An Exploration of New Engineering Curriculum Construction Based on OBE and Knowledge Graph

Youliang Tang, Jingqi Zhang, Ziming Sang, Chunming Xu, Tao Jiang*
School of Mechanical and Electrical Engineering, Suqian University, Suqian, Jiangsu, China
**Corresponding Author*

Abstract: With the accelerated digital transformation of higher education, optimizing the teaching model for Fundamentals of Mechanical Manufacturing Technology, a core course for mechanical design, manufacturing, and automation majors, has become essential to improving talent cultivation quality. This study explores how the Outcome-Based Education (OBE) approach and knowledge graph technology can be integrated to optimize the course's teaching model and improve learning outcomes and teaching quality. By clarifying course objectives, structuring the knowledge system, developing teaching resources, and implementing diversified assessment, the study constructs an OBE- and knowledge-graph-based teaching model for the course. The model provides theoretical and practical guidance for the course's digital transformation and supports innovation in mechanical engineering education.

Keywords: Outcome-Based Education; Knowledge Graph; Mechanical Manufacturing Technology; Curriculum Construction

1. Introduction

In recent years, Outcome-Based Education (OBE) and knowledge graph technology have attracted growing attention in education and have provided new approaches to curriculum development [1,2]. Integrating OBE with knowledge graph technology can establish a new framework for teaching "Fundamentals of Mechanical Manufacturing Technology" [3-5]. Outcome-oriented objectives and personalized knowledge visualization can strengthen student motivation and teaching effectiveness while giving instructors more precise feedback for continuous improvement [6]. Accordingly, this study investigates how the two approaches can be combined to optimize the course's teaching model, improve learning outcomes and teaching quality, support the course's digital transformation, and advance innovation in mechanical engineering education [7-12].

2. Specific Methods for Developing the Course "Fundamentals of Mechanical Manufacturing Technology"

2.1 OBE-Based Curriculum Objective Design

"Fundamentals of Mechanical Manufacturing Technology" is a core course for the Mechanical Design, Manufacturing and Automation major. It addresses the principles of metal cutting, process design, and machining-quality analysis and control required to manufacture parts to specified quality standards. The course has three main characteristics. First, it is content-rich and highly specialized, covering cutting principles, machining and assembly process specifications, and machining-quality analysis and control across the full parts-processing and assembly workflow. Second, it is interdisciplinary, integrating mechanical engineering, materials science, automation, physics, mathematics, probability, and statistics. Third, it is strongly practice-oriented, with three experiments, including one comprehensive experiment, as well as two weeks of course design and production internship. By combining theory and practice, this model focuses on developing students' ability to translate theoretical knowledge into practical application. Based on the OBE philosophy, the teaching objectives for this course are designed as follows: [7,10-12]:

Objective 1 (Knowledge Objective): Master the fundamental principles of metal cutting, including cutting tool selection methods, force and thermal phenomena during the cutting process, and the selection of cutting parameters. Understand the factors affecting machining quality and analyze errors in the machining process.

Objective 2: Process design objective: Master the design steps and calculations for process specifications with attention to quality, efficiency, and cost. Analyze the machining processes and structural manufacturability of typical parts, and evaluate their effects on production and the environment from the perspective of process economics.

Objective 3: Competency objective: Understand domestic and international trends and research priorities in mechanical manufacturing and typical-part processing, and communicate effectively about relevant theoretical and experimental topics.

2.2 Construction of a Curriculum Knowledge System Based on Knowledge Graphs

2.2.1 Summary of Teaching Content

Constructing a knowledge-graph-based system for "Fundamentals of Mechanical Manufacturing Technology" begins with a comprehensive review of the course content. The selected textbook is Fundamentals of Mechanical Manufacturing Technology (ISBN 978-7-113-30314-3), edited by Yong Zang, Youliang Tang, Tao Jiang, et al. Designed for application-oriented undergraduate education, it comprises nine chapters and six practical projects. Based on the talent-development program and course objectives, the course focuses on five areas: fundamental knowledge of metal cutting, basic theories of metal cutting, process design, typical-parts machining, and machining quality. Supporting resources include textbook content, multimedia materials, and matching experiments. Figure 1 shows the teaching content and its relationships.

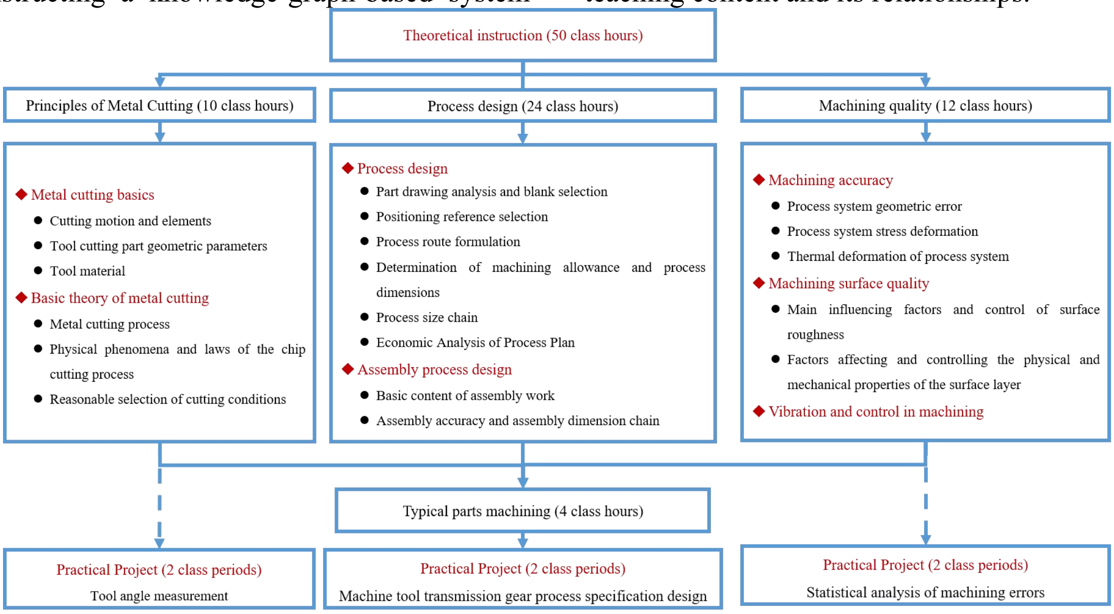

Figure 1. Teaching Content of the Course "Fundamentals of Mechanical Manufacturing Technology"

In addition to serving Mechanical Design, Manufacturing and Automation majors, the course is also offered to students in Intelligent Manufacturing Engineering and Automation. Therefore, the course content covers a wide range of complex knowledge points, including fundamental knowledge of metal cutting, basic theories of metal cutting, advanced machine tools, machine tool fixture design, process planning design, and machining quality. These knowledge points are closely interconnected, but traditional teaching methods often fail to clearly present these connections. Therefore, a systematic review of the course content is necessary to clarify each knowledge point and its interrelationships.

2.2.2 Knowledge Graph Construction

After summarizing the course content, the next step is to use knowledge graph technology to transform these knowledge points into a visual knowledge network. Knowledge graphs graphically present the various knowledge points and their relationships within a knowledge system, helping students to more intuitively understand the hierarchical structure and internal connections between knowledge [1,2,4]. The specific construction process is as follows:

(1) Node definition: Each knowledge point is defined as a node in the knowledge graph. For example, knowledge points such as "basic knowledge of metal cutting", "basic theory of

metal cutting", "metal cutting machine tools", "machine tool fixture design", "process specification design" and "machining quality" are each treated as independent nodes.

(2) Definition of relationships: Clarify the relationships between the knowledge points and define these relationships as connecting lines. For example, there is a basic relationship between "basic knowledge of metal cutting" and "basic theory of metal cutting", which can be represented by directed edges; there is a causal relationship between "basic theory of metal cutting" and "process specification design", which can also be represented by directed edges.

(3) Attribute definition: Define attributes for each node and relationship to provide more detailed information. For example, node attributes may include the definition, importance, and application scenarios of knowledge points; relationship attributes may include relationship type and degree of influence.

(4) Visual presentation: Use knowledge graph tools (such as Neo4j, D3.js, etc.) to visualize nodes, relationships and attributes to form a complete knowledge system graph.

In this way, students can intuitively see the hierarchical relationships and internal connections between various knowledge points, thereby better understanding and mastering the course content.

2.2.3 Dynamic Updates and Optimization of Knowledge Graphs

The dynamic updating function of the knowledge graph is crucial to ensuring the continuous optimization of the course knowledge system. With the continuous development of mechanical manufacturing technology, new processing methods, material applications, and quality control technologies are constantly emerging. Therefore, the knowledge graph needs to be updated regularly to reflect these latest developments. The specific updating process is as follows:

(1) Adding new knowledge points: Add new knowledge points to the knowledge graph in a timely manner. For example, with the rise of intelligent manufacturing technology, relevant knowledge points can be added, such as the architecture of intelligent manufacturing systems and intelligent processing technology.

(2) Relationship updating: Update the relationships between knowledge points based on new knowledge points and teaching needs. For example, newly added intelligent manufacturing technologies may have new relationships with existing basic theories of metal cutting and process design, which need to be updated in the knowledge graph.

(3) Attribute update: Update the attributes of nodes and relationships to reflect the latest knowledge information. For example, update the definition, importance, application scenarios and other attributes of knowledge points to ensure the accuracy and timeliness of the knowledge graph.

(4) Feedback mechanism: Establish a feedback mechanism for teachers and students to collect opinions and suggestions on the knowledge graph in a timely manner and further optimize the content and structure of the knowledge graph.

Through continuous updating and optimization, the knowledge graph can remain current and provide students with high-quality learning resources [6].

2.3 Development of Teaching Resources for Knowledge Points

In the course construction of fundamentals of mechanical manufacturing technology based on knowledge mapping, the development of teaching resources should cover multimedia courseware, video tutorials, online exercises and other aspects to meet the learning needs of different students and promote personalized learning [3,8].

(1) Multimedia courseware. Multimedia courseware is an indispensable part of modern teaching. In the course of fundamentals of mechanical manufacturing technology, developing high-quality multimedia courseware can show students abstract theoretical knowledge in an intuitive and vivid way. For example, using animation and graphics to show the cutting force, cutting heat and other phenomena in the metal cutting process can help students better understand the complex physical process. In addition, interactive modules such as virtual experiment and simulation operation can also be embedded in the courseware, so that students can carry out practical operation in the classroom, so as to enhance the interest and participation of learning.

(2) Video tutorial. As an important teaching resource, video tutorials can provide students with intuitive learning experience. Developing video tutorials (such as machine tool operation demonstration, fixture design process, typical

parts processing technology, etc.) for the course content of fundamentals of mechanical manufacturing technology will help students better understand and master practical operation skills. These video tutorials can not only be used for classroom teaching, but also be uploaded to the online learning platform for students' review and autonomous learning after class, so as to meet the needs of different students in learning time and progress.

(3) Practice online. Online practice is an important means to evaluate students' learning effectiveness. Develop an online practice system that matches the course content and can provide instant feedback and personalized learning support for students. Online exercises can include multiple types of questions such as single choice questions, blank filling questions, short answer questions, etc., covering all knowledge points of the course. Through the online question and answer function assisted by artificial intelligence, the system can automatically generate personalized exercise plans according to students' learning progress and answer performance, helping students consolidate knowledge and improve learning effect. In addition, the online practice system can also record students' learning data, provide teaching feedback for teachers, and help them adjust teaching strategies in time.

2.4 OBE-Based Diversified Evaluation System

The course objectives mainly focus on several assessment methods. Final grades include assignments (10%), experiments (10%), quizzes (20%) and final exams (60%). Final exams and quizzes are written, while laboratory work is assessed through student performance and laboratory reports. The assignment includes six online tasks and a peer review presentation. Online homework is graded through superstar learning platform, demonstrating the use of separate scoring criteria. Figure 2 shows the assessment system.

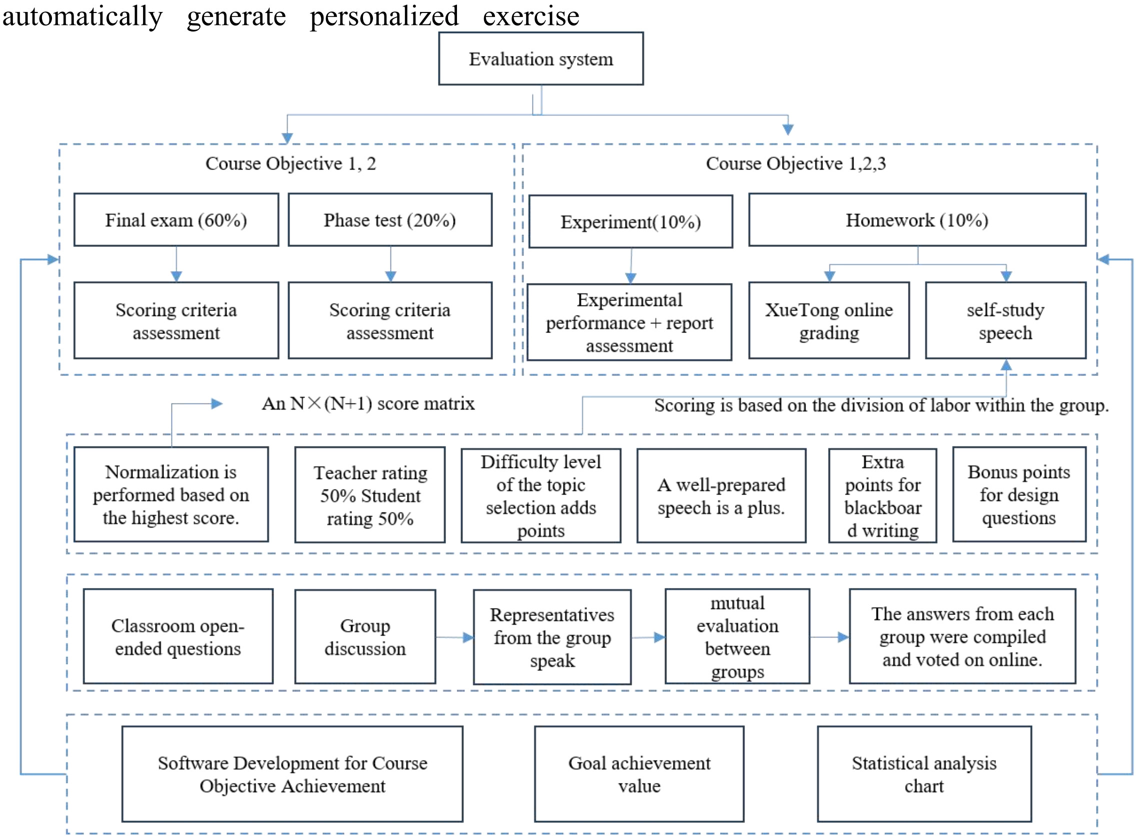

Figure 2. Evaluation System

3. Course Teaching Model Based on OBE and Knowledge Graphs

The OBE teaching model for "Fundamentals of Mechanical Manufacturing Technology" uses intended learning outcomes to design course objectives, content, methods, and assessment in reverse, ensuring that all teaching activities support student achievement [5,10,11]. It combines three approaches: research-informed teaching, information-technology-supported resource development, and student presentations with peer review. Knowledge graphs connect these approaches and help improve teaching quality and learning outcomes. The model supports students' understanding of course content while developing research literacy, practical skills, and innovative thinking, thereby contributing to innovation in mechanical engineering education

3.1 Scientific Research Supports Teaching

Research-driven teaching integrates research findings and thinking into the teaching process, enabling students to access cutting-edge research knowledge and methods, and cultivating their research literacy and innovation capabilities [9]. In the course "Fundamentals of Mechanical Manufacturing Technology," research-driven teaching can be implemented in the following ways.

(1) Integrating research findings into course content. Teachers' research findings are transformed into teaching resources, such as incorporating the latest research results in mechanical manufacturing technology and innovative processing techniques into the course content. For example, when explaining the principles of metal cutting, the latest cutting force models and research results on cutting heat distribution can be introduced to help students understand complex physical phenomena. Through knowledge graphs, these research findings are linked to the knowledge points in the course, forming a visual knowledge network to help students better understand and apply this cutting-edge knowledge.

(2) Scientific Research Case Analysis. By analyzing actual scientific research cases, students are guided to apply their knowledge to solve practical problems. For example, typical mechanical manufacturing research projects, such as precision machining technology in intelligent manufacturing, are selected, allowing students to analyze the key technical problems and solutions in the projects, thereby cultivating their engineering practice ability and innovative thinking. Knowledge graphs can be used to display the knowledge points and solution paths in the cases, helping students to systematically understand and analyze problems.

(3) Scientific Research Thinking Training. During the teaching process, students are guided to adopt scientific research thinking methods, such as posing questions, hypothesizing, experimental verification, and data analysis. For example, when learning process design, students are encouraged to design their own experiments to verify the impact of different process parameters on processing quality, thus cultivating their scientific inquiry abilities. Knowledge graphs can record students' scientific research thinking processes, helping them to organize their thoughts and optimize their research methods.

3.2 Application of Information Technology and Construction of Teaching Resources

The application of information technology can provide rich resources and flexible learning methods for teaching, meeting students' personalized learning needs. In the course "Fundamentals of Mechanical Manufacturing Technology," the application of information technology and the construction of teaching resources can be achieved through the following methods.

(1) Multimedia courseware and video tutorials. Develop high-quality multimedia courseware and video tutorials to present abstract theoretical knowledge to students in an intuitive and vivid way. For example, use animation to demonstrate phenomena such as cutting force and cutting heat in the metal cutting process to help students better understand complex physical processes. Knowledge graphs can be combined with multimedia courseware and video tutorials to provide connections and navigation between knowledge points, helping students learn the course content systematically.

(2) Online learning platforms. Utilize online learning platforms, such as Chaoxing Learning Platform and Zhihuishu, to publish course resources, including teaching materials, video tutorials, and online exercises. Students can learn course content online, complete assignments and tests according to their own learning progress and time schedule. Teachers can monitor students' learning progress in real time through the platform and provide personalized learning suggestions. Knowledge graphs can be embedded in online learning platforms to provide students with personalized learning paths and resource recommendations, meeting the learning needs of different students [5,6].

(3) Virtual experiment and simulation software. The introduction of virtual experiment and simulation software enables students to carry out practical operation in the virtual

environment, so as to improve their engineering practice ability and literacy. For example, using virtual machine tool software, students can practice machine tool operation in a virtual environment and be familiar with the operating procedures and processing technology of the machine tool. In addition, the combination of knowledge mapping and virtual experiment and simulation software can provide knowledge background and operation guidance for experimental operation, and help students complete experimental tasks more effectively.

3.3 Student Presentations and Peer Review

Student presentation and peer review is a student-centered teaching mode, which can stimulate learning initiative and cultivate the ability of communication, teamwork and critical thinking. In the course of "Fundamentals of mechanical manufacturing technology", the following methods can be adopted to implement student presentation and peer evaluation:

(1) Group project and presentation: divide students into groups and assign project tasks related to the course content (such as designing typical machining process procedures). Team members collaborate to complete the project and present it in class, presenting the project results and learning experience. Using knowledge map to show the knowledge points and problem solving paths in the project is helpful for students to systematically understand and analyze problems.

(2) Peer review and feedback: after the presentation, teachers and students will jointly evaluate and provide specific feedback from multiple dimensions such as knowledge mastery, expression ability and team cooperation. Knowledge mapping can record the display content and evaluation results, help students understand learning progress, and promote the continuous improvement of learning effect.

(3) Reflection and improvement: encourage students to reflect on the display process, summarize experiences and lessons and put forward improvement measures. Teachers can adjust teaching contents and methods according to students' reflection and feedback, and further optimize the teaching process. Knowledge mapping can record students' reflection and improvement measures, and help students systematically summarize and optimize learning methods.

4. Conclusion

Based on the concept of OBE and knowledge mapping technology, this study constructed and optimized the curriculum system of fundamentals of mechanical manufacturing technology. By clarifying the curriculum objectives, integrating teaching contents, constructing knowledge maps, developing teaching resources and designing diversified evaluation systems, a structured and visual curriculum knowledge system is established. Knowledge mapping not only makes the association between knowledge points clear and supports dynamic updating, but also provides a clearer learning path and a more personalized learning experience. The research driven teaching mode, the resource development supported by information technology, and the student display link including peer evaluation have further enriched the connotation of the course and enhanced the interaction between teachers and students and student participation; Diversified evaluation methods strongly support the continuous improvement of teaching effectiveness. This mode provides theoretical support and practical guidance for the digital transformation and high-quality development of the curriculum, and promotes the innovative development of mechanical engineering education.

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