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Research on the Teaching Mode Reform of Mechanical Engineering Drawing Courses Oriented by the Demands of New Quality Productive Forces

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Abstract: ***To meet the demands of new quality productive forces development for high-quality engineering talents, the mechanical drawing course, as a crucial foundational course in engineering education, urgently needs to promote the transformation of its teaching mode towards intelligence, digitalization, and personalization. Based on the current shortcomings of the mechanical drawing course in terms of teaching effectiveness, technology integration, and personalized support, this paper systematically explores the reform path for mechanical engineering drawing courses oriented towards the development of new quality productive forces. It first clarifies the curriculum philosophy centered on "digital transformation and multidisciplinary integration." Then, it proposes specific reform strategies from multiple aspects, including curriculum content restructuring, teaching resource development, competition mechanism embedding, and artificial intelligence technology integration. The aim is to enhance students' engineering practical ability and innovative literacy through practice.***

Keywords: New Quality Productive Forces, Mechanical Engineering Drawing, Teaching Mode Reform.

1. Introduction

In September 2023, during his inspection tour in Heilongjiang, General Secretary Xi Jinping proposed that "new-quality productive forces are advanced forms of productive capacity characterized by innovation as the primary driver, breaking away from traditional economic growth models and paths of productive force development. They feature high technology, high efficiency, and high quality, aligning with the new development philosophy." New-type productive forces constitute a production system characterized by higher efficiency, superior quality, lower costs, and greater environmental sustainability, achieved through technological innovation, management innovation, and institutional innovation. This underscores that the development of new-type productive forces fundamentally hinges on innovation. Spatial thinking and visual thinking are essential components of engineering professionals, form the foundation of engineering talent cultivation, and serve as the wellspring of innovation [1].

In the undergraduate teaching stage, the Mechanical Engineering Drawing course is currently the only discipline aimed at cultivating students' spatial thinking ability and visual thinking ability. It is an effective method and also a fundamental technical basic course that students first encounter upon entering university. Therefore, how to grasp the teaching principles of the mechanical engineering drawing course under the new situation, actively yet step-by-step and planned, promote the teaching reform of the mechanical engineering drawing course based on traditional teaching methods, and how to make the reform of the mechanical drawing course closely revolve around the core characteristics and requirements of new quality productive forces, is of significant practical importance for cultivating high-quality technical and skilled talents who can adapt to the development requirements of new quality productive forces.

2. Severe Challenges Facing Traditional Mechanical Engineering Drawing Courses

(1) Lagging Teaching Content. Currently, the teaching content of mechanical engineering drawing courses mainly includes descriptive geometry, basic knowledge of drawing, part drawings, and the drawing of assembly drawings [2]. This course not only contains extensive knowledge and strong theoretical aspects but is also difficult to apply in production practice. For example, traditional mechanical drawing courses emphasize details such as line types and section symbols in 2D drawings, but modern industries like aviation and automotive require embedding manufacturing information such as dimensional tolerances and surface treatments directly into 3D models, which is rarely covered in the courses. Furthermore, while CAD/CAM technology is increasingly used in the design and production of modern machinery, the teaching content still focuses on manual drawing, neglecting the cultivation of computer-aided design capabilities. Although CAD/CAM software has been introduced into mechanical drawing courses, the development of the software and its specific functions still cannot meet the actual needs of the industry. Research from an automotive company shows that 92% of manufacturing information for new energy motor housing design is transmitted through 3D models, while the coverage rate of related teaching content in university courses is less than 15%. This lag has created an "education-industry" gap, urgently requiring the restructuring of the mechanical engineering drawing course to match the competency requirements of talents for new quality productive forces.

(2) Traditional Teaching Mode. The current mechanical drawing course still primarily relies on the "chalk-and-talk" or "PPT-based" spoon-feeding teaching method. Teachers explain drawing standards item by item, and students passively absorb a large amount of theoretical knowledge. There is a lack of project-driven, problem-oriented

instructional design, and students' active learning ability and teamwork skills are not effectively exercised [3]. For instance, in teaching the expression methods of machine elements, teachers demonstrate standard sectional view drawing methods through PPT, and students passively replicate the steps, lacking in-depth discussion on design intent. The practical component of the course still focuses on hand-drawing 2D drawings, which completely deviates from the enterprise's need for 3D modeling, exploded views, and efficient output of engineering drawings. Teachers also need to manually correct students' drawings, making it difficult to comprehensively evaluate graphic standardization and accuracy with the naked eye. Therefore, manual correction is not only time-consuming and labor-intensive with low efficiency but also results in long feedback cycles, severely impacting students' learning experience and outcomes. The traditional teaching mode fails to achieve the transition from drawing skill training to "engineering language application," hindering the cultivation of digital design, intelligent collaboration, and innovative practical abilities required by new quality productive forces.

(3) Disconnect in Ability Cultivation. Against the backdrop of the rapid development of new quality productive forces, the traditional mechanical engineering drawing course is increasingly showing a disconnect between the abilities it cultivates and the demands of the times. New quality productive forces emphasize technological innovation as the core driver, integrating new technologies such as digitalization, intelligence, and greenization to promote industrial transformation and upgrading. This requires engineers to have not only a solid professional theoretical foundation but also comprehensive interdisciplinary abilities, proficiency with digital tools, and innovative design and collaboration capabilities. The traditional mechanical engineering drawing course lacks cultivation of students' innovative thinking, system integration ability, and engineering practical ability. This "drawing-centered" teaching model struggles to meet the demand for high-quality engineering and technical talents in emerging fields such as smart manufacturing, digital twins, and the industrial internet.

3. Core Concepts and Strategies for Reforming Mechanical Engineering Drawing Courses Oriented Towards New Quality Productive Forces

3.1 Reshaping the Course Philosophy

In the context of the rapid development of new quality productive forces, the philosophy of the mechanical engineering drawing course needs to shift from being drawing-centered to focusing on digital design expression and information management capabilities. As new quality productive forces take data as a key element and network collaboration as the core mode, if the mechanical engineering drawing course still focuses on cultivating students' hand-drawing skills, it will inevitably lead to a disconnect between student capabilities and market needs. In modern design and manufacturing processes, the 3D parametric model becomes the single source of truth for product definition. It directly carries all information, including geometric shape, dimensional tolerances, materials, process requirements, manufacturing annotations, etc. Therefore, the primary task of transforming the philosophy of the mechanical engineering drawing course is to place 3D modeling at the core, cultivating students' ability to create precise, standardized, and informationally complete 3D digital master models.

Furthermore, based on the urgent need for interdisciplinary engineering talents driven by new quality productive forces, the mechanical drawing course must break out of the silo of being an isolated course and upgrade to become a key bridge connecting design and manufacturing. Traditional teaching treats drawing as an independent basic course; students learn projection methods, expression methods for machine elements, part drawings, etc., only to find out in subsequent courses and enterprise settings that drawings are merely static snapshots of design intent, unable to drive CNC machine tools or interface with NC programs. The new positioning of the mechanical engineering drawing course can take the entire product lifecycle as the main thread, deeply integrating the course into the entire chain of "design-process-manufacturing-inspection," cultivating students' systematic ability to use the language of data to realize ideas and allow process feedback to inform design.

The course philosophy based on the context of new quality productive forces also requires deep integration with other disciplinary fields to achieve cross-disciplinary innovation. For example, integration with materials science, biological science, information science, and other fields can lead to the development of mechanical products with new material properties, biological functions, or information interaction capabilities, promoting industrial upgrading and innovative development. For instance, integration with biological science could involve designing mechanical systems that simulate muscle contraction for efficient energy conversion. This would break through the traditional geometric expression forms of the mechanical engineering drawing course, developing new symbol and annotation systems to describe complex biochemical interaction interfaces, using drawings to precisely express the compatibility interfaces of biological tissues.

3.2 Restructuring Course Content

To better adapt to the needs of new quality productive forces development and enhance students' comprehensive engineering literacy and innovation ability, the traditional mechanical engineering drawing course urgently needs content updates and teaching reforms, integrating modern elements such as digital design tools, 3D modeling technology, and engineering case analysis, while strengthening practical teaching and interdisciplinary integration.

First, the course content should systematically add teaching modules on the principles of digital design. This includes explaining basic theoretical knowledge such as parametric modeling concepts, feature-based modeling technology, and product data management [4]. Through learning this content, students can deeply understand the evolutionary logic from traditional engineering drawing to digital design and master the basic processes and methodologies of digital design. For example, focusing on explaining the fully digital process from conceptual design, detailed design to engineering drawing generation can help students establish a complete design thinking framework.

In the smart manufacturing system catalyzed by new quality productive forces, 3D modeling has become an indispensable skill for engineers. The teaching of mainstream simulation software applications needs to be strengthened in mechanical engineering drawing courses [5]. Software such as SolidWorks, CATIA, UG, and Pro/E can be incorporated into practical teaching sessions. During teaching, the focus should not only be on teaching basic software operations but also on cultivating students' ability to use simulation tools to solve practical engineering problems. In the past, 3D modeling methods in mechanical drawing courses mainly focused on static modeling of parts, lacking cross-disciplinary research integrating mechanics, physics, mechanical design, mechanical principles, and other subjects. Therefore, based on 3D modeling, by integrating engineering simulation software like ANSYS and ABAQUS into the 3D digital models, students can be guided to perform static, thermal-fluid-structural coupling, kinematic, and fatigue life simulations on key components; combined with optimization algorithms for iterative verification, the accuracy, reliability, and lightweight level of design schemes can be improved. For instance, typical cases can demonstrate how to verify structural strength through finite element analysis, optimize product fluid performance using computational fluid dynamics, and check the rationality of mechanism design using motion simulation.

New quality productive forces emphasize innovation-driven development, intelligence, and digitalization. Therefore, the mechanical drawing course must strengthen the cultivation of students' engineering practical ability [6]. Project-driven teaching introduces actual enterprise engineering projects as teaching cases, allowing students to complete the entire process from design to verification in a real or simulated engineering environment. The project-driven teaching model can effectively enhance students' engineering practical ability, innovative thinking, and teamwork skills, enabling them to better adapt to the future development trends of smart manufacturing. Figure 1 uses the design of a small mechanical transmission device as an example to show the specific flowchart for implementing project-driven teaching. Depending on the project workload and class size, groups of 4-6 students are formed, with reasonable task division based on students' different levels and characteristics. In the initial stage of the project, through a combination of in-class and out-of-class activities, students master basic knowledge points of mechanical drawing such as sectional views, cutaway views, and tolerance annotation, linking these knowledge points to specific parts or assembly problems in the project. Group members separately consult relevant literature to further understand thread markings, bearing codes, gear parameter tables, allowing students to learn with project tasks, making their goals clearer. During the project implementation process, the teacher's role shifts from lecturer to guide, consultant, and reviewer. Group or individual guidance is provided for students' sketches, expression schemes, dimensioning, part drawings, and assembly drawings, identifying and correcting problems promptly to avoid errors accumulating until the end. In the later stages of project implementation, simulating the enterprise drawing review process, students are organized to conduct cross-reviews or centralized teacher reviews, focusing on checking standardization, completeness, and rationality. The teaching model based on actual engineering can both exercise students' hands-on ability and cultivate their concepts of teamwork and project management.

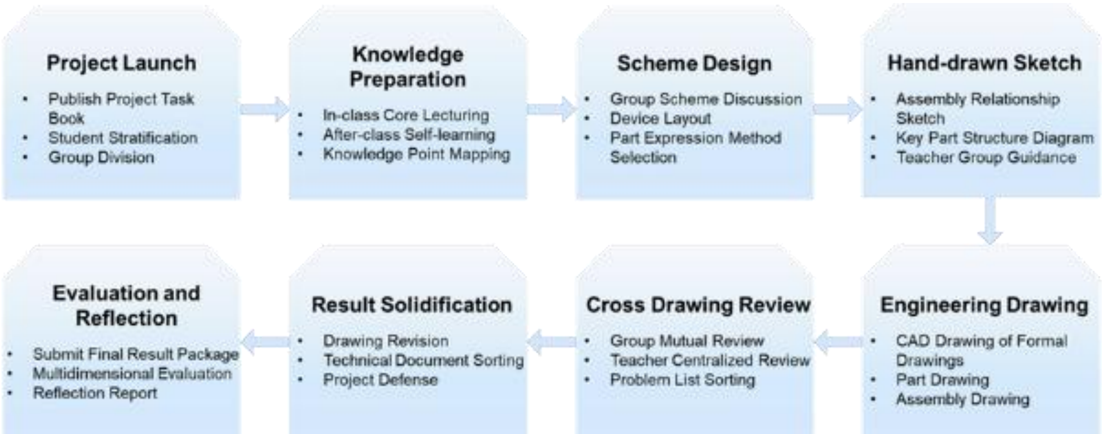

Figure 1: Implementation Process of Project-Driven Teaching Mode in Mechanical Engineering Drawing Course

3.3 Teaching Resource Development

With new quality productive forces centered on data-driven, intelligent collaboration, and green low-carbon development, traditional "paper-and-drafting tools" mechanical engineering drawing textbooks can no longer bear the requirements of interdisciplinary knowledge. Developing stereoscopic digital textbooks can integrate interactive simulation models and actionable manufacturing scripts into the same learning node, achieving a paradigm shift from "static drawings" to "dynamic engineering nodes," providing students with real-world scenarios connecting the entire lifecycle of design, manufacturing, and operation/maintenance, and cultivating digital engineering capabilities that meet the needs of smart manufacturing. Compared to the static text and graphics of traditional paper textbooks, digital textbooks, combined with information technology, integrate multimedia elements such as text, images, audio, and video, while also having interactive and real-time update functions, which can effectively improve classroom teaching efficiency and student learning interest. When students practice, the digital textbook uses AI technology to automatically identify where the student is stuck or has made a mistake, immediately providing hints and next-step suggestions. The digital textbook platform also dynamically adjusts practice difficulty, pushes micro-lecture videos, and even plans personalized learning paths based on each individual's learning trajectory. Knowledge is no longer unilaterally instilled but becomes a continuous dialogue, where students constantly try, and the system responds instantly, with learning pace and content flexibly changing accordingly. Ultimately, students internalize knowledge into ability through deep participation, and the habit of autonomous learning is formed. Besides, digital textbooks can ensure that the content keeps pace with the latest technological developments and teaching requirements. Teachers and students can add new teaching cases according to actual needs, and students with different progress levels can use them on demand.

As digital technology is widely applied in the education field, building a rich online resource library for the mechanical engineering drawing course, such as standard parts libraries, typical mechanism model libraries, design case libraries, virtual disassembly/measurement platforms, etc., is not only a technical means to provide resource support and guarantee for teaching but also an important measure to systematically promote educational modernization and construct a curriculum based on the development of new quality productive forces. Strengthening the construction of the course resource library can effectively enrich the supply scale and open sharing mechanism of high-quality educational resources, systematically integrate and intelligently manage digital resources, allowing teachers to closely combine various teaching resources with the course's teaching objectives and actual learning situations, enabling precise selection and effective use of teaching resources, thereby improving classroom teaching quality and student learning outcomes [7]. This transformation aligns with the current practical needs of the educational digitalization strategy and the innovative development of teaching modes.

The construction of the teaching resource library for the mechanical engineering drawing course involves the integration of high-quality, systematic, and diverse digital teaching resources. This type of resource library can systematically cover modules required by the course standards, such as theoretical explanations, drawing examples, 3D model animations, virtual simulation experiments, typical part drawing collections, and common error analysis, and can maintain its advancement and applicability through continuous updates. It not only promotes the comprehensive digitalization process of educational resources but also fosters equitable access between regions and institutions at the resource allocation level, breaking down the barriers of uneven resource distribution in traditional teaching. Based on this, the construction of the mechanical drawing resource library greatly expands the boundaries and depth of student learning. Students can flexibly utilize various resources such as paper textbooks, digital drawing libraries, online videos, and interactive simulations according to their own cognitive pace and learning style, achieving a cognitive leap from 2D drawings to 3D physical objects. Meanwhile, teachers can guide students to integrate real-life scenarios and regional industrial characteristics, incorporating enterprise real-case scenarios and production drawings into the learning process, enhancing the practical application ability of drawing reading, drawing, and modeling, truly realizing "learning for application."

3.4 Linking Competitions and Innovative Practice

In recent years, students have actively participated in various scientific and technological competitions, including the "Challenge Cup," "National University Students Advanced Graphical and Product Information Modeling Competition," "Mechanical Design Innovation Competition," etc. These competitions can comprehensively stimulate students' learning interest and creativity, focus on the development of their self-learning and teamwork skills, thereby greatly improving their comprehensive quality and innovation ability, effectively implementing the fundamental educational task of developing new quality productive forces [8]. In the teaching process of the mechanical engineering drawing course, the course syllabus can be appropriately integrated with the competition syllabi of these scientific and technological competitions. Through the high interest and challenge of competitions, students' learning interest can be attracted, and their innovation awareness and teamwork ability can be stimulated. Simultaneously, actively promoting interdisciplinary integration, breaking down barriers between traditional disciplines, and organically integrating the mechanical engineering drawing course with courses such as mechanical design, fundamentals of mechanical manufacturing, and precision design to construct interdisciplinary learning modules can both expand students' knowledge scope and deepen their understanding of the application of mechanical drawing in practical engineering, promoting the effective transformation of theory into practice.

To enhance students' practical ability, the teaching plan for the mechanical engineering drawing course can further increase the proportion of practical teaching in the curriculum system, adding various teaching forms such as experimental operations, skill training, and project design, helping students effectively transform the learned theory into practical application skills. The practical teaching component will also be closely linked with various disciplinary competitions, providing students with a platform for pre-competition training and preparation. The college can also strengthen the construction of academic clubs, integrate competition projects such as digital design and lightweight design into the daily activities of the clubs, and rely on the model of senior students guiding newcomers to promote experience inheritance and enhance teaching effectiveness. Establishing auxiliary courses such as basic ability training and modeling skill enhancement reflects the idea of "using competitions to stimulate learning, using learning to replace mechanical training," building a positive and competitive environment, and comprehensively enhancing students' professional literacy.

3.5 Empowerment through AI Technology

In the grand context of developing new quality productive forces and promoting high-quality economic and social development, mechanical engineering drawing, as the "language" of the engineering community and the cornerstone of mechanical design, must keep its teaching paradigm up-to-date, deeply integrating AI technology to cultivate innovative talents capable of navigating the future wave of intelligent design and manufacturing [9]. First, modern computer-aided design software integrated with AI functions can be introduced. These tools possess intelligent sketch prediction and auto-completion functions, capable of automatically generating precisely defined graphics that conform to geometric constraints based on the user's rough outline intent, greatly improving drawing efficiency. Meanwhile, AI-driven intelligent dimensioning and tolerance recommendation systems can automatically generate or optimize dimensioning schemes based on model features, assembly relationships, and process knowledge bases, avoiding human omissions and guiding students to understand the intrinsic connection between design and manufacturing. Additionally, an AI-assisted learning and personalized guidance system can be constructed in the teaching process. This system can analyze students' drawing steps and results in real-time, like a tireless "AI tutor," instantly identifying drawing errors such as incorrect projection relationships and non-standard annotations, providing modification suggestions, and pushing relevant knowledge point micro-lectures or classic cases. It can also generate personalized practice question banks based on each student's weak areas, achieving tailored teaching and strengthening learning outcomes, cultivating them into the interdisciplinary engineering talents urgently needed in the context of new quality productive forces, equipped with AI literacy.

4. Conclusion

This paper discussed the new requirements placed on the mechanical drawing course by the development of new quality productive forces. Based on this, it systematically proposed reform paths for the teaching philosophy, content, and mode of the mechanical drawing course oriented towards the needs of new quality productive forces. Through teaching reform practice, innovation will be promoted in multiple dimensions, including curriculum content restructuring, teaching resource development, competition mechanism integration, and artificial intelligence technology application. These reform measures will significantly enhance the teaching quality and effectiveness of the mechanical drawing course, providing important support for cultivating high-quality engineering and technical talents that align with the development direction of new quality productive forces.

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