Article

Research on the Reform Practice of New Engineering Course Group Construction

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Abstract: In response to the practical problems in the traditional teaching of industrial design majors, such as the fragmentation of the knowledge chain, the disconnection between theory and practice, and the gap between course teaching and industrial needs, this paper carries out a curriculum group teaching reform targeting four core courses: Product Design Materials and Technology, Product Structure Design, Mechanical Design Fundamentals, and Electrical and Electronic Technology. Relying on a school-enterprise and inter-school collaborative education model, engineering-oriented teaching projects are integrated, and a three-in-one teaching mode of "knowledge chain connection–dual-line classroom collaboration–physical verification closed loop" is constructed. The results of the reform practice show that this mode can break down the interdisciplinary knowledge barriers among material, structure, mechanism, and electronics, effectively make up for students' shortcomings in engineering physical implementation capability, and provide a low-cost, replicable practical approach for local provincial engineering universities to carry out interdisciplinary curriculum construction.

Keywords: emerging engineering education; curriculum group; interdisciplinary teaching; physical assessment

1. Introduction

Since the "Emerging Engineering Education" initiative was proposed by the Ministry of Education China of in 2017, the engineering education in higher education institutions has entered a critical period of reform and development. Documents including the Tianjin University Action, the Beijing Guide [1], the Fudan Consensus [2], and the Notice on the Second Batch of Emerging Engineering Research and Practice Projects [3] publicly released by the Ministry of Education in 2020 collectively emphasize that the reform practice projects of Emerging Engineering Education should be further implemented, the collaborative education mechanism should be improved, cross-border resources should be integrated relying on project clusters, full efforts should be made to promote education and teaching innovation, and professional boundaries should be broken to cultivate interdisciplinary talents that meet industrial demands and possess independent learning capabilities. The core essence of Emerging Engineering Education construction lies in breaking disciplinary barriers, cross promoting-border integration, and strengthening engineering practice. The Opinions on Accelerating the Construction and Development of Emerging Engineering Education and Implementing the Outstanding Engineers Education and Training. 0 issued2 Plan by the Ministry of Education clearly points out that it is necessary to "promote the organic integration of knowledge imparting, ability cultivation and value shaping" and "construct interdisciplinary an and integrated curriculum system", so as to transform classroom knowledge from "theoretical imparting" to "ability cultivation", and shift from the isolated operation of a single discipline to the integration of multiple disciplines. The industrial design major naturally fits this concept:

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an industrial product will inevitably go through the process of "material selection - structural design - mechanism transmission - electronic control" from concept to physical object. Therefore, the four links of "material - structure - mechanism - electronics" will be taken as the reform carrier of interdisciplinary construction to implement the curriculum system reform of the industrial design major.

2. Related Research

2.1. Research Status of Teaching System Construction

Domestic scholars have summarized the characteristics of "Emerging Engineering Education" as enabling the engineering education system to possess the capability of intelligently perceiving the demands of industrial transformation, making agile and accurate responses to such changes, retaining the foundation of traditional engineering disciplines while promoting the interdisciplinary integration and penetration between engineering and other academic categories [4,5,6], so as to cultivate innovative talents with comprehensive capabilities through new educational means and objectives [7].

The current development trend of "Emerging Engineering Education" should focus on the innovative, comprehensive and full-cycle talent cultivation concept, and optimize the specialty layout at the same time [8]. Guided by outcomes, combined with the CDIO teaching model, we should start from the dimensions of training objectives, curriculum system and interdisciplinarity to strengthen the importance of practical teaching [9]. In terms of the teaching system, most propositions take the integration of industry and education as the main line, integrate resources, innovate methods, and systematically reconstruct the teaching system [10], while advocating problem-oriented practical teaching, emphasizing that problem design must take into account both the practical teaching of requirements Emerging Engineering Education and the needs of students to consolidate knowledge [11]. In addition, by breaking disciplinary barriers, establishing disciplinary groups, increasing investment, the overall level of interdisciplinary teaching faculty can be improved [12]. In the construction of teaching strategies, we should establish a clear interdisciplinary education concept, set special up organizational institutions, and improve the guarantee mechanism [13]. Domestic experts have summed up two interdisciplinary curriculum modes: the single-discipline mode and the project-based mode. The former takes core courses as the axis and other courses as auxiliaries to carry out systematic reconstruction [14], while the latter holds that teaching research and development should feature research-driven teaching, emphasis on scientific research training, and practicality and interdisciplinary integration in discipline setting [15].

2.2. Analysis of Problems in the Curriculum System of Industrial Design Major

Through analyzing the current curriculum system of the industrial design major, it can be seen that the teaching pain point lies in the triple segmentation in the core curriculum system:

2.2.1. Segmentation of the Knowledge System Chain

The four corresponding courses, Materials and Technology for Product Design, Product Structure Design, Fundamentals of Mechanical Design, and Electrical and Electronic Technology, which cover the links of "material - structure - mechanism - electronics are", offered independently, forming their own separate systems, and there is a lack of conscious knowledge connection and competence penetration among these courses. Students can master mechanism design and strength verification through learning Fundamentals of Mechanical Design, but they have no idea how to integrate gears and linkage mechanisms into product modeling; Product Structure Design focuses on the design and assembly of shells and experiential knowledge of various connections, ultrasonic welding lines and the like, yet students lack practical operation experience; Materials and Technology for Product Design aims to familiarize students with characteristics of various materials and forming processes, but the coupling relationship between these contents and structure design is not clearly sorted out nor thoroughly

explained; Electrical and Electronic Technology is inherently difficult for industrial design students to learn, and the knowledge module of "matching between electronic components and shell structures" is barely covered in the existing curriculum system. After entering enterprises, students often have to go through a long "make-up learning" process. The above reasons make students unable to respond correctly when facing specific product design tasks: the knowledge in their minds operates in isolation and cannot be connected and assembled to form the "standard answer".

2.2.2. Segmentation of Theory and Practice

The traditional teaching mode is classroom theoretical instruction plus final examination/course assignment, supplemented by experiments and course design. The final outputs are all in the form of written reports and documents, lacking the complete experience of practical operation and transforming schemes into physical objects, so that "applying what one has learned" mostly remains "on paper". With the development of 3D printing technology, designed products can be directly presented by means of rapid prototyping. Problems such as fractures caused by insufficient structural design strength verification, plastic deformation of materials, assembly interference due to unreasonable dimension and structure, and out-of-control operations caused by circuit design errors, all these "feedback from physical objects" reveal the fragmentation of curriculum knowledge. Students are accustomed to drawing on screens and answering test papers to pursue theoretical feasibility, and these real engineering problems are exactly the "physical implementation" feasibility that is missing in the closed loop of traditional teaching.

2.2.3. Segmentation between Curriculum Resources and Industrial Resources

The update of curriculum content for the industrial design major mostly lags behind industrial development, and high-quality enterprise resources have not systematically entered the teaching sites. Local 3D printing enterprises represented by Heilongjiang Multi-dimensional Space Free Manufacturing Co., Ltd. have accumulated rich experience in product R&D and engineering verification, but real enterprise cases, advanced process standards and engineering verification procedures have not yet been transformed into teaching resources. The barriers between schools and enterprises prevent students from obtaining real engineering feedback on campus, forming a "last kilometer" gap between curriculum teaching and the actual demands of enterprises.

Against this background, this paper puts forward an exploration of the systematic reform path of "curriculum group + synchronous classroom + physical object assessment": guided by the Emerging Engineering Education concept of "interdisciplinary integration and practice-driven development", taking the trinity curriculum group of industrial design as the carrier, adopting the "two-line synchronous classroom" between schools and enterprises, as well as between different schools as the technical means, and taking 3D printed physical object assessment as the closed-loop output, this paper constructs a trinity curriculum group reform mode of "knowledge chain penetration - two-line classroom collaboration - physical object verification closed loop" to realize the vertical penetration of knowledge. Through the "two-line synchronous classroom" between schools and enterprises, as well as between different schools, enterprise engineering verification standards and high-quality external teaching faculty can be introduced into the teaching sites in real time to achieve horizontal integration of resources. Through 3D printed physical object assessment, "whether the physical object can operate successfully" replaces "whether the test paper has a high score" as the final criterion for competence achievement, so as to realize a fundamental transformation of the evaluation paradigm. The essence of this reform is to transform the abstract Emerging Engineering Education concept of "breaking engineering barriers and strengthening engineering practice" into a set of operable, evaluable and promotable teaching implementation schemes.

3. The Reform Path of the "Three-in-One" and the Implementation Plan of Synchronous Classrooms

3.1. Construction of the Curriculum System

We will break the independent teaching pattern of the four courses, establish a "chain-type" theoretical system that runs through the four courses, and finally form an integrated knowledge map and teaching implementation plan of "materials - structures - mechanisms - control". Relying on the enterprise resources of Heilongjiang Multi-dimensional Space-Time Free Manufacturing Co., Ltd. and the high-quality teachers of Nanyang Normal University, we will build a synchronous classroom mode of "online review by enterprise tutors + online teaching by teachers from other universities + offline organization by local teachers", so as to form a replicable and popularizable new teaching operation mode. Taking "whether the physical object can operate successfully" as the core judgment basis of competence, we will establish a multi-dimensional evaluation index system covering material rationality, structural feasibility, assembly manufacturability and control matching, improve the closed teaching loop of "scheme design - tutor review - on-site printing - physical verification - optimization and iteration", form standardized reform experience integrating "curriculum group knowledge chain reconstruction + dual-line synchronous classroom + physical assessment closed loop", and popularize and implement the operable and replicable construction mode of curriculum groups for provincial engineering colleges and universities.

We will systematically sort out the knowledge points of the four courses, namely *Fundamentals of Mechanical Design*, *Product Structure Design*, *Product Design Materials and Technology*, and *Electrical and Electronic Technology*, extract the cross-related nodes, and rearrange them into four progressive levels in accordance with the product development process. We will focus on mastering how material properties constrain structural design, how structural forms determine mechanism type selection, how mechanism motion puts forward control requirements, and how control feedback affects the optimization of materials and structures. According to the knowledge map and the serial logic of the connected projects, we will collaboratively revise the syllabi of the four courses: adjust the teaching sequence of some knowledge points to make the related contents connected sequentially in time; add the connecting teaching links between courses, and set up "interface lessons" at the beginning and end of each course, where teachers will teach the related contents of the preceding and following courses in an interdisciplinary manner.

3.2. Development of Typical Teaching Projects

Based on the knowledge map of the curriculum group, taking the "intelligent soil moisture monitoring device" as a typical teaching project, the project is divided into four sub-tasks corresponding to the courses according to the teaching progress, forming a chain-type progressive relationship of "output of the previous course → input of the subsequent course". This arrangement enables students to go through the whole chain design process of "material selection → mechanism design → structural modeling → control implementation" in a complete engineering project, and personally experience the restriction and collaborative relationship between each link, instead of completing unrelated assignments in isolation in the four courses.

3.3. Establishment of the Implementation Plan for the Construction of the "dual-Line Synchronous Classroom" between Schools, Enterprises and Inter-School Partners

A three-in-one teaching organization model of "online participation of enterprise tutors + online teaching of teachers from other universities + offline organization of local school teachers" is constructed. The teachers of the local school undertake the main teaching of the courses and classroom organization and management, enterprise tutors get involved online at key nodes (case introduction, scheme review, and physical product assessment), and teachers from other universities give lectures online on specific knowledge modules. A collaborative teaching operation scheme of "dual lines and three subjects" is formed to clarify the responsibilities, intervention timing and cooperation procedures of each subject.

3.4. Construction of the Evaluation System

We will build an assessment and evaluation system featuring "verifiable physical objects, measurable standards and joint evaluation by schools and enterprises", focus on the two core dimensions of "structural function" and "assembly quality", and convert engineering standards into operable assessment indicators. Taking the "intelligent soil moisture monitoring device" as an example: the total score is1 00 points, the physical assessment accounts for40% of the total score of the connected project, and the sub-tasks account for 60%. Enterprise tutors participate in the physical assessment link through online synchronous classrooms and make judgments remotely. For indicators that require close-range judgment such as sealing performance and surface quality, on-campus teachers will cooperate in shooting with the physical object, and enterprise tutors will score online and give comments.

4. Application Prospects

4.1. Providing an Implementation Plan for the Curriculum System Reform of the Industrial Design Major of Our University

The pilot and direct application object of this research is the industrial design major of the College of Engineering. Upon the completion of the project, a set of resource databases covering four courses will be formed, including standardized documents such as course syllabi, comprehensive project design schemes, and 3D printing physical object assessment and evaluation systems, which can be extended to other majors within the college.

4.2. Providing a Replicable Reform Paradigm for Similar Majors in Provincial Engineering Colleges and Universities

The mode of "curriculum group knowledge chain reconstruction + school-enterprise inter-school dual-line synchronous classroom" explored in this research has good popularization potential. Firstly, the idea of connecting the knowledge chain of "mechanical basis - structural design - material technology - control technology" can be migrated to relevant majors such as Mechanical Design, Manufacturing and Automation. Secondly, the school-enterprise inter-school synchronous classroom operates relying on online platforms, with low technical threshold and low construction cost, which is suitable for the school-running conditions of provincial colleges and universities. The inter-school teacher collaboration mode explored in this subject has unique promotion value: it does not rely on the signing of formal administrative agreements between the two universities, nor does it involve complex credit mutual recognition and student status management, but absorbs individual off-campus teachers with specific teaching expertise to participate in the form of "research group members". The off-campus electronic control teachers are embedded in the curriculum group teaching in the form of special topic modules, with a clear path and simple operation.

4.3. Constructing a Rapid Prototyping Teaching Platform Serving Longjiang's Intelligent Manufacturing

Guided by serving the intelligent manufacturing industry of Longjiang, this research forms a rapid prototyping teaching platform oriented to intelligent product development. The constructed curriculum group and synchronous classroom mechanism are essentially a rapid prototype verification platform from "creativity to physical object". The 3D printed physical objects completed by students in the courses are not only teaching achievements, but also can provide reference value for cooperative enterprises in aspects such as product appearance review, ergonomic verification, assembly relationship testing, and mechatronics coordination inspection..

5. Conclusion

Taking the cultivation of engineering competence of industrial design majors as the core goal, the concept of "cross-border integration and practice-driven" under the Emerging Engineering Education initiative is translated into a practical teaching reform

plan. Through the systematic reconstruction of the four courses covering "materials, structures, mechanisms and electronics", the long-standing disciplinary knowledge barriers are broken down. The dual-line synchronous classroom mode with school-enterprise and inter-school collaboration introduces real enterprise engineering experience and high-quality off-campus teachers into the teaching scene in a low-threshold and low-cost manner, which alleviates the practical problems of local provincial colleges and universities such as the shortage of interdisciplinary teachers and the difficulty in transforming industrial resources. The closed-loop physical assessment based on 3D printing has changed the evaluation orientation of "valuing written work over practical implementation" in traditional teaching, enabling students to establish interdisciplinary engineering thinking in the complete product development process and effectively improve their ability to solve complex engineering problems.

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