ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

Construction and Optimization of Food Engineering Course Group System Based on Engineering Education Accreditation

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Abstract: *To address the current challenges in food engineering course teaching, such as the fragmentation of course content, the disconnection between theory and practice, and students' insufficient ability to solve complex engineering problems, this study proposes a systematic approach to the construction and optimization of the food engineering course group system guided by the outcome-based education (OBE) philosophy. A "four-stage progression" course group architecture was proposed, characterized by "theory as the foundation, practice as the deepening, design as the integration, and the factory as the scenario." A three-tier progressive practical teaching system was established, comprising "foundational, comprehensive design, and applied innovation" levels. Additionally, a closed-loop "evaluation-feedback-improvement" mechanism for continuous improvement in teaching quality was implemented, centered on the philosophy of outcome-based education. The construction and optimization of this food engineering course group system have been shown to enhance the logical connections and content synergy among courses, thereby providing effective support for the systematic cultivation of students' engineering practice abilities in the Food Science and Engineering major, particularly their capacity to solve complex engineering problems. The present study offers a replicable model for reforming course systems in a similar major.*

Keywords: *Engineering Education Accreditation, Food Engineering Course Group, Outcome-Based Education Philosophy, Complex Engineering Problems, Course System Optimization*

1. Introduction

Engineering education accreditation is an internationally recognized quality assurance system for engineering education and a crucial cornerstone for achieving substantial international equivalence and mutual recognition of engineering qualifications [1]. Since China officially became a signatory to the Washington Accord in 2016, engineering education accreditation has become a key driver for universities to deepen engineering education reform and enhance the quality of talent cultivation [2,3]. The institution's core philosophy, OBE, places significant emphasis on a student-centered, outcomes-based, and continuous improvement model. This philosophy requires that the majors start with the core competencies that graduates are expected to demonstrate. It further entails a reverse-design approach to the curriculum, wherein the sequence and structure of courses are designed around the competencies to be developed [4]. Additionally, it involves the proactive implementation of teaching methodologies and assessment strategies that are aligned with the identified competencies [5]. Concurrent with the comprehensive advancement and deepening of the construction of "New Engineering," the paradigm of engineering talent cultivation is rapidly shifting from "knowledge transmission" to "competence cultivation," with particular emphasis on students' ability to solve complex engineering problems [6,7]. Consequently, course content must be enriched to increase in challenge and comprehensiveness. Furthermore, the cultivation of engineering practice ability should be strengthened through coordinated support from both software and hardware.

The food industry, a foundational and strategically pivotal component of the national economy, is currently undergoing a critical transition from conventional manufacturing towards digitalization, intelligentization, and green transformation. However, enterprises often face a lack of engineering and technical talent in areas such as equipment integration, process automation control, and online design [8]. This practical challenge indicates a fundamental discrepancy among the objectives of talent development in food engineering, existing course systems, and industry demands. In light of these challenges, the

ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

development and continuous refinement of a food engineering course group system that meets engineering education accreditation standards and aligns with industry development needs has become imperative for the Food Science and Engineering major to promote educational reform and enhance the effectiveness of talent cultivation.

2. Necessity of Course Group Construction

Course group construction is a teaching reform pathway that systematically restructures and organically integrates several core courses with inherent logical connections. These connections are based on the relevance of knowledge, logic, and the objectives of competence cultivation. By breaking down course barriers, coordinating teaching resources, and restructuring the content system, this model achieves the intensive allocation of teaching resources and the collaborative updating of knowledge content. While enhancing the overall effectiveness of the course system, it significantly strengthens the complementarity and mutual support among courses. This approach not only facilitates the collaborative evolution and scale-effect release of the course system but also effectively strengthens students' deep understanding of professional theories, the systematic construction of engineering knowledge, and their comprehensive ability to solve complex problems.

3. Guiding Ideology and Principles for Course Group Construction and Optimization

3.1. Guiding Ideology

The construction of this course group is fundamentally guided by the "Engineering Education Accreditation Standards" and centered on the outcome-based education (OBE) philosophy. Adherence to the basic path of "reverse design, forward implementation" is also imperative. Consequently, the educational objectives and graduation requirements for the major are defined in reverse order, with the major's competencies for engineering talent serving as the foundation. This approach involves systematically decomposing the graduation requirement indicators into course groups and specific courses, ensuring that the teaching objectives, content, and assessment methods of each course are clearly, measurably, and evaluably aligned with the corresponding indicators. In effect, this establishes a consistent closed-loop system of objectives, processes, and evaluations.

3.2. Principles of Construction and Optimization

3.2.1. Principle of Systematicity

This food engineering course group comprises seven courses: "Principles of Food Engineering," "Principles of Food Engineering Laboratory," "Principles of Food Engineering Course Design," "Food Machinery and Equipment," "Food Factory Design," "Food Factory Course Design," and "Comprehensive Food Engineering Laboratory." They form a logically coherent and functionally complementary organic whole. The course group's primary objective is to establish a comprehensive knowledge system that encompasses the entire "principles-equipment-process-factory" chain. "Principles of Food Engineering," the objective of which is to solidify the theoretical foundation of unit operations; "Food Machinery and Equipment," the purpose of which is to facilitate the concrete translation of principles into equipment; "Principles of Food Engineering Course Design," the objective of which is to provide unit-level engineering design training, which is then linked to "Food Factory Design" for system-level process layout and factory planning; "Principles of Food Engineering Laboratory," the objective of which is to reinforce theoretical validation; and finally, "Comprehensive Food Engineering Laboratory," the objective of which is to facilitate innovative engineering practices involving cross-disciplinary integration and multi-process coupling, achieving a complete leap in capabilities from foundational understanding to advanced application.

3.2.2. Principle of Progression

The course system has been meticulously designed to adhere to the principles of cognitive development and the logic of ability growth for engineering talent. The seven courses are organized into four distinct stages, with clear levels, progressive content, and a spiral-ascending competency structure. This organization follows a progressive path of "theory → practice, foundation → application, unit → system." This pedagogical approach is designed to facilitate the natural evolution of students' knowledge construction and skill development, progressing from simple to complex, from specific to general, and

ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

from partial to holistic.

3.2.3. Principle of Integration

We uphold the trinity of knowledge transmission, competency development, and value cultivation. It promotes the deep integration of theoretical teaching and engineering practice, the mutual permeation of course content and industry scenarios, and the synergistic development of engineering literacy and humanistic spirit. In the context of teaching practice, authentic real-world issues are integrated, including the challenges encountered in the food industry and the strategies employed to ensure national food safety. Furthermore, ideological and political elements, such as the spirit of craftsmanship, quality-responsibility awareness, professional ethics, and socialist core values, are embedded throughout the teaching process. This approach integrates professional training with ideological and political education, thereby comprehensively implementing the fundamental task of fostering virtue through education.

3.2.4. Principle of Dynamism

The course group has established a mechanism for dynamically updating teaching content. Each year, we meticulously monitor the latest advancements in fields such as artificial intelligence and intelligent manufacturing and promptly incorporate them into our instructional modules. At the same time, a regular review and update mechanism is employed for the course's teaching content, ensuring that the course's knowledge system remains congruent with the demands of high-quality development in the food industry.

4. Construction and Optimization of Course System

4.1. Course Group Architecture

In accordance with the above guiding ideology and construction principles, the course group constructs a three-dimensional system framework characterized by "four-stage progression and three-layer integration" (Figure 1). The framework is structured around the development of engineering competencies, with a vertical division into four stages of progressive ability and a horizontal integration of three dimensions: knowledge integration, ability integration, and quality integration. This integration aims to achieve an organic unity between course content and educational objectives.

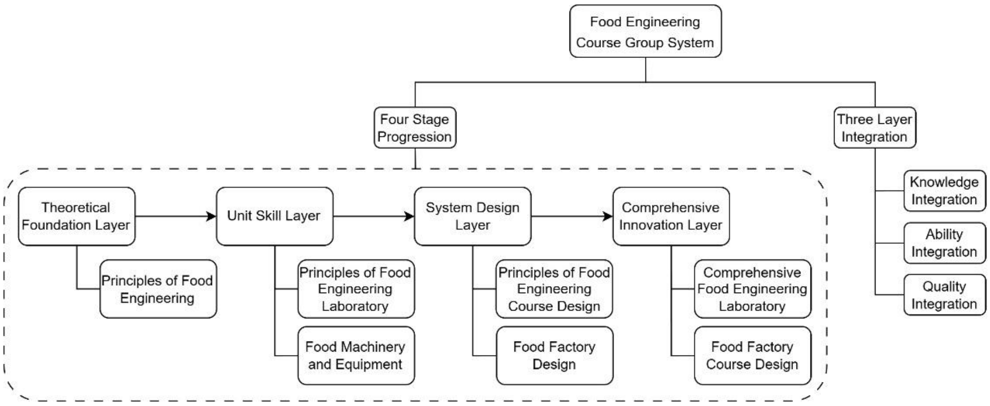

Figure 1: Framework diagram of the food engineering course group system.

4.1.1. "Four-Stage Progression" Competency Development Main Thread

The first stage is the theoretical foundation layer, corresponding to the course "Principles of Food Engineering." This course focuses on the fundamental principles of core unit operations in food engineering, such as fluid flow, heat transfer, and mass transfer. It aims to help students systematically master their physical mechanisms, mathematical models, and the logic of engineering applications, thereby equipping them to analyze and solve practical problems in food processing using theoretical knowledge. The course's primary objective is to provide a comprehensive foundation in the core principles of unit operations in food engineering, encompassing fluid flow, heat transfer, and mass transfer. The objective of this initiative is to facilitate students' systematic mastery of physical mechanisms, mathematical models, and the logic of engineering applications. This approach is designed to equip them to analyze and solve practical problems in food processing by leveraging theoretical knowledge. The teaching emphasis lies in solidifying students' understanding of the principles and computational methods of unit operations, while strengthening the foundations of mathematical and

ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

physical modeling necessary for engineering analysis. "Principles of Food Engineering" serves as a pivotal link between foundational and specialized engineering courses, providing the theoretical foundation for the entire field of food engineering. It provides a common set of principles that underpin subsequent engineering courses, facilitating a cohesive and well-structured educational experience.

The second stage is the unit skill layer that focuses on unit skills and comprises two courses: "Principles of Food Engineering Laboratory" and "Food Machinery and Equipment." This stage is dedicated to achieving an organic integration of engineering principles with practical application. On the one hand, "Principles of Food Engineering Laboratory" serves as an extension and validation platform for theoretical instruction. Through structured experimental projects, the program aims to facilitate students' deeper comprehension of fundamental principles through hands-on experience, systematically training them in core experimental skills such as experimental design, data collection and processing, error analysis, and problem diagnosis. On the other hand, "Food Machinery and Equipment" systematically imparts the fundamental principles, structural characteristics, performance parameters, and selection criteria of typical machinery and equipment used in food processing. Consequently, it establishes a closed-loop cognitive pathway, delineating a sequence of "principles-equipment-application." This course is designed to complement the "Principles of Food Engineering Laboratory" course, fostering a seamless integration of theoretical foundations with practical applications. This approach helps students develop preliminary capabilities in equipment selection, matching, and preliminary design, laying a practical foundation for the systematic resolution of complex engineering problems.

The third stage is the system design layer, comprising "Principles of Food Engineering Course Design" and "Food Factory Design." This stage is designed to enhance students' systematic thinking and integrated design capabilities, facilitating a shift in perspective from the details of unit operations to the overall process system. "Principles of Food Engineering Course Design" emphasizes the process design of unit operation equipment. This course requires students to apply engineering principles comprehensively to collaboratively complete design assignments, thereby enhancing their engineering design capabilities and practical problem-solving skills, while also fostering innovation-oriented thinking and a spirit of teamwork. On the other hand, "Food Factory Design" emphasizes the pedagogy of systematic design methodologies, including comprehensive factory planning, process flow design, workshop layout, and hygiene standards. This course aims to cultivate students' ability to master the entire planning process from site selection and workshop layout to hygiene, safety, and environmental protection. The two courses have complementary content, and jointly form a complete chain for cultivating the design ability of "unit-system-overall."

The fourth stage is the comprehensive innovation layer, which relies on two advanced courses ("Comprehensive Food Engineering Laboratory" and "Food Factory Course Design") to achieve integrative and creative objectives that cultivate students' abilities within the course group. This stage follows the logical approach of "experimental research driving factory design," requiring students to work in teams to integrate the theoretical knowledge, individual skills, and systematic methods accumulated in the previous three stages. This stage thereby completes a full-cycle engineering practice ranging from product concept proposal and experimental research to industrial implementation. Specifically, "Comprehensive Food Engineering Laboratory" focuses on three primary areas: novel food development, traditional process optimization, and improvements in quality control. Students must participate in the entire process, including the selection of raw materials, formulation design, exploration of process parameters, pilot-scale experimental operation, data analysis, and comprehensive product quality evaluation. In real research scenarios, they identify key process parameters and measure data to produce engineering-feasible research outcomes, providing reliable technical inputs and data support for subsequent factory design. Building on this foundation, "Food Factory Course Design" requires students to use the products developed in "Comprehensive Food Engineering Laboratory" as design objects and to complete a comprehensive food factory design proposal. Through the closed-loop integration of "research and design," students gain a deep understanding of the logic behind transforming laboratory results into industrial applications, effectively enhancing their capabilities in complex system integration design, cross-course knowledge integration, and team collaboration. The two courses, using "product research leading factory design" as an integration paradigm, not only significantly enhance students' intrinsic motivation and problem-oriented learning but also facilitate a leap from knowledge acquisition to engineering innovation capabilities, and from linear, unit-based thinking to non-linear, systems-based thinking.

4.1.2. "Three-Layer Integration" Support System

Knowledge Integration: To optimize the overall knowledge structure of the course group, the core

ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

knowledge points of these seven courses are systematically organized into a knowledge linkage map. For example, the explanation of "heat transfer" principles and computational models in "Principles of Food Engineering" directly supports the structural analysis and performance evaluation of heat-exchange equipment in "Food Machinery and Equipment" and further provides a theoretical basis for heat-balance calculations in "Food Factory Design". This map effectively resolves issues of content duplication. It disconnects among courses, enabling discrete knowledge points to be vertically integrated and horizontally coordinated, ultimately forming a logically rigorous and clearly structured professional knowledge network.

Ability Integration: The courses organically integrate five core abilities, including computational, design, operational, analytical, and innovative, into the teaching design of each course. Relying on a spiral competency training pathway of "lecture-experimental verification-design reinforcement," this approach ensures that students, through a continuous and progressive learning process, gradually achieve a comprehensive leap in ability from mastering individual skills to systematically solving complex engineering problems.

Quality Integration: Adhering to the trinity of value shaping, knowledge transmission, and competency development, ideological and political education is deeply integrated into professional knowledge instruction to fully implement the fundamental task of fostering virtue through education. The course group emphasizes translating core socialist values into tangible, actionable engineering ethics principles, focusing on cultivating students' patriotism, sense of social responsibility, professional ethics, environmental awareness, and respect for the rule of law. In teaching practice, the "Dayu's Water Control" case is used to explain the principles of fluid transport, thereby conveying the wisdom and spiritual legacy of ancient times. Examples of "China creation" are analyzed to examine the localization process for key food-processing equipment, thereby inspiring students' national confidence and sense of mission in independent innovation. Furthermore, the national "Dual Carbon" strategic goals are used to reinforce students' understanding of green engineering. The efficacy of these educational practices is evidenced by their ability to facilitate the seamless integration of craftsmanship, scientific spirit, and contemporary missions, thereby fostering a deep integration of professional education and value-oriented guidance.

4.2. Optimization and Coordination of Course Content

4.2.1. Constructing Matrix Linking Course Objectives to Graduation Requirements

In accordance with the core requirement of the "Evaluation of Graduation Requirement Achievement" in the Engineering Education Accreditation Standards, this course group systematically identifies the specific indicators for each graduation requirement. A relationship matrix is constructed between course objectives and graduation requirement indicators to clarify the extent to which each course supports each graduation requirement. This matrix not only ensures precise alignment between course teaching objectives and the major's talent-cultivation orientation but also provides a structured foundation for subsequent achievement evaluations, thereby enabling closed-loop management and dynamic optimization of talent-cultivation objectives.

4.2.2. Cross-Course Integration of Core Knowledge Points and Progressive Ability Design

The logical coherence and synergy of the course system are highlighted through the selection of the core knowledge thread of "fluid flow and transportation." This thread, which runs through all food engineering programs, is chosen to systematically illustrate its organic integration across multiple courses and the progressive development of competencies. These competencies reflect the full-cycle competency development pathway of "cognitive understanding-design application-comprehensive innovation."

In the foundational cognitive stage, "Principles of Food Engineering" focuses on the basic laws of fluid statics and dynamics, pipeline resistance calculation models, and pump selection theory, emphasizing the explanation of physical mechanisms and training in mathematical modeling. "Food Machinery and Equipment" is grounded in engineering principles and meticulously designed to enhance students' understanding of equipment structure, operational standards, and the rationale behind engineering selection decisions. "Principles of Food Engineering Laboratory" guides students in verifying theoretical formulas and identifying sources of error by operating and measuring parameters in typical fluid transportation systems. This approach establishes a deep connection between abstract principles and concrete equipment.

In the design and application stage, "Principles of Food Engineering Course Design" assigns unit design tasks for transportation systems. Students are required to independently complete the entire design

ISSN 2522-6398 Vol. 9, Issue 6: 35-42, DOI: 10.25236/FER.2026.090605

process, including flow rate calculation, pipe sizing, resistance loss calculation, and pump selection, based on given process conditions, facilitating a transition from theoretical deduction to practical engineering design capabilities. "Food Factory Design" further integrates fluid transportation systems into the factory-wide utility engineering framework. Using typical factory case studies, the course conducts load balancing analysis and process layout optimization, focusing on cultivating students' systematic thinking and holistic planning awareness.

Finally, in the comprehensive innovation stage, "Food Factory Course Design" requires students to plan the material and energy transportation scheme for the entire factory as part of a complete factory design task. "Comprehensive Food Engineering Laboratory", based on product process optimization, guides students to deeply analyze how changes in fluid properties affect transportation stability and process efficiency, conduct multi-objective collaborative optimization, and enhance their comprehensive judgment and innovative practical abilities to solve complex engineering problems.

Through the collaborative design, the “fluid flow and transportation” knowledge module has formed a progressive competency chain of "theoretical foundation-experimental validation-unit design-system integration-comprehensive innovation." This chain covers the cultivation requirements for "complex engineering problem-solving ability," as emphasized by engineering education accreditation.

4.3. Innovative Construction of Practical Teaching System

Practical instruction is a key vehicle for cultivating talent in engineering majors. To systematically enhance students' engineering literacy and practical skills, this course group has developed a three-tier, progressive practical teaching system: "foundational-comprehensive design-applied innovation." This system is deeply integrated with off-campus industry-university-research resources, forming a complete practical teaching system with internal-external linkage and progressive levels.

4.3.1. Basic-Level Experimental Teaching

Basic experimental teaching, as the starting point for cultivating practical ability, primarily uses classic verification experiments from "Principles of Food Engineering Laboratory". This level emphasizes standardizing experimental procedures and reinforcing safety and data awareness. Through observation of phenomena, data processing, and analysis of results, students deepen their understanding of core principles such as the conservation of mass and energy. This, in turn, solidifies the foundation of engineering thinking and empirical capabilities and provides methodological support for subsequent comprehensive, design-oriented practical activities.

4.3.2. Comprehensive Design-Oriented Practical Teaching

Comprehensive design-oriented practical teaching focuses on cultivating engineering systems thinking and project execution skills, using "Principles of Food Engineering Course Design" (unit-level) and "Food Factory Course Design" (system-level) as core vehicles. The teaching approach adopts a project-driven and team-collaboration model, requiring students to independently complete the entire process, from conceptual design and process calculations to drawing preparation, for real-world process scenarios. This level effectively cultivates students' ability to solve complex, systemic engineering problems through a two-dimensional, progressive training approach that moves "from point to plane, and from unit to system."

4.3.3. Applied Innovation-Oriented Practical Teaching

Applied innovation-oriented practical teaching aims to cultivate students' high-level abilities to address complex engineering problems, with implementation centered on design-oriented, comprehensive, and innovative experimental projects in the "Comprehensive Food Engineering Laboratory". This level emphasizes the cross-integration and self-construction of knowledge across multiple courses, focusing on cultivating students' problem-identification skills, solution design capabilities, team collaboration skills, and technical presentation abilities. Moreover, a virtual simulation platform for food factories is introduced to enable students to adjust equipment parameters and optimize process flows in a virtual environment, thereby further enhancing their engineering practice skills. This level of teaching aims to achieve a leap from knowledge application to innovative inquiry, comprehensively improving students' overall quality.

4.3.4. Enterprise-University-Research Collaborative Education Mechanism

At the off-campus practice level, established enterprise-university joint practice bases and industry-academy platforms are utilized to transform real enterprise cases into teaching projects. The typical

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technical challenges encountered by enterprises are selected and converted into open-ended topics for course design and comprehensive experiments. On the other hand, the enterprises' current technical standards, quality management systems, and typical production-line operating technologies are embedded in the teaching content, and enterprise engineers with rich engineering experience are invited to participate in practice guidance, mid-term defenses, and achievement evaluations. This mechanism achieves resonance between teaching content and industry frontiers and deep integration of teaching processes with engineering practice, thereby enhancing the alignment between talent cultivation and industry needs.

5. Construction of OBE-Based Teaching Evaluation System

5.1. Diversified and Process-Oriented Assessment Methods

Traditional course evaluation models emphasize memorization of knowledge and summative tests, making it difficult to comprehensively and objectively assess students' engineering practice capabilities, application skills, and levels of innovative thinking. Therefore, based on the OBE philosophy, this course group constructs a diversified, process-oriented assessment system centered on the attainment of abilities, emphasizing continuous tracking and dynamic feedback, and adopting a composite evaluation paradigm of "process-oriented assessment as the mainstay, summative assessment as the supplement." In process-oriented assessment, the weight of formative assessment components such as project reports, experimental operation performance, group collaboration, peer evaluations, and oral presentations is significantly increased in the overall grade. In summative assessment, the proportion of memorization-type questions is greatly reduced and replaced with comprehensive, analytical, and design-oriented questions. The focus is on assessing students' depth of understanding of engineering principles, their ability to analyze and solve problems, and their ability to conduct system design in real or simulated engineering contexts.

5.2. Closed-Loop Quality Assurance Mechanism of "Evaluation-Feedback-Improvement"

According to the core principle of continuous improvement advocated by the Engineering Education Accreditation Standards, this course group systematically constructs a closed-loop quality assurance mechanism covering the entire teaching process: "evaluation-feedback-improvement." Through multiple rounds of iterative quality diagnosis and optimization, it achieves a spiral improvement in teaching quality.

5.2.1. Quantitative Analysis of Course Objective Attainment

At the end of each semester, teachers analyze the attainment of course objectives using data collected from various assessment components. This analysis integrates quantitative calculations (e.g., average attainment scores, standard deviations, attainment rates) with qualitative assessments (e.g., characteristics of typical answers, attribution of ability weaknesses) to comprehensively evaluate the attainment level of each course objective, identify weaknesses in teaching design, content organization, method implementation, and resource support, providing empirical evidence and clear direction for the next round of teaching reform.

5.2.2. Evaluation System with Multi-Stakeholder Collaborative Participation

To enhance the comprehensiveness, authenticity, and professionalism of the evaluation, this course group introduces a multi-stakeholder participation mechanism that includes student self-assessment, peer assessment, and evaluation by an industry mentor. In addition to conventional faculty evaluations, the system incorporates student self-assessment (focusing on learning reflection and metacognitive development) and peer assessment (strengthening collaborative awareness and critical thinking). Especially in practical components such as course design and comprehensive design, enterprise mentors are actively engaged as external evaluators. They directly participate in outcome reviews and provide process guidance, offering actionable recommendations to promote the effective integration of teaching and engineering practice.

5.2.3. Evidence-Based Continuous Improvement Mechanism

This course group uses the results of course objective attainment analysis and multi-source teaching feedback data (including student questionnaires, discussion records, supervisor opinions, enterprise engineer suggestions, etc.) as the core evidence for continuous teaching improvement. It establishes a

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closed-loop operation mechanism of "faculty collective discussion → teaching plan revision and classroom implementation → teaching supervision and peer observation → multi-dimensional feedback data integration and analysis → targeted improvement measure implementation." Relying on the regular collaboration among the course group's teaching team, this mechanism continuously enhances the alignment of course objectives with graduation requirements and the attainment of quality in talent cultivation through systematic measures such as dynamic updates to teaching syllabi, reconstruction of teaching content, and optimization of teaching methods.

6. Conclusion

Guided by engineering education accreditation and using the OBE philosophy as the logical thread, this paper systematically constructs and optimizes the teaching system for the food engineering course group. Through the overall architecture design of "four-stage progression, three-layer integration," it achieves vertical integration of knowledge logic across courses and horizontal synergy of ability cultivation. Relying on the three-tier progressive practical teaching system of "foundational-comprehensive design-applied innovation," it strengthens students' engineering literacy, systematic thinking, and innovative capabilities. The OBE-based "evaluation-feedback-improvement" closed-loop quality assurance mechanism ensures the continuous improvement of teaching quality. The development and implementation of this course group system have effectively addressed the strategic demand for senior engineering talent in the food engineering field in the new era and have achieved positive results in teaching practice.

Acknowledgements

This study was supported by the Quality Engineering and Teaching Reform Project of Zhaoqing University (zlgc2024011) and the Zhaoqing University-Zhanjiang Food and Drug Inspection Institute Joint Laboratory (No. 52).

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