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Precision-Oriented Course Development and Practice for Cultivating Innovative and Application-Oriented Talents through Case-Based Teaching: A Case Study of Fundamentals of Interchangeability and Measurement Technology

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Abstract: This course development initiative adopts case-based teaching as a key approach to meeting the practical needs of cultivating innovative and application-oriented talents in the context of emerging engineering education. Focusing on key challenges in differentiated instruction, talent development, and teaching effectiveness, a precision-oriented approach to teaching reform was developed. By selecting representative engineering cases and incorporating authentic engineering contexts into classroom instruction, the approach facilitates targeted knowledge delivery. A knowledge graph is employed to integrate course content and overcome disciplinary boundaries, thereby establishing a systematic and progressive teaching content framework. In addition, a four-stage assessment mechanism is implemented to strengthen process-oriented evaluation and competency-based assessment. Practice has demonstrated that this approach effectively enhances students' engineering literacy and overall competencies, while offering good feasibility and potential for wider application.

1. Introduction

The director general of the department of higher education of the ministry of education, emphasized in report, "Strengthening the New Infrastructure of Teaching to Support High-Quality Talent Development," that the core of high-quality higher education lies in the quality of talent development, which further identified the "new infrastructure" of higher education teaching in the new era as comprising academic programs, courses, textbooks, and educational technologies. To fully implement the fundamental mission of fostering virtue through education, it is therefore essential to ensure the quality of academic programs, courses, and textbooks while enhancing the level of educational technology. Accordingly, undergraduate education should remain the foundation of higher education, address key challenges in educational reform and development, and cultivate highly competent innovative and application-oriented talents. This approach can enable higher education institutions to provide direct and effective support for national and local economic restructuring, high-quality industrial development, and rapid technological innovation [1-2].

Case-based teaching originated from instructional practices that incorporate specific contexts and scenarios into course instruction and has become a widely used and effective educational approach. By creating concrete learning contexts, it makes tacit knowledge explicit and transforms explicit knowledge into internalized understanding, thereby promoting the integration of disciplinary knowledge and learners' cognition. Under the guidance of instructors, representative cases are designed in line with instructional objectives, through which students acquire knowledge and engage in case analysis, discussion, and practice. This approach enhances students' ability to analyze and solve engineering problems while developing their capacity to apply theory to practice, engage in self-directed learning, communicate effectively, think innovatively, and collaborate.

Fundamentals of Interchangeability and Measurement Technology is a core foundational course in the Mechanical Design, Manufacturing and Automation program and plays a key role in supporting the program's educational orientation and talent development objectives. A review of teaching practices in recent years identified three major challenges [3-5]. (1) Difficulty in implementing differentiated instruction. In the context of large-scale foundational education and talent development, personalized learning emphasizes differentiated instruction through customized teaching, complex learning data, and diversified assessment. However, the limited availability of teaching resources, coupled with substantial individual differences among students, makes it difficult for instructors to comprehensively and accurately monitor each student's learning process. (2) Difficulty in establishing a coherent talent development system. As general education expands in breadth and professional applications deepen, emerging engineering education and discipline-based talent development have broadened the role of established foundational courses, emphasizing the integration of general and specialized education. However, insufficient coordination among courses has resulted in gaps in the logic, continuity, and systematic organization of the knowledge system. (3) Difficulty in evaluating teaching effectiveness. The coexistence of standardized assessment criteria and diverse levels of student understanding, together with increasingly diverse faculty structures and individualized talent development, has naturally led to differentiated instruction. This poses considerable challenges for the unified management and standardized assessment of student teams [6-7].

To address the challenges of large-scale personalized education and support the cultivation of highly competent innovative and application-oriented talents, this study proposes a precision-oriented course development and practice model based on case-based teaching, using Fundamentals of Interchangeability and Measurement Technology as an example. In response to the needs of emerging engineering education, the model follows a three-layer logic of "precision–drip–irrigation," with innovative and practical competence development as its central focus and disciplinary advances as an important reference. The first layer, "precision," emphasizes the targeted delivery of knowledge by integrating high-quality engineering cases with authentic engineering scenarios, guiding students to actively apply and analyze acquired knowledge. The second layer, "drip," focuses on the sustained internalization of knowledge by integrating course structure, knowledge, and competencies and using high-quality cases to promote classroom engagement, active learning, and teaching innovation. The third layer, "irrigation," emphasizes the systematic development of students' competencies by incorporating disciplinary advances, broadening their professional perspectives, and establishing a well-structured knowledge and competency framework. Through the progressive integration of these three layers, the model enhances teaching quality and promotes the high-quality development of the course, while contributing to the cultivation of students' scientific and technological innovation awareness, scientific literacy, practical competence, and overall competitiveness.

2. Research Content and Methodology

To address the challenges of large-scale personalized education and support the cultivation of highly competent innovative and application-oriented talents, this study proposes a "precision-drip-irrigation" framework for course development and practice based on case-based teaching, using Fundamentals of Interchangeability and Measurement Technology as an example. The framework comprises three progressive layers. "Precision" refers to the targeted delivery of knowledge through the integration of high-quality course cases, which guide students to actively apply acquired knowledge, analyze problems, and reconstruct authentic engineering scenarios. "Drip" refers to the sustained internalization and integration of knowledge, achieved through a knowledge graph that connects course structure, knowledge, and competencies and promotes continuous learning. "Irrigation" refers to the systematic development of students' knowledge and competencies through a four-stage assessment framework specifically designed for case-based teaching. Together, the three layers form a progressive pathway from targeted knowledge delivery to sustained knowledge internalization and ultimately to systematic competency development, thereby improving teaching quality and effectiveness and promoting the high-quality development of the course.

2.1. Implementing Differentiated Instruction

Given the importance of teaching case development, case integration should follow the principles of typicality, relevance, currency, and applicability. High-quality online and offline course resources are integrated with the teaching team's research, teaching, and competition projects to identify representative cases that effectively illustrate relevant theories and concepts and have broad applicability. Emphasis is placed on differentiated instruction through customized teaching processes and diversified assessment methods. Students are guided to actively apply acquired knowledge to analyze problems and reconstruct authentic engineering scenarios, thereby achieving targeted knowledge delivery through "precision".

2.2. Establishing a Coherent Talent Development System

Fundamentals of Interchangeability and Measurement Technology is characterized by numerous standards, symbols and codes, abstract concepts, and technical terms, as well as extensive and highly practice-oriented content. At the same time, its knowledge base spans multiple foundational courses, including graphical representation and dimensioning in Mechanical Drawing, the fundamentals and applications of typical mechanical components in Mechanical Design, mechanical structures in Theory of Machines and Mechanisms, and computer-aided drawing. This broad knowledge base requires effective integration and coordination across courses. To address this need, case content is refined and connected with relevant knowledge from related courses, while a knowledge graph is employed to integrate general and specialized education and establish cross-course linkages. This integration strengthens the logical coherence, continuity, and systematic structure of the knowledge system, enabling course content to be delivered progressively and continuously through the "drip" approach. Ultimately, these efforts contribute to the development of a coherent and sustainable talent development system.

2.3. Evaluating Teaching Effectiveness

The assessment system should be designed according to the principles of consolidating foundational knowledge, emphasizing practical application, and developing competencies. Course knowledge should be translated into practical skills for assessment through a four-stage framework comprising continuous assessment, practical assessment, midterm assessment, and final assessment. This framework optimizes the overall assessment process, strengthens the role of continuous assessment, reinforces the evaluation of practical competencies, and enhances the specificity of midterm assessment. Standardized assessments are normalized to ensure consistency, while diversified evaluation is embedded throughout routine teaching. These measures facilitate unified team management and standardized assessment, enabling the four-stage assessment framework to systematically integrate knowledge and competencies, improve teaching quality and effectiveness, and ultimately support the cultivation of highly competent innovative and application-oriented talents.

3. Conclusion

To address the challenges of large-scale personalized education and support the cultivation of highly competent innovative and application-oriented talents, this study proposes a precision-oriented course development and practice model based on case-based teaching. In response to the needs of emerging engineering education, the model takes the development of innovative and practical competencies as its central focus and integrates advances in the discipline. Using high-quality cases from Fundamentals of Interchangeability and Measurement Technology, students are guided to actively apply acquired knowledge to analyze problems. By simulating authentic scenarios, students can enhance their ability to analyze and solve problems through discussion and collaborative inquiry. Case-based teaching also encourages active participation, thereby fostering teamwork and communication skills. In addition, it stimulates students' interest in learning and broadens their knowledge base. Although developed in the context of mechanical engineering, case-based teaching is also applicable to disciplines such as computer science and software engineering, demonstrating broad applicability. When integrated with the principles of deep learning, case-based teaching can further activate students' intrinsic motivation and promote higher-order thinking and deeper understanding.

In conclusion, the precision-oriented course development and practice model based on case-based teaching for cultivating innovative and application-oriented talents demonstrates broad potential for dissemination and application. Its openness and interactivity, together with its successful application across multiple disciplines, provide a strong basis for its wider adoption and further development.

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