortcomings - improvement directions" is formed to provide a basis for scheme design.

Based on the research, the project objectives and core innovation points are clarified. The objectives focus on "improving students' ability to solve complex engineering problems and innovative literacy", and the innovation points highlight the school's characteristics; Subsequently, the top-level design framework of the comprehensive experimental project group is completed, clarifying the content boundaries, cultivation goals, and connection logic of the four modules, and formulating technical routes and detailed implementation plans.

Based on the scheme, resource demand assessment and budget planning are conducted, clarifying the needs for hardware, software, case libraries, etc., and detailing various expenses to ensure that resource investment matches the objectives and provides guarantee for the project promotion.

3.2 Core Innovation and Resource Development Stage

Guided by the concept of "integrating engineering practice and cutting-edge technology", a number of cross-module core comprehensive experimental projects are developed. At the same time, supporting task books, guidelines, and evaluation standards are compiled. The task books clarify the engineering background and ability objectives, the guidelines focus on technical points, and the evaluation standards highlight process and innovation indicators.For hardware development, key equipment is purchased and debugged according to the plan, existing resources are integrated, and flexible equipment combination is realized through modular design. An intelligent management system is introduced to improve efficiency and safety, and a modular and intelligent hardware experimental platform is built.

Digital resources are developed simultaneously. Virtual simulation modules and digital twin applications that are suitable are introduced or developed to ensure the consistency of virtual and real parameters and operation logic; Case libraries, standard libraries, and material libraries are built. The case libraries collect real enterprise cases, and the standard libraries update industry specifications.

In addition, experimental teaching videos, safety animations, and online guidelines are produced. The videos explain key operations, the animations strengthen safety awareness, and the guidelines provide independent learning paths, improving the resource system and laying a foundation for the efficient implementation of experimental teaching.

3.3 Testing and Trial Operation Stage

To verify the feasibility of the comprehensive experimental teaching reform scheme, 1-2 core experimental projects are selected for trial operation in pilot classes. Priority is given to projects covering "basic + modern" or "comprehensive + virtual" to take into account the verification of different experimental types. Student feedback is collected through classroom observation, questionnaires, and interviews, and teachers' experience is collected through teacher logs and seminars; At the same time, the effect of "virtual-real combination" is evaluated, and quantitative indicators are set from aspects such as operation specifications and problem-solving efficiency to compare the differences between traditional experiments and virtual-real experiments.

Based on the feedback and evaluation results, the experimental projects are optimized, the resource platform is improved, the teaching process is refined, and the evaluation methods are revised, laying a mature foundation for the subsequent large-scale promotion.

3.4 Comprehensive Implementation and Promotion Stage

The iteratively optimized comprehensive experimental project group is formally incorporated into the training program of the Materials Forming and Control Engineering major, and opened to all students according to the curriculum modules to ensure that experimental teaching is deeply integrated with the professional talent cultivation goals and covers the entire cycle of students' ability cultivation. At the same time, the hardware experimental platform and digital resource library are opened for sharing, and a management and maintenance mechanism for regular equipment maintenance and dynamic resource update is established to ensure the long-term stable availability of resources and improve the efficiency and sharing value of use.

A long-term feedback mechanism is built. The teaching data collection system is used to continuously collect information such as students' learning effects and teachers' teaching suggestions. Based on this, the experimental content is updated, cutting-edge resources are supplemented; The experience of project construction is summarized, and a replicable model of "module design - resource support - evaluation optimization" is refined. It is promoted and exchanged inside and outside the school through inter-school seminars, teaching achievement exhibitions, and other channels to realize the radiating application of achievements, promote the overall improvement of experimental teaching of the Materials Forming and Control Engineering major.

4. Conclusion

The innovative design and resource construction of comprehensive experimental teaching projects for the Materials Forming and Control Engineering major focuses on industrial transformation and talent cultivation needs. It constructs a four-module progressive teaching content system of "basic experiments - modern technology - comprehensive innovation - virtual simulation", supports the construction of a diversified, intelligent, and virtual-real integrated experimental teaching resource ecosystem, innovatively proposes a four-dimensional dynamic evaluation model of "preview test - experimental process data collection - defense evaluation - project report", and forms a complete implementation path covering "research and design - development and construction - testing and optimization - promotion and improvement".

This reform effectively solves the problems of traditional experimental teaching, such as disconnection from industry, outdated resources, and single evaluation. Through the integration of real engineering scenarios and the application of cutting-edge technologies, it significantly improves students' ability to solve complex engineering problems and innovative literacy. At the same time, it refines a replicable experimental teaching reform model and resource sharing mechanism. It not only provides strong support for improving the quality of talent cultivation in the Materials Forming and Control Engineering major, responds to the requirements of Emerging Engineering construction and engineering education professional certification, but also provides a reference model for experimental teaching reform of similar majors, promotes the coordinated development of engineering education and the manufacturing industry, and helps cultivate high-quality engineering and technical talents who meet the needs of the new era.

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