Bridging Theory and Practice: Application of Outcome-Based Education in Product Structure Design Courses

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Abstract: In the context of rapid global manufacturing development, traditional product structure design courses urgently need innovation to meet industry demands. To effectively integrate theory and practice, this study explores the application of Outcome-Based Education (OBE) in product structure design courses. By restructuring the course framework and integrating the theoretical teaching of continuous and intermittent motion mechanisms, detailed explanations of the shell and connection structures are provided to comprehensively improve students' theoretical design knowledge. In the practical segment, a series of activities, including design proposal discussions, conceptual and detailed design, as well as product manufacturing and assembly, enable students to deeply apply learned theories in real projects, significantly improving their innovative design capabilities and teamwork skills. The course reform emphasizes a student-centered approach, utilizing project-driven teaching methods that allow students to solve real design problems and stimulate their interest and self-directed learning abilities. Finally, this paper evaluates the practical effectiveness of OBE in teaching product structure design, proving its efficacy in enhancing teaching quality and students' practical skills. The results demonstrate that the OBE-based teaching model significantly improves students' professional skills, providing valuable experience in educational reform for industrial design.

Keywords: Outcome-Based Education; Product Structure Design; Educational Innovation; Practical Skills Enhancement; Interdisciplinary Teaching Methods

1. Introduction

With the rapid development of the global economy and technological revolutions, particularly in the context of Industry 4.0 and digital transformation, manufacturing and product design are undergoing significant changes [1]. The rise of smart manufacturing is driving designers to integrate new technologies such as 3D printing, enhancing the complexity and intelligence of designs [2]. Consequently, product structure design courses need to update their teaching content and adopt innovative teaching strategies that emphasize practical application and interdisciplinary projects to strengthen students' hands-on skills and problem-solving abilities [3]. The application of Outcome-Based Education (OBE) has optimized teaching methods, ensuring that students achieve the expected learning outcomes by the time they graduate, thus laying a solid foundation for them to stand out in a competitive job market [4].

Some cutting-edge research has explored how to combine OBE with modern educational technologies [5]. Chan et al. introduced a dynamic OBE model by explicitly incorporating assessment scores into the OBE matrix, conducting both quantitative and qualitative validation [6]. Syeed et al. provided a comprehensive OBE framework successfully applied to the design and implementation of undergraduate programs in computer science and engineering, assisting institutions in designing OBE model courses that meet international academic equivalence and accreditation standards [7]. Li et al. explored the BOPPPS model based on OBE principles in clinical basic experimental teaching, reforming teaching objectives, content, and design paths to align with disciplinary characteristics [8]. Vivek et al. conducted a methodological assessment of course outcomes (CO) among students using different learning methods. The results showed that the introduction of digital tools as teaching aids had a positive impact on achieving CO [9]. Zamir et al. found that the transition from non-OBE to OBE demonstrated significant superiority in student learning, course delivery, and teaching techniques [10]. Zheng et al. implemented a sustainable teaching model based on OBE principles and the TSEM (Teaching, Learning, Evaluation, and Management) framework, exploring its effectiveness in the context of "Artificial Intelligence and Education" [11].

This paper aims to explore the application of Outcome-Based Education principles in product structure design courses to address the rapid changes in technology and market demands in the manufacturing industry. The study involves redesigning the course structure, integrating modern technology and practical teaching, and employing case analysis and empirical research methods to evaluate the effectiveness of the teaching reforms in detail. The results of this study indicate that the OBE teaching model significantly enhances students' practical skills and innovative thinking, demonstrating its effectiveness in improving educational quality and meeting the needs of the industrial design profession.

2. Current Status and Challenges of the Course

The current product structure design courses primarily rely on traditional theoretical teaching methods, emphasizing design principles, material properties, and basic manufacturing processes. Although the courses cover key stages from concept development to product realization, the content is mainly delivered through classroom lectures and textbook knowledge, using technical tools limited to basic CAD software and model-making equipment. This theory-heavy teaching model results in a disconnect between theory and practice, making it difficult for students to apply what they have learned to real design projects. Additionally, the courses fall short in fostering students' innovative thinking and problem-solving abilities. Therefore, the main teaching challenge is how to effectively integrate theoretical knowledge with practical application to enhance students' comprehensive design and innovation capabilities.

This challenge highlights a critical gap between course content and industry needs, particularly in the integration of theory and practice. Despite students mastering basic design theories, the lack of sufficient practical opportunities often makes it difficult for them to apply these theories to solve real industrial problems. As a result, they may not meet employers' expectations for designers who can immediately tackle complex design issues upon entering the workforce. The industry increasingly prefers designers who not only have solid theoretical knowledge but can also demonstrate innovation and teamwork skills through practical experience. If this teaching gap is not addressed, it will directly affect students' career development. Therefore, closely combining theory with practice by integrating real project cases into the teaching process is crucial for improving educational quality, meeting industry demands, and supporting students' future success.

3. OBE-Based Course Reform Strategies

3.1 Course Objectives

The product structure design course has been redesigned based on the principles of Outcome-Based Education to ensure each objective aligns closely with industry needs and specific professional skills. The revised course objectives include the following: (1) Develop a thorough understanding of the basic principles and methods of product structure design. Through project applications, students will learn the functional requirements of various structures to design products that meet engineering, aesthetic, and user experience standards. (2) Equip students with the skills to use modern CAD software for structural design, including the design of shells and box structures, connection structures, and power transmission mechanisms. This ensures students can proficiently utilize these tools to realize complex design solutions. (3) Learn how to translate design concepts into detailed drawings and models, and use visual expression tools to effectively present their design solutions. This enhances their technical communication and presentation abilities. (4) Foster innovative thinking, encouraging students to explore new design solutions and problem-solving methods. Additionally, cultivate their entrepreneurial spirit, laying the foundation for future careers and potential entrepreneurial activities.

These course objectives are meticulously crafted following OBE principles, starting from the expected learning outcomes and reverse-engineering the course content. Each objective aims to directly enhance students' competitiveness in the job market, particularly in technical application, innovative design, and professional communication. Continuous dialogue with industry experts ensures that the teaching objectives align with current and future industry standards and meet the specific demands of professional roles in terms of skills and knowledge. This outcome-oriented objective setting not only equips students with immediate professional capabilities but also deepens their understanding through practical application, enabling them to adapt to a rapidly changing work environment. Consequently, this approach enhances the effectiveness and relevance of education.

3.2 Course Content

Guided by the OBE principles, the content of the product structure design course has been comprehensively updated and expanded, particularly enhancing practical elements and integrating new technologies. The course is now divided into two main parts: theoretical teaching and practical teaching, each meticulously designed to closely align with the intended learning outcomes and meet specific professional competency requirements.

The theoretical part delves deeply into the core concepts of product structure design, such as the working principles of continuous and intermittent motion mechanisms, and the design principles of shells and connection structures. This content not only provides the necessary technical knowledge foundation but also emphasizes the application of design thinking in solving real engineering problems. Through case analysis and problem-solving teaching methods, the theoretical instruction aims to cultivate students' critical thinking and innovation abilities.

The practical part involves a series of design projects and laboratory work, allowing students to apply theoretical knowledge to specific design tasks. From initial design proposal discussions to the execution of detailed designs, and onto product manufacturing and assembly, students have the opportunity to use modern CAD software and 3D printing technologies to practically implement their design concepts. These practical activities not only deepen students' understanding of classroom content but also significantly enhance their technical skills and teamwork abilities.

Throughout the various stages of design practice, the course stimulates students' innovative thinking. Students are encouraged to explore innovative solutions at each project stage, such as cleverly applying linkage mechanisms to achieve new functions or incorporating unique aesthetic elements in shell design. This teaching approach enables students to transform their theoretical knowledge into practical applications and develop the ability to view problems from different perspectives and find solutions. By setting up the course in this manner, students can continuously experiment and improve in real design contexts, thereby enhancing their innovation consciousness and entrepreneurial spirit, laying a solid foundation for their future careers and entrepreneurial endeavors.

3.3 Teaching Methods

To better implement OBE and support the achievement of course objectives, the product structure design course has adopted various innovative teaching methods, including collaborative learning, project-driven learning, and flipped classrooms: (1) Through group work, students collaboratively solve design problems, sharing different perspectives and skills, thereby deepening their understanding of the course content. This method encourages students to explore complex engineering concepts and design challenges through discussion and cooperation. (2) The course integrates theoretical content with practical applications through design projects, enabling students to learn and practice new skills in real-world contexts. Each project is designed to help students achieve course objectives, such as using CAD software to design complex structures or creating prototypes with 3D printing technology. (3) The traditional roles of lectures and homework are reversed. Students learn new content at home through videos or other resources, while classroom time is dedicated to discussions, practical exercises, and in-depth analysis. This increases teacher-student interaction and provides opportunities for personalized learning.

These teaching methods are designed to promote active learning and student engagement, with each method specifically aligning with the learning outcomes of the course. For example, collaborative learning fosters communication and teamwork skills through group work, project-driven learning emphasizes the integration of theory and practice, and flipped classrooms optimize the learning process, allowing students to explore and understand complex issues more deeply. By implementing these methods, students can more effectively achieve course objectives while also enhancing their problem-solving abilities and innovative thinking.

Despite the numerous benefits these teaching methods bring, there are also challenges in their implementation. Teacher training is a major issue, as instructors need to master these new methods and integrate them effectively into existing courses. Additionally, student adaptability poses a challenge, especially when transitioning to more autonomous and collaborative learning models. To address these issues, the course design includes regular training for teachers and guidance and support for students, ensuring that all participants can adapt to the new teaching methods.

3.4 Course Assessment

The course assessment has been thoroughly reformed within the OBE framework to ensure that the assessment methods comprehensively cover and effectively reflect the extent to which students have mastered the learning outcomes of the course. The assessment content includes students' theoretical knowledge, technical skills, innovative abilities, and practical application capabilities, all of which are core competencies required for career development.

The regular grades of the course account for 50% of the total evaluation score, including small assignments and process assessments. Small assignments are used to test students' understanding of theoretical knowledge and application abilities, focusing on the timeliness, accuracy, completeness, and innovativeness of students' completion of assignments. For example, when discussing linkages or intermittent motion mechanisms, students need to not only list their mechanical and motion characteristics but also provide specific examples to demonstrate the practical applications of these mechanisms, thereby reflecting the depth and breadth of their understanding. Process assessments include literature reading, best notes, and classroom interactions, aimed at promoting students' active learning and enhancing classroom engagement. Literature reading helps students develop critical thinking, while best notes and classroom interactions encourage students to actively express and share their views, and also serve as an incentive for students' daily learning behaviors.

The final assessment score also accounts for 50% of the total evaluation, with the evaluation criteria focusing on the innovation, feasibility, design completeness, and accuracy of the project. This part of the assessment is carried out through a comprehensive final project, where students need to demonstrate how they integrate the knowledge learned in the course into a specific product design. The project not only requires students to demonstrate high-level design skills but also to consider the feasibility of product manufacturing and the accuracy of design in technical details, which are all crucial abilities in the field of industrial design.

The entire assessment system is designed around the OBE concept, ensuring that each student can achieve the preset learning outcomes through specific assessment activities. Each assessment helps to form a comprehensive understanding of students' abilities, guiding them in areas where improvement is necessary. Furthermore, this assessment method emphasizes the ability to learn from practice and solve problems through innovation, both of which are essential for the success of modern engineers and designers.

4. Implementation and Effectiveness of Course Reform

The course reform began with updating the syllabus and course content, integrating the latest industrial design theories and technological trends. This includes advanced CAD applications and 3D printing instruction, ensuring that the teaching content keeps pace with the modern design industry. The reform also introduced project-driven learning and collaborative learning methods, emphasizing hands-on practice and teamwork. For instance, through team projects, students engage in every step from design concept to product prototype. Additionally, the flipped classroom model was adopted to enhance students' autonomous learning abilities, effectively combining theoretical learning with practical application.

Challenges encountered during the implementation of the reform included the adaptation of teachers and students to the new teaching modes and resource allocation limitations. The institute addressed these issues by offering teacher training and student workshops to help both educators and students understand and adapt to the new learning and teaching methods. Regular assessments and adjustments ensure adequate support for teaching activities.

The effectiveness of the course reform is evaluated through students' learning outcomes and teaching feedback. Students have demonstrated higher technical proficiency and innovative thinking in actual design projects, particularly in comprehensive design projects where they apply theoretical knowledge learned in class to solve real design problems. The reform has also significantly enhanced students' career readiness, making them more adaptable to the rapidly changing demands of the design industry.

To ensure the long-term effectiveness of the teaching reform, the institute has established a continuous improvement mechanism. This includes regular review and update of course content, ongoing optimization of teaching methods, and regular dialogues with the industry. These measures ensure that the course content and teaching methods continuously adapt to new technological advancements and market changes, maintaining the quality of educational activities.

5. Conclusion

This study systematically explores and implements the application of Outcome-Based Education principles in product structure design courses, aiming to bridge the gap between educational content and actual industry needs, and to enhance students' practical skills and innovative thinking. From this research, we have drawn the following main conclusions:

(1) The reforms include updating the syllabus, introducing new teaching methods such as project-driven learning, collaborative learning, and flipped classrooms, and improving assessment methods. These reforms ensure that students can apply the knowledge they have learned to actual design work, significantly enhancing the practicality and effectiveness of education.

(2) Students have shown significant improvement in their theoretical knowledge and practical skills, particularly in innovative design and teamwork abilities.

(3) Given the rapid changes in educational demands and industry development, it is recommended to establish a continuous improvement mechanism to regularly update course content and teaching methods, ensuring that educational quality remains aligned with industry standards.

Through OBE-based educational reform, this study not only improves the teaching quality of product structure design courses but also provides a reference model for other courses in engineering and design education. This helps cultivate high-quality design talent that meets the needs of modern industry, promoting the joint progress of education and industry.

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