

Method and Practice of Digital Graphics Course Based on Knowledge Graph of New Quality Productive Forces

Tianyi Sui, Jianbin Liu, Shan Jiang, Jian Xu

School of Mechanical Engineering, Tianjin University, Tianjin 300072, China

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Abstract New quality productive forces characterized by innovation and innovation-driven development are essentially talent-driven. The cultivation of engineering practice and innovation ability of science and engineering talents is closely related to the development of national science and technology. It serves as a decisive factor in seizing opportunities of the new round of scientific and technological revolution and industrial change. To align digital engineering graphics education with the evolving demands of industries driven by new quality productive forces and engineering practice, this paper proposes teaching methods based on digital teaching practices at Tianjin University. These methods aim to deepen students' understanding of new quality productive forces in engineering practice. The knowledge map of new quality productive forces is designed to enhance students' innovation ability based on cartographic knowledge. It achieves this by refining typical engineering application scenarios that address global scientific and technological issues, tackle economic challenges, meet national strategic needs, and improve people's life and health. This approach aims to cultivate innovative engineering and technical talents with a solid theoretical foundation, comprehensive innovation abilities, and strong engineering practice ability.

Keywords new quality productive forces, engineering graphics, knowledge mapping, engineering and technical personnel, teaching thinking

1 Introduction

Engineering education evolves through the interaction between teachers and students. It is essential not only to convey key teaching content but also to encourage students to actively explore knowledge in related fields

while cultivating the skills and competencies required for adapting to societal development (Yang, 2024). In the new era, the development of new quality productive forces has become the mainstream direction of the future of society. Characterized by innovation, new quality productive forces are both inherent requirements and priorities for promoting high-quality development. To support this trend, higher education stakeholders are expected to enhance the innovation in teaching and produce talents that drive industrial development in new quality productive forces (Lu, 2024).

Talent and innovation are closely intertwined, with talent being the foundation and the most influential factor in innovation activities. Innovation-driven development is essentially talent-driven. In the new era, the reform and development of digital higher engineering education have reached a new historical starting point (Schleicher, 2024). The cultivation of engineering practice and innovation abilities in science and engineering talents is crucial to national scientific and technological development. It is a decisive factor in seizing opportunities presented by the new wave of scientific and technological revolution and industrial transformation (Zheng & Wei, 2023). Concurrently, the active integration of digital teaching methods to enhance students' learning enthusiasm and broaden their knowledge base has become an important way to improve their practical and innovative abilities (Dong, 2024). Therefore, digital engineering education must be closely linked with and support industrial development and engineering practice (Potkonjak et al., 2016). It should refine typical engineering application scenarios facing the global scientific and technological frontiers, major economic battlefields, national strategic needs, and people's life and health (Zhou & Xu, 2023).

Specifically, in engineering graphics education, it is essential for digital graphics instruction to equip students with a deep understanding of the specific applications of engineering across various fields. This involves fostering students' ability to autonomously

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Shan Jiang (✉)

E-mail: shanjiang@tju.edu.cn

develop methods for applying graphics knowledge in diverse scenarios while enhancing their innovative capabilities. The ultimate objective is to cultivate engineering and technical talents with a strong theoretical foundation, comprehensive innovation skills, and practical engineering abilities.

2 Teaching and Practical Needs of Digital Engineering Graphics under the Background of New Quality Productive Forces Development

Engineering graphics, as a basic course for undergraduates in engineering colleges, aims to impart the essential knowledge and skills required for advanced mechanical courses. This course covers a wide range of topics and is important for students to get in touch with the mechanical profession and its field (Huang & Meng, 2005). In the engineering graphics learning, it is crucial to address how students adapt to the evolving demands and understand the shifting focus under the new quality productive forces development. This challenge has become the central concern in curriculum reform.

2.1 | Significance of Digital Engineering Graphics Education Reform for Talent Cultivation under the Background of New Engineering Disciplines

It is critical to introduce the latest developments in industry and technology, as well as the evolving requirements for talent cultivation, into teaching process. This involves updating teaching content and curriculum systems to build courses and instructional materials that align with industrial demands. Addressing the “last mile” problem is a central challenge in new engineering education (Zhong, 2017). The concept of new quality productive forces, establishing smooth connections between science, education, and talent, has become vital for creating a virtuous cycle for high-quality development. This requires universities to respond to the actual needs of revolutionary technological breakthroughs, innovate allocation of production factors, and facilitate the deep transformation and upgrading of industries, particularly in key areas such as future emerging industries.

As new engineering education reform and the demand for talent aligned with new quality productive forces evolve, it is imperative to adjust the engineering graphics instructional system to match contemporary industrial changes and advancements. Strengthening the connection between teaching content and

international frontier scientific research achievements, as well as strategic emerging industries, is essential. Enhancing students’ practical and innovative skills, stimulating their creative thinking, and integrating theoretical knowledge and practical application are vital for cultivating technical talents with a strong theoretical foundation, comprehensive innovation ability, and practical engineering expertise.

2.2 | Current Problems in the Knowledge System of Digital Engineering Graphics Teaching

Engineering graphics focuses on the fundamental principles and methods for both geometric and engineering reading, as well as drawing. For lower-grade undergraduate students, this course is crucial in developing students’ interest in mechanics, expanding their vision of engineering and technology, and developing effective learning strategies and basic engineering skills. Its primary objectives include enabling students to proficiently read and draw projections, master basic methods of dimensioning, and interpret part and assembly drawings. Additionally, students are required to master drawing techniques with tools such as rulers and compasses, as well as freehand sketching and computer-aided drawing techniques. Through these methods, they will be able to effectively create simple geometric shapes and combinations.

Based on these teaching objectives, the traditional engineering graphics teaching knowledge system introduces some engineering application cases. However, in the face of the new engineering education and the new demands for talent cultivation in contemporary high-quality development, the following problems exist: First, the connection between teaching knowledge system and frontier scientific and technological engineering fields is not close enough; second, there are limited opportunities for students to engage in engineering practice scenarios during digital learning process, resulting in insufficient extensibility for their practical experience; third, the logicity of the course knowledge system is inadequate, as it is the internal connection of knowledge points driven by practice. In response to these problems, the teaching team of Tianjin University has carried out a series of explorations on the knowledge system of engineering graphics.

3 Exploration of the Knowledge System of Digital Engineering Graphics Education Oriented to Emerging Fields

To better connect with the application scenarios of new

quality productive forces and teaching and research directions, the teaching team integrates knowledge points throughout the entire graphics teaching process. Utilizing different fields as points, engineering cases as lines, and knowledge groups formed by the specific content of cases as surfaces, the teaching team aims to construct a relatively complete knowledge system of graphics. This approach provides an important framework for bringing more strategic emerging industries into the engineering graphics teaching.

3.1 | Establishment of the Knowledge System of Digital Engineering Graphics Education Oriented to Emerging Fields

New quality productive forces refer to advanced productivity freed from the traditional economic development mode, which includes emerging and future industries. The emerging industries include new-generation information technology, biotechnology, new energy, new materials, high-end equipment, green environmental protection, and aerospace. The future industries include brain-like intelligence, quantum information, genetic technology, future networks, deep-sea and space exploration, hydrogen energy, and energy storage. Selecting typical scenarios suitable for the teaching process of engineering graphics and organically integrating them with the teaching process is the key to optimizing and improving the course content. This approach ensures that the instruction better meets the demands of cultivating engineering talents in the contemporary era.

It is urgent for teaching team to enhance the forward-looking layout of the educational knowledge system and facilitate the alignment of instructional contents with industrial demands. According to the context of emerging and future industries, the teaching team has made strategic adjustments and expansions to the curriculum system. For example, the teaching team adds advanced course units, including engineering

graphics in manufacturing, digital twin and its applications, and engineering visualization in virtual reality environment to keep pace with industrial development trends. The course knowledge system emphasizes key areas of new quality productive forces, such as aerospace, new energy, and high-end equipment, as shown in Figure 1. It aims to thoroughly explore graphic knowledge in these industries, seamlessly integrate relevant industrial cases into curriculum, and guide students to comprehensively understand the characteristics of emerging and future industries.

3.2 | Analysis of Teaching Cases of Digital Engineering Graphics for Specific Application Scenarios of New Quality Productive Forces

The graphics-oriented engineering practice decouples and reconstructs scientific research projects focused on new quality productive forces. This practice decomposes engineering practice problems and organizes them according to the graphics-oriented knowledge graph. It guides students to deeply participate in, perceive, understand, and master graphics-oriented knowledge points in cutting-edge scientific research projects. By participating in multidimensional learning process, students effectively improve their professional competence and innovation ability, better preparing themselves for future industries. For example, the high-end equipment, one of the strategic emerging industries, is the cornerstone of a strong country, which covers a wide range, such as aerospace, semiconductors, new energy, industrial robots, and industrial machines. To introduce high-end equipment into the knowledge-point teaching of engineering graphics course, it is essential to identify specific cases which stimulate students' learning interest, present a certain level challenge, and adapt to different teaching stages.

Taking etching equipment in semiconductor

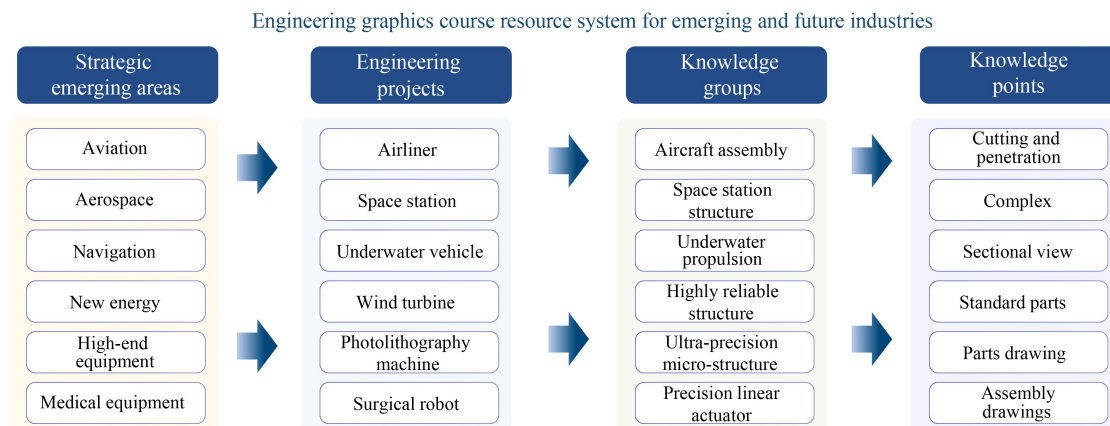


Figure 1 Graphical knowledge groups with emerging domains as dimensions.

manufacturing process as a typical case in the course, as shown in Figure 2, the knowledge points are introduced in the following order: the application background of etching equipment, the process flow of photolithography, epitaxy, and etching in chip manufacturing process, the key component of ceramic electrostatic sucker in etching machine, and its wafer adsorption function. The working principle of the suction cup adsorbing a wafer through electrostatic force is introduced, and the important role of structure of the suction cup in its adsorption function is analyzed through the principle. This integration of current technical status into teaching contents serves to enhance the relevance and practicality of the material being taught. Then, the key components of high-end equipment are connected with the core knowledge points, and the in-depth analysis is carried out. The results of the analysis present five relevant connections showing that the convex point structure of the wafer suction cup and the surface face system are related to the dimensional labeling in graphics; the internal multi-layer structure and the fluid channel are related to the section view; the surface quality requirements of the wafer contact area are related to the surface quality requirements of the part drawings; and the final ceramic electrostatic suction cup composed of multiple parts is related to the assembly drawings. The functions and design methods of internal and external structures in key components such as wafer suction cups are connected with their graphical representation, and the parts are integrated with the whole process through the introduction of full section view, knowledge point learning, and classroom knowledge analysis and application. This method ensures that students not only master essential concepts in engineering graphics, but also acquire related knowledge in semiconductor

manufacturing. By linking these elements, students gain a comprehensive understanding and expand their horizons. Additionally, this approach arouses students' interest in emerging areas of high-quality productive forces and advanced technologies.

4 Application of the Knowledge System in the Teaching Process of Digital Engineering Graphics Course

Since 2013, Tianjin University has united with numerous domestic universities to develop the engineering graphics course knowledge system supported by information technology. This initiative led to the establishment of the East–West University Course Sharing Alliance which aims to share high-quality teaching resources nationwide, especially in remote and resource-limited areas in the west. The goal is to improve the spatial thinking abilities and nurture excellent engineering talents. Through a series of teaching reform initiatives, Tianjin University has been piloting engineering graphics online course since 2015. This course has benefited nearly 195 universities across the northeast, southwest, and northwest regions, with over 60,000 students participating in total, including more than 10,000 from Tianjin University.

Since the course has deeply carried out the construction of the new quality productive forces knowledge system, students have responded enthusiastically. Practical activities not only hone students' skills in solving engineering problems but also broaden their horizons in the frontiers of mechanical field. As a result, many students have developed a strong interest in key national strategic fields such as aerospace and

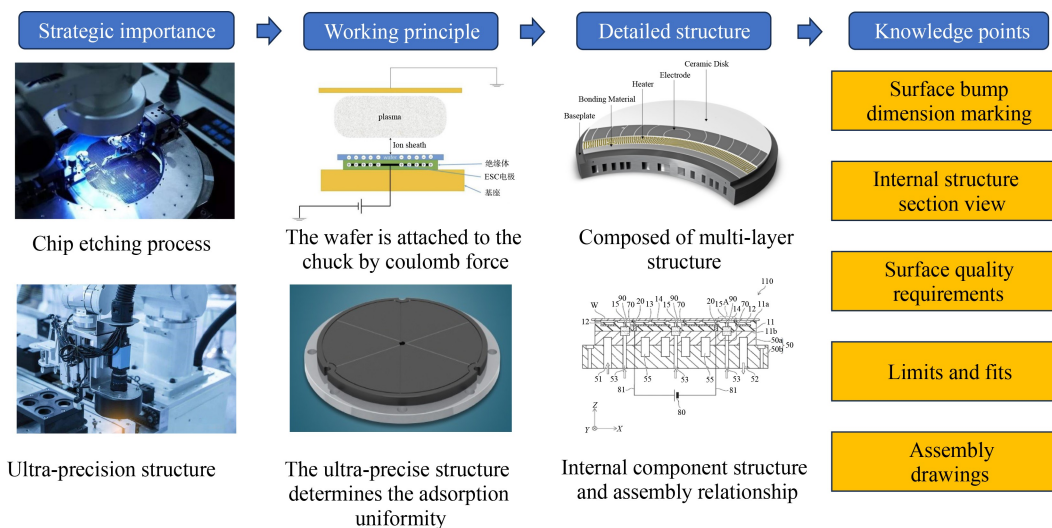


Figure 2 Example of disassembling engineering drawing knowledge points in scientific research projects and engineering projects.

semiconductors, effectively broadening their knowledge system related to emerging frontiers. This engagement lays a solid foundation for subsequent mechanical courses, especially for cultivating students' innovative and creative abilities based on graphic knowledge.

5 Conclusions

This paper analyzes the new demands of new quality productive forces for engineering talent education and identifies current problems in the knowledge system of digital engineering graphics teaching. To address these challenges, we designed a method for deeply integrating strategic emerging fields with digital engineering graphics education. Our exploratory efforts have yielded significant results. The construction of the engineering graphics knowledge system to new quality productive forces is a systematic project. It necessitates that frontline engineering graphics teachers to lead with their own research directions, deeply explore the engineering application points in engineering graphics, and further expand the depth and breadth of the course. This contributes to the cultivation of engineering and technical talents with a broad perspective and innovation ability.

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Data Availability Statements The authors confirm that all data generated or analysed during this study are included in this published article.

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