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Calculation and Evaluation of Course Objective Attainment for Principles of Food Engineering Based on Outcome-Based Education Philosophy

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Abstract: *Under the background of engineering education accreditation, it is crucial to evaluate course objective attainment based on the Outcome-Based Education (OBE) philosophy to ensure and improve teaching quality. For example, in the Principles of Food Engineering course, this study developed an evaluation system that covered three specific course objectives. Multidimensional quantitative evaluations were employed, including knowledge tests, homework assignments, classroom performance, and final examinations, supplemented by qualitative analysis from student questionnaires. The results show that the average attainment values for the total course objective and its sub-objectives both exceeded the qualified standard of 0.7. Attainment of the basic theoretical objective (Objective 1) was highest. Conversely, the attainment of advanced ability objectives, such as problem analysis and solution design (Objectives 2 and 3), was relatively lower, with noticeable shortcomings among individual students. The quantitative and qualitative findings were consistent, revealing teaching strengths and weaknesses. Accordingly, improvement measures were proposed, including optimizing teaching content, strengthening case-based teaching, and adjusting assessment weightings. These measures provide an empirical basis for enhancing course quality in line with OBE philosophy.*

Keywords: *Outcome-based education philosophy, Principles of food engineering, Course objective attainment, Engineering education accreditation, Continuous improvement*

1. Introduction

The accreditation of engineering education, as an internationally recognized system for assuring educational quality, is important for enhancing the cultivation of engineering talent and promoting the internationalization of professional education [1]. The program is founded on three core principles: student-centeredness, outcomes-based education (OBE), and continuous improvement [2]. The aim is to achieve international substantive equivalence in the quality of talent cultivation. The OBE philosophy is a driving force in engineering education reform. The process entails designing curricula in reverse order, starting with the desired final learning outcomes for students [3]. Additionally, a closed-loop mechanism for continuous improvement is to be implemented through the systematic evaluation of learning outcomes [4]. Within this framework, the evaluation of course objective attainment serves as the pivotal link between graduation requirements and teaching activities. It provides the foundation for evaluating teaching effectiveness and driving continuous improvement, ultimately forming a quality closed loop of evaluation, feedback, and improvement [2, 5].

The cultivation of innovative talents with the capacity to address complex engineering challenges has emerged as a national strategic imperative. The Principles of Food Engineering course serves as a core, foundational professional course that connects theoretical foundations to practical applications within the Food Science and Engineering major. The course's content demonstrates a profound integration of theories of momentum, heat, and mass transfer with various typical unit operations. The course is distinguished by its theoretical abstraction and strong engineering practicality, and it plays an irreplaceable role in cultivating students' ability to solve complex food engineering problems [6, 7]. Nevertheless, the advanced level of theoretical content, incorporating numerous sophisticated formulas and engineering principles, poses considerable challenges for the objective assessment of teaching and learning outcomes.

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The evaluation of course objective attainment serves as a critical internal quality assurance mechanism for implementing the OBE philosophy and meeting the requirements of engineering education accreditation. The present study evaluates the attainment of the course objective for Principles of Food Engineering, using the OBE philosophy. The overall aim of this research is to provide practical evidence and reference for the continuous improvement of teaching quality in this course and the achievement of talent cultivation goals in the Food Science and Engineering major. To this end, the research will clarify the supporting relationship between course objectives and graduation requirements, design diversified assessment methods and evaluation criteria, and establish a standardized process for calculating and analyzing attainment levels.

2. Methods

2.1. Design of Course Objectives

The establishment of the talent development objectives and graduation requirements for the Food Science and Engineering major at Zhaoqing University was informed by comprehensive market research and expert deliberation. These requirements were then decomposed into observable indicators, and a course support matrix was designed to determine which indicators each course supports. The Principles of Food Engineering teaching team developed the course syllabus in accordance with the major's talent cultivation plan. The specific course objectives are as follows:

The primary course objective (Course Objective 1) of this course is to facilitate mastery of fundamental theories of unit operations, momentum transfer, heat transfer, and mass transfer in the context of food processing. The ability to formulate suitable mathematical models and solve them for typical unit operations must be demonstrated. Such unit operations include, but are not limited to, fluid flow and heat transfer. The establishment of these models and their subsequent solution must be achieved using material balance, energy balance, and related theories.

The second course objective (Course Objective 2) is to cultivate the ability to apply fundamental principles from the disciplines of mathematics, natural sciences, and engineering sciences to identify and evaluate the key links and parameters in complex food engineering problems. The subsequent step involves decomposing these problems into unit operation challenges, conducting a thorough analysis of each, and proposing feasible solutions.

The third course objective (Course Objective 3) is to acquire the capability to implement the fundamental principles of food engineering design. This objective is to be accomplished by employing unit operation analysis, with the overarching aim of ensuring that comprehensive requirements concerning safety, health, the environment, regulations, and standards are thoroughly addressed. The objective is to design engineering solutions that are both reasonable and feasible.

2.2. Correspondence between Course Objectives and Graduation Requirements

The Principles of Food Engineering course covers an array of subjects, including an introduction to the field, fluid mechanics, fluid transport, relative flow between particles and fluids, heat transfer, the fundamentals of mass transfer, absorption, distillation, and food drying. The three-course objectives have been meticulously designed to support three first-level indicators and three second-level indicators within the graduation requirements. The specific relationship among them is presented in Table 1.

Table 1: Relationship between course objectives and graduation requirements.

First-Level Indicator	Second-Level Indicator	Course Objective	Design Weight
Engineering Knowledge	The students must demonstrate the ability to establish appropriate mathematical models for specific food processing unit operations or processes and to solve them.	Course Objective 1	0.50
Problem Analysis	The students must apply the fundamental principles of mathematics, the natural sciences, and engineering to identify and assess the key links and parameters of complex food engineering problems.	Course Objective 2	0.35
Design/Develop Solutions	The students must acquire proficiency in the fundamental methodologies and techniques of food engineering design and product development, and they must also comprehensively understand the factors influencing design objectives and technical solutions.	Course Objective 3	0.15

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2.3. Methods for Calculating and Evaluating Course Objective Attainment

The course under discussion implements the OBE philosophy, utilizing diverse assessment methods and emphasizing formative evaluation. The assessment employs a combination of quantitative and qualitative evaluation methods to achieve a comprehensive objective evaluation of course objective attainment.

2.3.1. Quantitative Evaluation

The evaluation of course objective attainment for Principles of Food Engineering comprises two components: the attainment of individual course sub-objectives (R_i) and the attainment of the total course objective (R_{total}). The specific calculation formulas for R_i and R_{total} are shown in Equations (1) and (2), respectively [8].

$$R_i = \frac{a_i\mu_1 A + b_i\mu_2 B + c_i\mu_3 C + d_i\mu_4 D}{\left(a_i\mu_1 + b_i\mu_2 + c_i\mu_3 + d_i\mu_4\right)\times 100} \tag{1}$$

$$R_{total} = \frac{\mu_1 A + \mu_2 B + \mu_3 C + \mu_4 D}{100} \tag{2}$$

In the equations, R_i (i=1, 2, 3) denotes the attainment of the i-th course sub-objective; R_{total} signifies the attainment of the total course objective; letters A, B, C, D represent the scores for knowledge tests, homework assignments, classroom performance, and final examination, respectively, all of which are scored on a percentage basis; μ_1, μ_2, μ_3, μ_4 denote the weights assigned to knowledge tests, homework assignments, classroom performance, and final examination in the total course grade; a_i, b_i, c_i, d_i (i=1, 2, 3) represent the weight coefficients for knowledge tests, homework assignments, classroom performance, and final examination corresponding to Course Objective 1, Course Objective 2, and Course Objective 3, respectively. The specific values are enumerated in Table 2.

Table 2: Weight distribution for the course objective attainment.

Assessment Method	Weight	Sub-objective Weight		
		Course Objective 1	Course Objective 2	Course Objective 3
Knowledge Tests	0.15	0.60	0.30	0.10
Homework Assignments	0.15	0.70	0.20	0.10
Classroom Performance	0.10	0.50	0.30	0.20
Final Examination	0.6	0.50	0.35	0.15

2.3.2. Qualitative Evaluation

The course employs a single-choice questionnaire to solicit students' subjective perceptions of the attainment of course sub-objectives. The questionnaire options are categorized into five levels: "fully attained", "well attained", "basically attained", "poorly attained", and "not attained". It is therefore evident that a qualitative analysis survey form for course sub-objectives was created. The analysis of questionnaire data can facilitate a qualitative investigation into students' perceived attainment of the course objective. This process may yield qualitative evaluation results.

2.3.3. Assessment of Attainment

In accordance with the university's regulations, students must achieve an average course grade of 60 to graduate under normal circumstances. To earn a bachelor's degree, students must achieve an average grade of 70 or higher. Given the aforementioned factors, the course has been assigned a standard value of 0.7 for attaining its stated objectives. In other words, when the attainment value of the course objective is greater than or equal to 0.7, it is determined that the objective has been attained.

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3. Result Analysis and Continuous Improvement

3.1. Quantitative Evaluation Analysis

3.1.1. Analysis of Overall Student Course Objective Attainment

The analysis was conducted using the calculation method for course objective attainment. The course grades of 30 students from Class 2, Grade 2022, in the Food Science and Engineering major, in the second semester of the 2024–2025 academic year, served as the sample. The results of the study are presented in Table 3.

Table 3: The results of the course objective attainment calculation.

Statistical Parameter	Sub-objective Weight			
	Course Objective 1	Course Objective 2	Course Objective 3	Total Course Objective
Minimum Value	0.505	0.432	0.446	0.474
Maximum Value	0.889	0.883	0.885	0.887
Average Value	0.757	0.729	0.734	0.744
Standard Deviation	0.073	0.086	0.084	0.079

As illustrated in Table 3, the mean attainment value for the total course objective is 0.744. Specifically, the mean attainment values for Course Objectives 1, 2, and 3 are 0.757, 0.729, and 0.734, respectively, all of which exceed the qualified standard of 0.70 set for this course. This outcome suggests that the course has largely achieved its anticipated objectives and has met the associated criteria for graduation. However, a more detailed analysis of the three sub-objectives indicates variations in their attainment. The data indicates that Course Objective 1 attained the highest value of 0.757, while Course Objective 2 attained the lowest value of 0.729. This finding suggests that the attainment of competency-based objectives, which emphasize engineering problem analysis, solution design, and integrated application (Course Objectives 2 and 3), was slightly lower than that for knowledge-based objectives, which focus on basic theories and quantitative calculations (Course Objective 1). This outcome indicates that students' ability to translate fundamental principles into the capacity to identify and analyze complex food engineering problems, along with their systematic thinking for proposing preliminary solutions, remains a relatively weak link in the teaching process. The attainment of Course Objective 3 (0.734) is positioned between the other two objectives. This outcome may be attributed to the comprehensive nature of the content, which encompasses both design practices and the consideration of non-technical constraints, such as safety and regulations.

The standard deviations for each course objective (0.073–0.086) and the overall objective standard deviation (0.079) were all at a low level. This finding suggests that the learning outcomes of the 30 students were concentrated within a narrow range, indicating a high degree of consistency in teaching implementation. However, it is noteworthy that the minimum attainment values for all course objectives were significantly lower than the average values. It is noteworthy that the minimum value for Course Objective 2 was only 0.432. This outcome suggests that, while the general course objectives have been met, some students have not demonstrated proficiency in cultivating core competencies, particularly in domains that require extensive application of knowledge for engineering judgment and problem decomposition.

3.1.2. Analysis of Individual Student Course Objective Attainment

The mean performance of the entire class across all course objectives is a measure of overall objective attainment. However, this measure does not reflect the specific contributions of individual students to those objectives. To achieve a comprehensive understanding of the relationship between individual and collective performance, the course objective attainment for each student in the class was quantified (see Figure 1).

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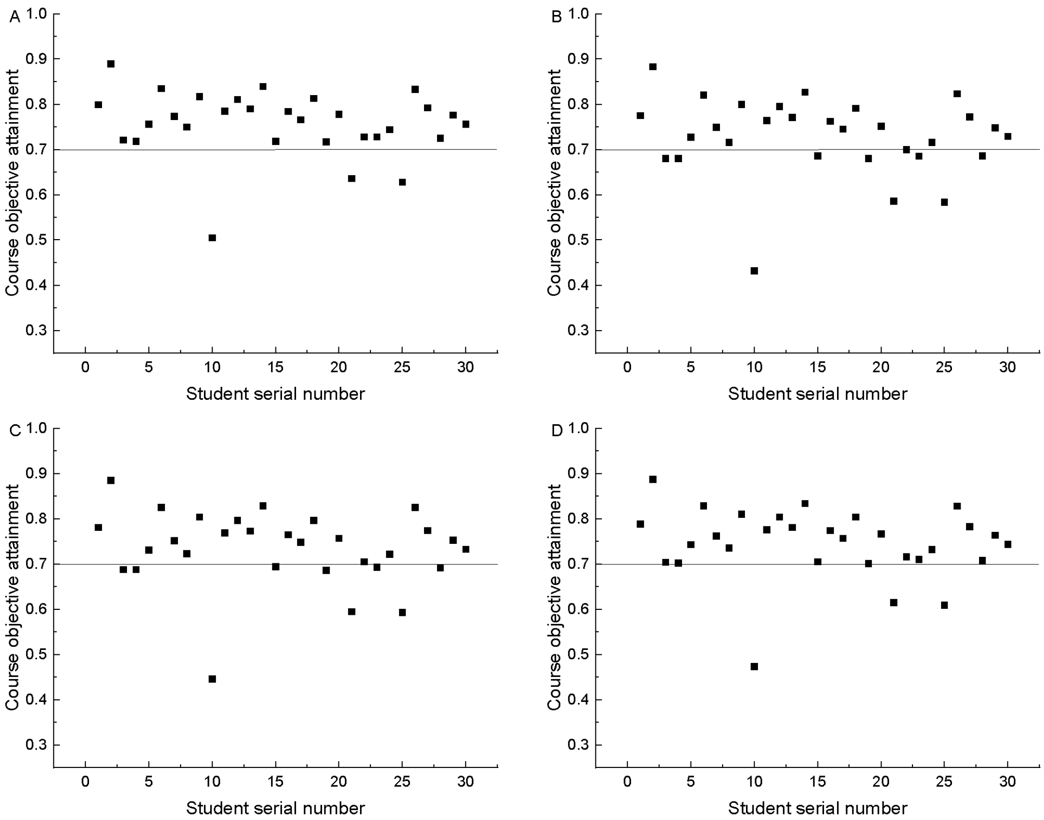

Figure 1: Distribution of individual student attainment for course objective 1 (A), course objective 2 (B), course objective 3 (C), and total objective (D).

The objective of Course Objective 1 is to ensure that students attain a comprehensive understanding of the fundamental theories of momentum, heat, and mass transfer. Additionally, students are expected to develop proficient mathematical modelling capabilities for unit operations. As illustrated in Figure 1A, only three students have attained scores below the expected value of 0.7, namely 0.505, 0.636, and 0.628. The majority of students demonstrated performance that surpassed established expectations, with an average score of 0.757. This finding suggests that the course has effectively fostered the development of fundamental theoretical and modelling competencies. Most students can effectively use material and energy balances to establish and solve unit operation models. A further analysis of the students who did not attain the required standard reveals that these three students significantly lowered the overall average, with their values far below the expected threshold. Given the assessment weightings (the combined contribution of knowledge tests, homework assignments, classroom performance, and the final examination to Objective 1 is 0.783), it can be inferred that these students likely encountered significant difficulties with key formative assessment components supporting this objective. These challenges may have manifested in areas such as understanding basic formulas during knowledge tests, model-building exercises in homework assignments, and model comprehension and application in the final examination. Consequently, pedagogical enhancements ought to be directed towards such students by fortifying diversified instruction and praxis in fundamental theories.

The objective of Course Objective 2 is to cultivate students' comprehensive analytical skills so that they can identify and decompose complex engineering problems and propose solutions. As illustrated in Figure 1B, nine students failed to attain the anticipated value of 0.7, with values ranging from 0.680 to 0.686. This finding indicates substantial deficiencies in their analysis of the engineering problem. It is evident that students who lost a substantial number of points on the comprehensive questions in the final examination, which required the integrated application of mathematical and engineering principles, the identification of key parameters, and problem decomposition, face the persistent challenge of learning to transform fundamental knowledge into problem-solving ability. Subsequent instruction should incorporate more complex case analyses to facilitate students' transition from knowledge understanding to problem analysis.

The objective of Course Objective 3 is to cultivate students' preliminary ability to design engineering solutions that consider multiple constraints, including but not limited to safety, health, and environmental

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factors. As illustrated in Figure 1C, nine students did not meet expectations, with values of 0.688, 0.688, 0.446, 0.694, 0.686, 0.595, 0.693, 0.593, and 0.692, respectively. It is noteworthy that the list of students who did not achieve the required standard for the course significantly overlaps with that of Course Objective 2, indicating a consistent group of students struggling with both advanced skills, namely problem analysis and design proposal. It was evident that students who did not meet expectations demonstrated deficiencies in integrating unit operation knowledge, which hindered their ability to propose reasonable, feasible, and compliant design solutions. This finding indicates shortcomings in their engineering synthesis and practical skills. In the context of future educational endeavors, it is imperative to elucidate engineering design standards and to integrate a greater number of small-scale design projects that are both pragmatic and that require multi-factor evaluation and training.

The attainment of total course objectives indicates students' overall mastery of the three objectives. As illustrated in Figure 1D, three students exhibited total attainment below 0.7, with values of 0.474, 0.615, and 0.609, respectively. These three students have not met the stipulated criteria for Course Objective 1. Furthermore, the attainment of Course Objectives 2 and 3 is generally low. This finding suggests that achieving Course Objective 1 has a significant impact on overall objective attainment. The absence of a robust theoretical foundation exerts a direct constraint on the subsequent development of problem analysis (Objective 2) and solution design (Objective 3) abilities, culminating in a substantial diminution in overall achievement. It was evident that students who achieved the overall objective demonstrated balanced development across their sub-objectives, with only minor deficiencies observed in specific advanced goals. Therefore, it is imperative to ensure that all students thoroughly grasp the fundamental principles and modelling methods of food engineering. This requirement is a key prerequisite for improving the course's overall teaching quality and students' comprehensive abilities. Teaching interventions must prioritize students who are significantly lagging in Course Objective 1.

3.2. Qualitative Evaluation Analysis

A comprehensive analysis of the qualitative attainment of the three sub-objectives in the Principles of Food Engineering course is crucial for evaluating teaching effectiveness from students' subjective perspectives. This analysis is based on the final questionnaire survey results, which provide essential evidence for this evaluation. All questionnaires were returned, and the specific statistical results are shown in Figure 2.

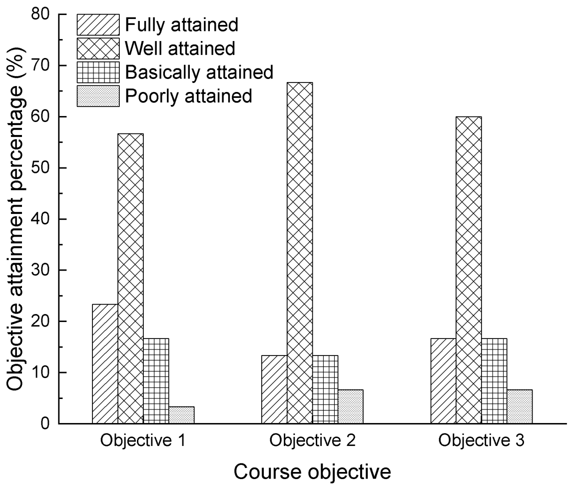

Figure 2: Statistical outcomes of the questionnaire survey of course objective attainment.

As shown in Figure 2, the statistical results of the course objective attainment questionnaire survey indicate that Course Objective 1 attained the highest level of qualitative fulfilment, with the combined categories of "fully attained" and "well attained" accounting for 80.00% of all responses. This outcome suggests that incorporating teaching material and energy balances, in conjunction with model solving using conventional unit operations such as fluid flow, heat transfer, and mass transfer, has facilitated students' comprehension of the fundamental principles and calculation methods in food engineering. This finding is consistent with the high attainment for this objective in the quantitative evaluation. The student perceptions of achievement for Course Objectives 2 and 3 are relatively similar. The combined percentages of "fully attained" and "well attained" were 80.00% and 76.67%, respectively, which were slightly lower than for Course Objective 1. This finding indicates that cultivating students' capacity to

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apply mathematical and natural science principles to evaluate and decompose key steps in complex food engineering problems, as well as to design solutions that consider multiple constraints such as safety, health, and environmental factors, poses a greater challenge. While most students self-assessed as having reached the "basically attained" level, the proportion that attained the "fully attained" level remains comparatively low. This finding suggests the necessity for ongoing enhancement of students' systematic thinking and comprehensive application ability in solving complex engineering problems.

3.3. Continuous Improvement

The correlation between the quantitative and qualitative analyses of course objective attainment indicates that teaching should prioritize facilitating students' transfer of basic theories to complex problem analysis and solution design. We propose the following improvement measures based on the analyses. Firstly, in optimizing teaching content, it is imperative to refine and restructure the teaching focus to emphasize key learning objectives. This pedagogical approach integrates complex engineering case studies from the food industry to cultivate students' ability to identify critical parameters, deconstruct problems, and formulate solutions that address multiple constraints. The objective of these measures is to address the shortcomings in achieving Objectives 2 and 3. Secondly, pedagogical methods ought to transition towards interactive, inquiry-based approaches that guide students in analyzing cases and enhance their systems-thinking skills. Thirdly, effective teaching implementation should explicitly articulate the course objectives and assessment requirements. In addition, the efficacy of differentiated tutoring should be reinforced to avert the manifestation of foundational weaknesses that could impede the cultivation of subsequent advanced abilities. Furthermore, assessment methods require refinement by moderately increasing the weight and frequency of comprehensive design and case analysis in both formative and summative evaluations. This approach is designed to facilitate student learning through a system of assessment, thereby incentivizing them to prioritize training in comprehensive application skills. Finally, it is imperative to ensure the continuous development and updating of the teaching case database. This approach aims to ensure that teaching content is closely aligned with food engineering practice, thereby promoting balanced attainment and the enhancement of students' engineering abilities.

4. Conclusions

The objective of this study was to develop and implement a system for calculating and evaluating course objective attainment in Principles of Food Engineering in accordance with the OBE philosophy. I clarified the course's support relationship for key indicators in the graduation requirements, including Engineering Knowledge, Problem Analysis, and Design/Develop Solutions. The evaluation results indicate that students have a relatively solid grasp of fundamental theories. Still, their comprehensive abilities, such as the identification and decomposition of complex engineering problems and the design of solutions under multiple constraints, remain relatively weak. The findings from the evaluations of both subjective qualitative and objective quantitative support the validity of the assessment conclusions. The system effectively diagnoses teaching effectiveness and student learning differences, providing empirical evidence to enhance teaching quality. Future pedagogical approaches should emphasize content restructuring, method innovation, and assessment optimization, with a particular focus on improving the analysis of complex engineering cases and design practice. This strategy will facilitate students' effective transformation of knowledge into advanced abilities, thereby continuously enhancing the quality of talent cultivation.

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