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Digital Empowerment of Mechanical Engineering Drawing Blended Teaching Reform under the Background of New Engineering

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Abstract: Aiming at the problems of "emphasizing general norms and neglecting professional characteristics" and "lacking digital empowerment" in the teaching of mechanical engineering drawing under the background of new engineering disciplines, a mixed teaching reform plan is proposed with the core concept of "adaptation of mechanical majors, integration of digital technology, and collaborative education between industry and education". By restructuring the course content system of "basic core+mechanical characteristics+digital expansion", a three-dimensional teaching mode of "online self-learning+offline precision teaching+virtual simulation training" is established, integrating specialized digital tools such as SolidWorks and UG, and establishing a diversified evaluation system of "process+ability", to achieve the digital upgrade of mechanical engineering drawing teaching.

1. Introduction

Engineering drawing is a core foundational course for mechanical engineering majors, which directly connects with subsequent professional courses such as mechanical design, mechanical manufacturing, and numerical control technology. It undertakes the important mission of cultivating students’ spatial imagination ability, mechanical structure expression ability, and engineering specification awareness [1]. Its teaching quality directly affects students’ understanding and practical ability development of mechanical parts processing technology and equipment structure design. With the deep integration of new engineering construction and intelligent manufacturing strategy, the requirements for mechanical talents in fields such as engineering machinery, high-end equipment, and automobile manufacturing have shifted from "being able to recognize and draw drawings" to "being able to optimize drawings based on process requirements and use digital tools to complete design expression". The limitations of traditional engineering drawing teaching, which emphasizes general norms over mechanical professional characteristics, are becoming increasingly prominent.

There are three prominent problems in the current teaching of engineering drawing in mechanical engineering: firstly, the teaching mode is fixed at "blackboard drawing+standardized explanation", which students passively accept and lack the linkage thinking of "three-dimensional structure two-dimensional drawing processing technology" for mechanical parts. Secondly, the teaching content focuses on general drawing standards, with insufficient digital expression, parametric modeling, and CAD/CAM integration of core mechanical components, which is disconnected from the digital drawing needs of industries such as automotive manufacturing and high-end equipment. Thirdly, the practical process relies on physical models, making it difficult to carry out digital disassembly, mapping, and optimization design training for complex mechanical components such as reducers and engine connecting rods [2-3]. Therefore, with the support of digital technology and focusing on the characteristics of mechanical engineering, the reform of engineering drawing teaching has become an urgent need to improve the quality of mechanical talent cultivation.

2. The Core Concept and Goal of Teaching Reform in Engineering Drawing

In order to meet the needs of cultivating mechanical professionals in the context of new engineering disciplines and promote the deep adaptation of engineering drawing teaching to industry development and technological progress, the following core concepts and specific goals have been clarified in this teaching reform:

2.1 Core Reform Concept

Guided by the requirements of cultivating new engineering mechanical talents, establish the "three focuses" reform concept: firstly, "deep integration of digital technology and teaching", integrating specialized mechanical software such as SolidWorks and UG and virtual simulation technology throughout the teaching process, replacing traditional drawing tools, and strengthening the digital expression ability of mechanical parts [4]. Secondly, there is a precise alignment between content and the mechanical industry, closely focusing on job demands in fields such as automotive, high-end equipment, and engineering machinery, optimizing course content, and establishing a digital correlation between "drawings, processes, and equipment". Finally, there is a two-way integration of process and capability evaluation, breaking the single assessment and incorporating practical achievements such as digital modeling and virtual surveying of mechanical parts into the evaluation, achieving the goal of "promoting capability through evaluation".

2.2 Specific Teaching Objectives

Based on the training objectives of mechanical professionals, three major focus goals will be achieved through reform: basic ability goal - to enable students to proficiently master the national standards for mechanical drawing, accurately read and draw typical mechanical part drawings such as shafts, gears, and boxes, as well as assembly drawings such as reducers and clutches, and possess proficient application abilities of tools such as SolidWorks and AutoCAD. Engineering literacy goal

- to cultivate students' drawing expression thinking based on mechanical processing technology, forming a linkage cognition of "drawing process equipment" and rigorous engineering specification habits. Innovation Capability Goal - Guide students to use parametric modeling, virtual simulation and other tools to complete the optimization design and drawing iteration of mechanical parts, and form preliminary mechanical innovation design thinking [5]. The core concepts and objectives of the teaching reform in Engineering Drawing are summarized in Table 1.

Table 1 Core Concepts and Objectives of Engineering Drawing Teaching Reform

Module	Core content	Key points
Core reform concept (guided by the cultivation of new engineering mechanical talents)	Deep integration of digital technology and teaching	SolidWorks/UG/virtual simulation runs through teaching. Replace traditional tools. Strengthen digital expression
	Accurate integration between content and the mechanical industry	Docking with fields such as automobiles and high-end equipment. Optimize course content. Establish the understanding of "drawings process equipment"
	Dual integration of process and capability evaluation	Breaking the single assessment. Incorporate modeling/virtual surveying results. Realize the goal of 'promoting capability through evaluation"
Specific teaching objectives	Basic Ability Objectives	Mastering national standards. Read/draw typical part drawings/assembly drawings. Proficient in using drawing software
	Engineering literacy goals	Process oriented drawing expression. Linkage cognition of "drawings process equipment". Strict and standardized habits
	Innovation Capability Goal	Utilize parametric modeling/virtual simulation. Optimization design of parts. Forming innovative thinking

3. Specific Measures for the Reform of Blended Teaching

3.1 Refactoring the "Layered and Progressive" Curriculum Content System

In the curriculum reform, the traditional chapter-based content arrangement needs to be restructured. The course content is reorganized into three levels: foundation, core specialty characteristics, and frontier expansion, so as to achieve an accurate integration of knowledge teaching and professional requirements.

Basic Core Layer: Focusing on the core capabilities of mechanical drawing, retaining classic content such as "projection principles, view representation, and dimension annotation", eliminating redundant manual drawing training, and adding a "digital representation of mechanical parts" module. Using the teaching logic of "3D modeling driven 2D drawing", taking shaft parts as an introductory case, a 3D model with keyways and threads is constructed using SolidWorks, and a 2D engineering drawing that complies with the mechanical national standard (GB/T17452-1998) is generated. The focus is on explaining the correlation between tolerance annotation and 3D model settings, helping students establish a corresponding thinking of "mechanical structure digital model engineering drawing" [6].

Professional feature layer: Adhering to the full chain requirements of "design manufacturing assembly" in mechanical engineering, three core modules are set up: "Mechanical Core Parts Drawing", "Assembly Drawing Design and Process Connection", and "CAD/CAM Integration". Among them, the "Mechanical Core Parts Drawing" focuses on typical parts such as shafts, disks, gears, camshafts, and casings, with a focus on explaining the standardized expression of key slots, threads, tool grooves, and other structures, as well as the marking of geometric tolerances (such as circular runout and cylindricity requirements for shaft parts). In the course Assembly Drawing Design and Process Connection, a two-stage reducer is adopted as the core teaching carrier. The course elaborates on the representation of assembly relationships, the formulation of technical requirements (such as gear meshing clearance and bearing preload requirements), as well as its correlation with the machining process of parts. The "CAD/CAM Integration" module integrates parametric modeling and CNC machining path generation into UG software, achieving seamless integration of "2D drawings -3D models - machining codes" and adapting to the needs of intelligent manufacturing positions [7]. At the same time, for the subdivision directions of mechanical majors (such as intelligent manufacturing and automotive engineering), elective contents such as "Drawing of Automotive Transmission Parts" and "View Expression of CNC Lathe Spindle Components" will be added to achieve content adaptation of "professional core+direction expansion".

Digital Expansion Layer: To meet the digital transformation needs of the mechanical industry, three major topics have been established: "Parametric Design of Mechanical Parts", "CAD/CAM Integrated Application", and "Digital Twin and Drawing Association". Based on the parametric functions of SolidWorks, training on drawing updating driven by axial part dimensions is carried out to simulate enterprise engineering design change scenarios. In collaboration with enterprise teams, a case study on digital engineering drawing of engine connecting rods is conducted. By adopting 3D scanning point cloud data to reconstruct engineering drawings, students' ability in digital reverse engineering drawing is cultivated.

3.2 Constructing a Blended Learning Model of "Three-Dimensional Linkage"

Integrate online and offline teaching resources, build a three-dimensional teaching model of "online self-learning+offline precise teaching+virtual simulation practice", and achieve closed-loop teaching of "pre class in class post class".

Online self-learning session (pre class): Based on the school's online platform, we will build a "digital resource library for mechanical drawing". The core resources include a 3D model library for typical mechanical parts (shafts, gears, boxes), a micro course video on "parametric modeling drawing generation", a collection of real enterprise drawing cases, and an online self-test question bank (focusing on mechanical examination points such as geometric tolerance annotation and part structure expression). Before class, a targeted task list will be released, such as "completing step axis modeling and generating 2D drawings based on SolidWorks". The platform will automatically calculate the modeling time, drawing error rate, and other data. Based on this, teachers can identify common problems such as "non-standard expression of tool return grooves" and "errors in marking geometric tolerances", providing accurate positioning for offline teaching.

Offline precision teaching session (in class): Adopting a "problem oriented+mechanical case driven" mode, focusing on breakthroughs in online problems. For example, in the teaching of sectional views, the reducer box is taken as a typical teaching case. The dynamic cutting process is demonstrated by virtue of UG 3D models to compare the expression characteristics and applicable scenarios of full sectional views and half sectional views. Combined with the precision requirements for hole machining of box parts, the internal correlation between dimension marking of sectional views and mechanical machining processes is explained. In the enterprise case teaching session, the engineering drawings of engine crankshafts are introduced to analyze the matching logic between circular runout tolerance marking and the grinding process of main journals, so as to cultivate students' engineering design thinking of drawings serving manufacturing processes. Meanwhile, a practical teaching module of digital software operation is added to guide students on-site to master the method of automatic updating of engineering drawings after parametric modeling of gears by using SolidWorks.

Virtual simulation practice session (after class): Build a "mechanical exclusive" virtual training platform and carry out three core projects: basic projects (virtual surveying and drawing of shaft/disk parts), comprehensive projects (virtual disassembly and assembly of secondary reducers - part surveying - assembly drawing design), and innovative projects (structural optimization and drawing iteration of mechanical parts based on 3D modeling). For example, in the "Gearbox Assembly Drawing Design", students use VR devices to complete virtual disassembly and assembly of gearboxes, obtain fitting relationship data of gears and bearings, draw assembly drawings in AutoCAD, import them into the "Mechanical Drawing Process Review System", automatically check whether the "fit clearance annotation meets the assembly requirements", and finally submit them to the enterprise engineer for review. The platform is also equipped with a "CNC turning drawing docking" module, which enables students to directly import axis part drawings into the CNC simulation system to verify the feasibility of machining.

3.3 Integrating Teaching Methods and Tools Empowered by Technology

Supported by modern engineering technologies, innovative teaching methods are adopted to realize the digitalization, visualization and intelligence of the teaching process. Mechanical 3D visualization tool: Build a full range of 3D model libraries covering "shaft disk gear box", and use SolidWorks animation functions to break down teaching difficulties. For example, when explaining the "intersection line", the animation demonstrates the intersection process of "axis and sleeve welding" and marks the key control points of the intersection line. When explaining the "gear structure", the size correlation between the "tooth root circle" and the "indexing circle" is displayed through the model section, and corresponding 2D drawing annotations are generated synchronously to achieve the intuitive transformation of "3D structure 2D expression".

Mechanical Virtual Simulation System: Introducing the "Mechanical Engineering Drawing Virtual Training Platform" and setting up three functional modules: "Part Surveying", "Assembly Drawing Design", and "Drawing Review". In the "Parts Surveying" module, students can measure the dimensions of virtual axis parts (including details such as threads and keyways). In the "Assembly Drawing Design" module, virtual assembly is completed by dragging and dropping parts, and the system automatically prompts "incorrect expression of fitting relationship". In the drawing review module, the enterprise-level design review and approval process is simulated to foster students' awareness of standardization.

Intelligent tool for mechanical drawings: Introducing the "Mechanical Drawing AI Correction System" to automatically identify and locate errors in mechanical specific annotations such as circular runout tolerances for shaft parts and gear indexing circle dimensions. When annotating "shaft cylindricity tolerances", the system can provide optimization suggestions in comparison to the national standard GB/T 1182-2008. Through Tencent's document collaboration feature, students are organized as teams to complete the "reducer assembly drawing design", sharing the drawing process in real time and simulating the collaborative scenario of "drafter designer" in enterprises.

3.4 Establish a "Multi-Dimensional" Curriculum Evaluation System

Break away from the traditional evaluation mode of one-off final examination determining overall performance, and establish a diversified assessment system integrating process evaluation, terminal evaluation and value-added evaluation, so as to comprehensively assess students' knowledge mastery and competency development.

Process evaluation (accounting for 60%): covering three parts: online learning, offline performance, and practical projects. Online learning assesses video viewing completion and exercise accuracy based on platform data. Offline performance is evaluated through classroom discussion participation and case analysis quality. The practical project takes "drawing quality+team collaboration+innovative ideas" as the core indicator to score projects such as part surveying and assembly drawing.

4. Effectiveness and Reflection on Teaching Reform Practice

4.1 Practical Effect

After the implementation of this practical program, students' professional practical core abilities have been significantly improved. They can not only proficiently complete the design and modeling tasks of mechanical core components, but also actively optimize design schemes based on actual engineering needs. Their ability to solve engineering problems and innovative thinking in practice have been greatly enhanced compared to before the reform, and they have received high recognition from cooperative enterprises for their practical abilities. After specialized practical training, students have significantly improved their mastery and application proficiency of core professional technologies. They are able to independently complete practical tasks related to component performance analysis and damage prediction under complex working conditions. The efficiency and quality of team collaboration in completing comprehensive practical projects have been significantly improved, fully demonstrating engineering practical literacy that meets industry needs. The practical reform has achieved significant results, greatly enhancing students' ability to transform and apply theoretical knowledge. In professional related practical tasks and competitions, they are able to flexibly apply the learned technology to solve practical problems. Key ability indicators such as component design standardization and performance analysis accuracy have been significantly improved, and their confidence and initiative in professional learning have also been significantly enhanced.

4.2 Problems and Reflections

In the practice of reform, it has also been found that there are exclusive problems in the mechanical profession: firstly, some teachers lack practical abilities in digital technologies such as "UG parametric modeling drawing association update" and "CAD/CAM data connection", making it difficult to accurately guide advanced practices. The second issue is that the surveying and mapping scenarios for "large components of construction machinery" in virtual simulation resources are not perfect enough, and there is a gap between them and the actual needs of enterprises. The third issue is that the quantitative standards for the rationality of mechanical drawing processes in process evaluation are not detailed enough, and the scoring is easily influenced by subjective factors.

In response to the above issues, further efforts will be made in the following two aspects: developing a "virtual mapping library for core components of construction machinery" in collaboration with enterprises, and adding training scenarios such as engine cylinder blocks and gearbox housings. Introducing enterprise drawing review criteria, this practice refines quantitative indicators such as matching of dimensional tolerances with machining processes and rationality of geometric tolerance dimensioning, and realizes objective assessment with the support of an artificial intelligence system.

5. Conclusion and Outlook

Under the background of new engineering disciplines, the reform of engineering drawing teaching in mechanical engineering must be centered on "digital empowerment of professional abilities". By reconstructing the content of specialized mechanical courses, innovating the teaching mode of "digital tools+practice", and improving the ability oriented evaluation system, the transformation from "standardized teaching" to "digital engineering expression ability cultivation" can be achieved. Practice has shown that the integration of digital technology has effectively improved the drawing accuracy, 3D modeling ability, and process adaptation thinking of mechanical engineering students, enhancing the connection between courses and intelligent manufacturing positions. In the future, it is necessary to further deepen collaboration with mechanical manufacturing enterprises, fully integrate enterprise digital drawing standards and design processes into teaching, and provide the mechanical industry with high-quality talents who understand drawings, understand software, and are good at innovation.

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