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RESEARCH ARTICLE

Construction and Practice of Outcomes-Based Education-Guided Project-Driven Teaching Model for Engineering Economics in Application-Oriented Undergraduate Universities

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Abstract

Engineering Economics is a core course for the Engineering Cost major in application-oriented undergraduate universities, yet traditional teaching often suffers from a theory-practice gap, low student participation, and polarized academic performance. Guided by Outcomes-Based Education (OBE), this study developed a three-in-one project-driven teaching model integrating modular theory, whole-process project practice, and diversified assessment. Theoretical content was reorganized into four application modules within a closed-loop "lecture-practice-assessment" process. A real local project—the renovation of an unfinished building into affordable rental housing in Zhaoqing City—served as the practical carrier, incorporating differentiated parameters, rotating group roles, and full-process Excel modeling. Formative assessment accounted for 40% of the total grade. The model was implemented over three semesters with 134 Engineering Cost students from the 2022–2024 cohorts at Guangdong Technology College. After the reform, the average course score increased from 70.38 to 85.65, the good and excellent rate from 31.4% to 83.9%, and the failure rate decreased from 25.5% to 3.2%. Moreover, 87.5% of students could construct dynamically linked financial models, while the classroom head-up rate in the reform class exceeded 85%, compared with approximately 50%–60% in the concurrent control class. The results demonstrate that the model effectively enhances learning outcomes and practical engineering economic analysis skills, providing a replicable approach for similar courses in application-oriented undergraduate universities, although further multi-institutional validation is needed.

Keywords: OBE, engineering economics, project-driven teaching, application-oriented undergraduate, excel modeling, engineering cost.

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1 Introduction

Driven by both the development of emerging engineering disciplines and the professional accreditation of engineering education, application-oriented undergraduate universities shoulder the fundamental mission of cultivating field engineers and project management talents [1]. Engineering Economics aims to train students to apply basic economic principles to conduct economic analysis and evaluation of engineering technical schemes so as to realize the optimal integration of technology and economy [2]. Its teaching effect acts as a key link to precisely align professional training objectives with industrial market demands [3]. Nevertheless, the traditional teaching mode of Engineering Economics has long been plagued by dilemmas including disconnection between theory and practice, low student engagement, and difficulty in reaching competency training targets [4]. For students in application-oriented undergraduate institutions, the abstract economic concepts and relatively complex calculations involved in Engineering Economics may further increase the difficulty of connecting theoretical knowledge with practical engineering applications [5]. Therefore, exploring an innovative teaching model that organically integrates theoretical instruction with practical competency cultivation has become an urgent priority for the curriculum reform of Engineering Economics in application-oriented undergraduate universities.

Outcome-Based Education (OBE) provides fundamental theoretical guidance to address the above challenges. First systematically elaborated by educator William G. Spady in 1982, OBE emphasizes clearly focusing and organizing an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences [6]. Its outcome-oriented design principle emphasizes student achievement, systematic assessment, and continuous improvement, thereby supporting the shift from content-centered instruction toward outcome-based engineering education [7, 8]. Outcome-oriented curriculum design is also embedded in international engineering accreditation frameworks. Leading accreditation systems such as those aligned with the Washington Accord require programs to define measurable student outcomes, systematically assess their attainment, and apply evaluation results to drive continuous quality improvement [9, 10]. Within engineering education, the OBE philosophy has been widely applied to multiple areas including training program formulation, curriculum system reconstruction and teaching quality assessment, and it has been verified to effectively improve students' clinical reasoning, practical skills and autonomous learning capabilities [11].

Project-Based Learning (PjBL) is one of the effective teaching strategies to implement the backward design concept of OBE and advance student-centered teaching reforms [12]. PjBL engages students in authentic and complex projects, where they actively construct knowledge, develop professional skills and cultivate critical thinking through solving practical problems and tackling challenges [13]. Its theoretical origin lies in John Dewey's educational philosophy of Learning by Doing, while constructivist learning theory lays its cognitive psychological foundation. The theory emphasizes that knowledge is constructed through social collaboration and active inquiry within real-life contexts [14, 15]. Previous studies have demonstrated that high-quality project-based learning can improve students' intrinsic motivation, problem-solving skills, and collaborative learning [16, 17]. In Industrial Engineering courses, students participating in external consulting projects can not only deepen their understanding of theoretical knowledge but also develop vital non-technical soft skills such as communication, teamwork and time management [18]. In chemical and petrochemical engineering education, project-based industrial-process activities have been reported to promote active participation, technical discussion, and application of engineering knowledge [19]. However, research by Kolmos et al. also indicates that the successful implementation of PjBL heavily relies on teachers' role transformation, elaborately designed project tasks and a matching evaluation system [20].

Although OBE and PjBL have each been validated as effective educational philosophies and teaching methods in their respective fields, systematic research that deeply integrates the two and comprehensively applies them to the Engineering Economics course at application-oriented undergraduate institutions remains insufficient. Existing studies on Engineering Economics education have explored approaches such as OBE-guided curriculum reconstruction and project-based teaching to strengthen the connection between theoretical knowledge and engineering practice [5, 21, 22]. A small number of scholars have attempted to combine OBE and PjBL. For example, in clinical psychiatric teaching, the integrated

OBE-PjBL teaching model outperforms traditional teaching in improving students' theoretical grades and practical abilities [11]; in biological laboratory courses, OBE-guided PjBL teaching has also been proven to significantly raise student participation and learning outcomes [23].

Current research mostly stays at the macroscopic introduction of OBE or PjBL theories and simple superposition of teaching procedures, lacking systematic and operable localized implementation frameworks [3]. Most reform practices still prioritize theoretical lectures supplemented by case analysis or simulated projects, without systematic practice that incorporates the full lifecycle of local real engineering projects into curriculum teaching [4, 5]. Project-based approaches in Engineering Economics have therefore been introduced to connect abstract economic concepts with integrated modeling and decision-making tasks, allowing students to apply multiple analytical methods within a coherent project context [24]. Previous studies have employed quantitative comparisons of student performance to evaluate instructional interventions in Engineering Economics [25]. However, evidence integrating academic performance, practical project outputs, learning behavior, and student feedback within a unified evaluation framework remains relatively limited.

To fill the above research gaps, this study selects third-year students majoring in Engineering Cost at Guangdong Technology College as research subjects and carries out a systematic teaching reform practice spanning three successive cohort-semesters. This research deeply integrates OBE's backward design principle with PjBL's project-driven strategy, takes real local engineering projects in Zhaoqing as practical carriers, and comprehensively reconstructs the curriculum's teaching objectives, content framework, practical procedures and assessment mechanisms. The core research objective is to explore an effective path that realizes deep integration of theoretical teaching and local engineering practice as well as seamless connection between competency cultivation and job requirements, so as to provide a replicable and promotable empirical example for the teaching reform of similar courses in other application-oriented undergraduate universities.

2 Teaching Pain Point Diagnosis and Student Learning Situation Analysis

To accurately identify prominent drawbacks in course teaching and acquire baseline data for subsequent reforms, a comprehensive pre-reform questionnaire survey was distributed to all 63 undergraduates from two Grade 2022 Engineering Cost classes (serving as the control group in follow-up research) prior to reform implementation. A total of 56 valid questionnaires were collected, yielding an effective response rate of 88.9%. Meanwhile, a systematic collation was conducted on complete teaching files, classroom observation records covering 128 class hours, and final examination data generated over two semesters of the 2022-2023 academic year. Diagnostic results reveal conspicuous deficiencies in four dimensions: teaching philosophy, curriculum content, instructional methods, and assessment system, collectively forming a dual predicament marked by "passive learning among students and heavy workload for instructors".

The course has long adopted the traditional teacher-centered model. Among the total 64 class hours, 48 hours of theoretical teaching mainly rely on one-way PPT-based lecturing. Instructors take charge of deriving core formulas such as net present value and internal rate of return, while students merely take notes passively without independent thinking or interaction. Observation data collected over two consecutive semesters reveal that under this model, the average proportion of students sitting in front rows is only 12.8%; the average number of voluntary questions and responses per class is fewer than 1.2, and over 80% of classes see no active student participation throughout the whole session. The pre-class questionnaire indicates that 89.3% of students report their effective concentration span in class is less than 20 minutes. This phenomenon of a "silent classroom" runs counter to the widely advocated student-centered teaching philosophy and leads to inefficient learning outcomes. Given the importance of active participation in Engineering Economics learning, previous studies have introduced active-learning strategies, including partially flipped instruction, problem-solving activities, discussions, and teamwork, to increase student engagement in the course [26].

Teaching strictly follows the chapter sequence of textbooks and prioritizes theoretical derivation. It fails to build effective links between economic analysis

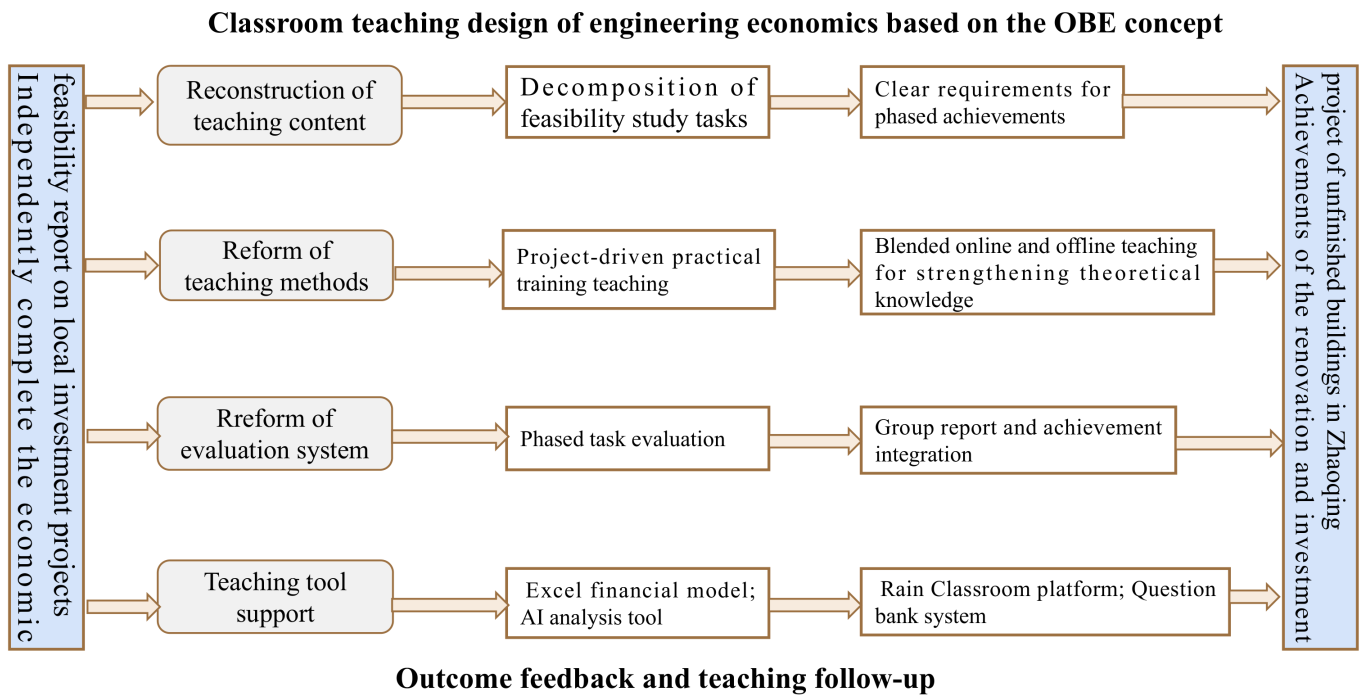

Figure 1. Roadmap for the engineering economics classroom reform.

methods and the daily work of cost engineers, nor does it illustrate the vocational application value of the course with local practical cases. Only 17.9% of students regard the course as "extremely important" for their future careers, while as high as 46.4% consider it "not very important" or "completely useless". Students' limited recognition of the practical relevance of the course may contribute to insufficient learning motivation and classroom engagement. Previous studies in Engineering Economy education have therefore explored hybrid and flipped teaching approaches to increase opportunities for active learning and improve student engagement and learning outcomes [27].

Engineering Economics contains numerous abstract concepts and complicated calculations, which set certain requirements for students' foundational knowledge of mathematics and economics. However, students enrolled in application-oriented undergraduate universities generally have weak basic knowledge and uneven logical thinking abilities. The survey shows that 62.5% of students self-assess their foundational knowledge as "very weak" or "relatively weak", and merely 8.9% rate their foundation as "sound". The traditional one-size-fits-all lecture method leaves underprepared students unable to follow the teaching content and advanced students lacking sufficient learning challenges, resulting in widespread inattention in class. The pre-class preview rate is lower than 15%, and the plagiarism rate of after-class assignments reaches 42.9%. Studies point out that for formula-intensive courses, a single terminal exam cannot accurately evaluate students' true knowledge mastery, and may instead trigger exam-oriented cramming behaviors [28].

Prior to the reform, the course adopted an assessment model dominated by summative evaluation, with final written examinations accounting for as much as 70% of the total grade. Regular performance scores consist only of attendance and homework. Assessments lay excessive emphasis on rote memorization and numerical calculation, ignoring the evaluation of practical application, teamwork and innovative ability. 87.5% of students believe the existing assessment system "cannot reflect practical application capabilities", and 82.1% admit they "cram formulas intensively one week before the exam". This high-stakes single-exam evaluation mechanism fails to motivate students' consistent daily learning, and cannot guide them to conduct deep learning or develop higher-order thinking skills, leading to unsustainable learning effects. Engineering Economics courses need to shift their focus from calculation to analysis and decision-making so as to maintain their practical relevance and vitality [29].

Based on the quantitative diagnosis covering the above four dimensions, this teaching reform establishes an overall framework centered on the OBE philosophy

Table 1. OBE-Based Modular Closed-Loop Design for Theoretical Teaching.

Module Name	Core competency development objectives	Corresponding practical training support
Module 1: Time value of money and equivalence calculations	Cultivate the concept of the time value of money, develop the ability to construct cash flow diagrams, and skillfully perform value conversions of funds at different time points.	Lays the foundation for discounting calculations in investment plan formulation and financial evaluation.
Module 2: Estimation of fundamental economic parameters for projects	Accurately identify and estimate the total project investment, costs, operating revenue, and taxes for a construction project, and complete basic financial data sheets.	Directly corresponds to the practical training task of investment estimation and economic parameter calculation, providing essential data input.
Module 3: Financial evaluation indicators and their application	Understand the economic meaning of dynamic evaluation indicators such as NPV and IRR, master their calculation methods and application scenarios, and conduct comparative selection among mutually exclusive alternatives.	Serves as the core support for the financial evaluation modeling practical training task, forming the decision-making core of feasibility studies.
Module 4: Risk and uncertainty analysis	Master break-even analysis and sensitivity analysis methods, identify key risk factors and quantify their impact, and understand the logic of risk response.	Directly guides the practical training task on risk and uncertainty analysis, completing the final critical section of the feasibility report.

and implemented via project-driven pedagogy, as illustrated in the reform roadmap (Figure 1). First, following Spady's OBE theory, the reform adheres to the principle of "beginning with the end in mind and backward design" to clearly define core competency objectives that students must achieve upon completing the course [6]. Second, knowledge, skills, and competency modules supporting these objectives are backward-designed from the competency targets. Finally, these modules are organically integrated into the PjBL teaching process based on authentic local engineering projects. Diversified formative assessments running through the entire semester are adopted to guarantee the full achievement of learning objectives [24].

3 Teaching Model Construction and Implementation

3.1 Modular Reconstruction of Teaching Content

To address the problems of fragmented content, complex formulas, high difficulty in understanding, and low learning enthusiasm in traditional theoretical teaching of Engineering Economics, this reform strictly follows the backward design principle of OBE. Taking students' ability to independently complete a comprehensive investment project feasibility study report as the core learning outcome, the original 48 class hours of theoretical teaching content were systematically reconstructed around the core knowledge and application skills required for this outcome. The complete compilation process of the feasibility study report was decomposed, and four core knowledge modules supporting the writing of each chapter of the report were extracted, so that the theoretical learning of each module directly corresponds to the specific compilation tasks in the report (see Table 1).

Instead of the traditional linear teaching model that follows the chapter order of textbooks, this reform reorganizes theoretical knowledge into four core application modules guided by the inherent cognitive logic and actual workflow of engineering project economic evaluation. Each module is equipped with a "lecture-practice-assessment" closed-loop teaching process (see Table 2). This content reconstruction aims to achieve two key transformations: first, shifting the knowledge organization logic from disciplinary systems to practical application scenarios, enabling students to clearly understand the specific uses of each part of knowledge in practice; second, transforming the classroom teaching model from one-way teacher lecturing to two-way teacher-student interaction and immediate feedback, effectively improving students' classroom participation and cognitive activity.

As shown in Table 1, the core of modular reconstruction lies in establishing a clear mapping

Table 2. Closed-Loop Teaching Process Design: Taking Module 3 "Financial Evaluation Indicators and Their Applications" as an Example.

Phase	Implementation Points	Corresponding Competency Development Link
Concentrated Lecture	Explains the economic implications and decision-making logic of NPV and IRR using daily cases (mortgages, credit card installments) and engineering examples (photovoltaic power plants, affordable housing).	Establishes intuitive understanding of core concepts and lays the cognitive foundation for subsequent calculations.
Targeted Practice	Distributes classroom workbooks for cash flow statement preparation and NPV/IRR exercises. Teachers provide on-site guidance to promptly identify and correct common issues in indicator calculation and sign judgment.	Transforms abstract concepts into hands-on skills and achieves initial knowledge internalization through immediate practice.
Integrated Assessment	Assigns tiered assignments via the Yu Classroom platform (basic calculations for formula consolidation + mini-cases for scheme comparison training). The system automatically grades basic questions, while teachers provide centralized online explanations for common decision-making errors in cases.	Achieves the leap from "being able to calculate" to "being able to judge" through tiered training and precise feedback.

relationship of "knowledge points – module competencies – report chapters – practical training tasks". When learning each module, students can clearly understand the specific position and role of the current knowledge in the subsequent feasibility study report, giving theoretical learning clear purpose and practical orientation, and effectively solving the problem of "disconnection between learning and application" in traditional teaching.

3.2 Theoretical Teaching Methodology

Regarding theoretical teaching methods, traditional courses follow the intrinsic disciplinary logic of overview, time value of money, evaluation indicators, uncertainty analysis, and value engineering. While this ensures conceptual coherence, it often disconnects from real-world application scenarios. This reform reorganized the module sequence to strictly align with the actual workflow of feasibility study report preparation. As students progress through each module, they clearly understand how and where knowledge will be applied in subsequent practical tasks, giving theoretical learning clear purpose and practical urgency.

To ensure the achievement of competency objectives for each module, a "lecture-practice-assessment" closed-loop teaching process was designed for every module (see Table 2), forming a complete chain from knowledge input to competency output.

To address common issues in traditional large-class lectures such as mobile phone use, inattention, and low participation, this reform introduced uniformly compiled classroom workbooks. Mandatory 15-20 minute in-class hands-on training sessions after each core knowledge point achieve three key breakthroughs: first, enforcing active participation by requiring students to calculate and think independently, transforming passive listening into immediate application; second, enabling instant feedback as teachers quickly identify common problems and individual differences through classroom observation, providing targeted group or one-on-one guidance; third, facilitating process documentation, with workbook completion serving as an objective basis for formative assessment.

In-class hands-on training effectively promotes immediate knowledge internalization, while the online Yu Classroom platform undertakes pre-class guidance and post-class consolidation functions. Pre-study materials are delivered to help students build preliminary understanding, and tiered post-class assignments enable automatic grading and learning data analysis, allowing teachers to accurately assess both class-wide and individual knowledge mastery.

In summary, the modular reconstruction of theoretical teaching is not a simple adjustment of class hours, but a systematic redesign of teaching content, organizational forms, and assessment methods oriented toward final learning outcomes and centered on effective student participation. By building a clear competency progression path through modularization (Table 1) and establishing an efficient instant feedback and

Table 3. Practical Training Project: Renovation of an Unfinished Building into Affordable Rental Housing in Zhaoqing.

Practical Phase	Corresponding Theoretical Module	Practical Hours	Core Tasks	Phase Outputs
Phase 1: Investment Estimation and Financing Scheme Design	Module 1	4	Basic data collection and analysis, investment estimation model construction, preliminary financing scheme design	Investment estimation table, financing scheme description
Phase 2: Economic Parameter Calculation	Module 2	4	Rental pricing strategy analysis, operating cost structure decomposition, revenue model construction	Operating income and tax estimation table, cost and expense estimation table
Phase 3: Financial Evaluation Modeling	Module 3	4	Financial statement modeling, profitability analysis, investment return evaluation	Cash flow statement, income statement, financial evaluation indicator calculation results
Phase 4: Risk and Uncertainty Analysis	Module 4	4	Key risk identification and quantitative assessment, sensitivity analysis, BIM technology application exploration	Break-even analysis chart, sensitivity analysis table, risk response recommendations

consolidation mechanism using workbooks and the Yu Classroom platform (Table 2), this reform lays a solid knowledge foundation for subsequent project-driven practical training.

3.3 Construction of Project-Driven Practical Teaching System

To fundamentally address the core disconnection between theoretical teaching and practical application, this reform, guided by the OBE concept, redesigned the 16-hour practical teaching component as a highly integrated, task-driven systematic project. It adopts a real local project—the renovation of an unfinished building into affordable rental housing in Zhaoqing City—as the overall practical carrier. This project integrates regional characteristics, social value, and comprehensive economic analysis elements, placing abstract engineering economics concepts into concrete decision-making contexts.

The practical teaching system strictly aligns with the theoretical modules, forming a complete chain of "theoretical module → practical phase → final output". The 48-hour theoretical courses and 16-hour practical courses are implemented synchronously across the four modules, with each theoretical module immediately followed by its corresponding practical phase to ensure immediate knowledge application. The specific class hour allocation and correspondence are shown in Table 3.

As shown in Table 3, the four practical phases strictly follow the generation logic of the "Economic Evaluation Chapter" in feasibility study reports, forming a complete decision support process from investment estimation to revenue prediction, comprehensive benefit evaluation, and finally risk testing and scheme robustness assessment. Each phase's outputs serve as data inputs for the next phase, allowing students to experience the entire process of "building a complete investment analysis report from scratch" and achieve the deep learning goal of "learning by doing and understanding through reflection".

3.3.1 Differentiated Parameter Design Principles and Group Collaboration Model

To address the result duplication problem caused by homogeneous tasks in traditional practical teaching, this study designed a differentiated parameter system based on real project data. By assigning key economic variables with subtle differences to different groups, it compels every student to fully participate in the entire process of Excel model construction, formula linking, and data calculation, effectively eliminating simple result duplication. Sensitive variables that significantly impact financial evaluation results were selected as differentiated parameters, including unit renovation cost (±15% variation range), expected rental level (±10% variation range), and financing interest rate (±20% variation range). All parameter values were set based on actual survey data of similar affordable rental housing projects in Zhaoqing City from 2023 to 2024, ensuring all group data fall within reasonable industry ranges.

This practical teaching was conducted with 31 students

Table 4. Group Role Division and Responsibilities.

Role	Number	Core Responsibilities
Project Leader	1	Oversee overall progress planning, coordinate internal division of labor, review phase results, and deliver classroom presentations.
Data Estimator	1	Collect local market data, organize basic parameters, and complete investment estimation and operating cost calculation.
Model Builder	1-2	Construct full-process Excel financial models, establish formula links, and perform dynamic debugging.
Analyst	1	Interpret financial indicators, conduct uncertainty analysis, demonstrate feasibility conclusions, and write reports.

from the 2024 cohort comprehensive reform class of the Engineering Cost major, who were divided into 8 groups of 3-4 students each following the principle of "heterogeneous grouping and complementary advantages". Standardized division of labor templates and collaboration processes were designed to solve the problems of "free-riding" and uneven participation in group practice. Each group was assigned four core roles with clear specific responsibilities across the four practical phases (see Table 4), ensuring task decomposition and responsibility assignment to individuals.

Core roles within each group are rotated after each practical phase to ensure every student works in at least two different positions by the end of the course and masters the full-process skills of project economic analysis. Each practical phase follows a standardized workflow: "task release → group division of labor → independent completion → intra-group cross-validation → teacher guidance → result submission → classroom peer evaluation", with clear time nodes for each link.

3.3.2 Full-Process Excel Modeling and Formative Assessment Design

This reform elevated Excel from an auxiliary calculation tool to the core analysis and modeling platform throughout the entire practical process. The teaching focus shifted from manual calculation to problem-solving using functions and models, systematically training comprehensive application of basic aggregation functions (SUM, AVERAGE), advanced financial functions (IRR, NPV, PMT), and data analysis tools (PivotTable, Data Table, Goal Seek).

This course adopts a diversified evaluation system, with formative assessment accounting for 40% of the total course grade. Formative assessment consists of four components, with independent scoring for each practical phase to ensure continuous tracking and timely feedback on students' learning processes. The specific scoring rules are shown in Table 5.

Table 5. The Assessment Scoring Rules.

Assessment Type	Assessment Dimension	Scoring Criteria	Scoring Basis
Formative Assessment (40%)	Classroom Performance	Attendance, quality of classroom exercises, interaction participation	Classroom workbooks, Yu Classroom records
	Phase Model Submission	Excel model completeness, formula link correctness, dynamic adjustability	Submitted Excel source files for each phase
	Intra-group Peer Assessment	Role performance, collaboration attitude, task completion quality	Anonymous peer assessment questionnaires at the end of each phase
	Final Report	Report structure completeness, data accuracy, conclusion logic, chart standardization	Final submitted feasibility study report
Summative Assessment (60%)	Final Written Exam	Core concept understanding, basic calculation ability, comprehensive application ability	Final closed-book examination paper

Table 6. Descriptive Statistics and Comparison of Final Examination Scores Across the 2022–2024 Cohorts.

Cohort	No. of Students	Mean ± SD	Max	Min	Pass Rate	Excellent Rate	Good and Excellent Rate
2022 (Traditional Teaching)	51	70.38 ± 16.23	98	21	74.5%	13.7%	31.4%
2023 (Partial Reform)	52	80.12 ± 10.56	97	35	94.2%	23.1%	57.7%
2024 (Comprehensive Reform)	31	85.65 ± 7.89	96	42	96.8%	45.2%	83.9%
Overall ANOVA	$F(2, 131) \approx 15.79$, $p < 0.001$						

Note. Pass = ≥60/100; Good = 80–89/100; Excellent = ≥90/100.

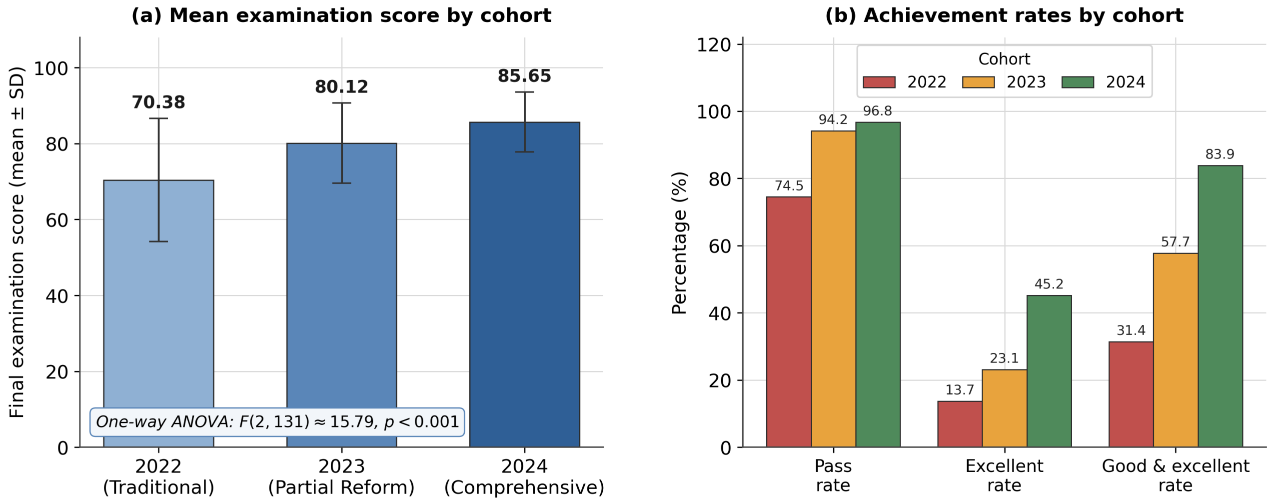

Figure 2. Comparison of final examination performance across the 2022–2024 cohorts. (a) Mean final examination scores (mean ± SD) and the overall one-way ANOVA result; (b) Pass, excellent, and combined good-and-excellent rates for each cohort.

3.3.3 Implementation of Optional BIM Task

While ensuring all students achieve core competency objectives, this design added an optional advanced task titled "BIM and Cost Data Correlation Analysis" to provide challenges for students with interdisciplinary integration abilities and interests. The task guides students to integrate core BIM technology of the Engineering Cost major into pre-project economic analysis, exploring cost-driven estimation models based on accurate quantity takeoff using Revit, focusing on solving industry pain points such as insufficient accuracy and difficult dynamic adjustment of traditional estimation methods.

This practical teaching was conducted with 31 students (8 heterogeneous groups) from the 2024 cohort comprehensive reform class, and 3 groups voluntarily chose to complete this advanced task. Among them, one group successfully realized automatic import and data linkage between Revit model quantity takeoff and Excel financial estimation models, achieving real-time updates of engineering quantities and costs when the BIM model was modified; one group constructed a two-way linkage mechanism between BIM models and financial evaluation models, enabling rapid calculation of the impact of design changes on project financial feasibility; one group completed full-life-cycle economic comparison of three different renovation process schemes based on BIM models, forming a complete scheme comparison report and decision recommendations.

4 Evaluation of Reform Effectiveness

To comprehensively and objectively evaluate the effectiveness of this round of Engineering Economics classroom teaching reform guided by the OBE concept and centered on project-driven learning, this study adopted a mixed-methods approach for comprehensive analysis from both quantitative and qualitative dimensions. Evaluation data were derived from the 2022-2024 course assessment database ($n = 134$), phased and final deliverables submitted by groups in the 2024 reform class ($n = 8$ reports), learning behavior records from the Yu Classroom platform, anonymous student course evaluation questionnaires (29 valid responses, 93.5% response rate), and targeted student interviews ($n =$

6). The comprehensive evaluation shows that the reform has achieved significant results in improving students' academic performance, developing practical competencies, transforming learning attitudes, and promoting the transformation of teaching outcomes.

4.1 Significant Improvement in Final Examination Scores

The statistical and comparative analysis results of final examination scores for the Engineering Economics course among the 2022-2024 cohorts of the Engineering Cost major are presented in Table 6 and Figure 2. The 2022 cohort adopted the traditional lecture-based teaching model, the 2023 cohort introduced partial project-driven teaching links, and the 2024 cohort fully implemented the whole-process project-driven teaching reform based on the OBE concept. No statistically significant differences were detected among the three cohorts in admission scores or prerequisite-course GPA ($p > 0.05$), although the observational cohort design does not establish baseline equivalence.

One-way ANOVA showed a statistically significant difference in mean final examination scores among the three cohorts ($F(2,131) \approx 15.79$, $p < 0.001$). Post-hoc pairwise comparisons (Tukey HSD) confirmed that all three cohorts differed significantly from one another (all $p < 0.05$). As the teaching reform was progressively implemented, the mean final examination score increased from 70.38 in the 2022 cohort to 85.65 in the 2024 cohort, while the good-and-excellent rate increased from 31.4% to 83.9% and the failure rate decreased from 25.5% to 3.2%. These findings indicate a clear improvement in student performance across successive cohorts and suggest that the progressive implementation of the OBE-guided project-driven teaching model was associated with improved academic outcomes.

4.2 Quantitative Analysis of Practical Ability Improvement

Compared with changes in examination scores, improvements in students' practical skills, tool application, and comprehensive problem-solving abilities were also observed. Analysis of the final deliverables submitted by the eight student groups in the 2024 comprehensive reform cohort showed that all groups (8/8, 100%) completed Excel-based financial evaluation models. Seven of the eight student groups (7/8, 87.5%) successfully constructed dynamically linked financial models in which cash flow statements, income statements, and financial evaluation indicators such as NPV and IRR were automatically updated when key input parameters, including total investment, costs, and revenues, were modified. Six groups (6/8, 75.0%) correctly used cell references and formula links to minimize hard-coded values. In the risk and uncertainty analysis component, seven groups (7/8, 87.5%) completed break-even analyses, of which six groups (6/8, 75.0%) correctly produced break-even charts. All eight groups (8/8, 100%) completed one-way sensitivity analyses, and six groups (6/8, 75.0%) correctly used Excel Data Table or equivalent simulation functions to generate sensitivity analysis tables.

4.3 Qualitative Evidence of Changes in Learning Attitude and Classroom Ecology

Changes in learning attitude and classroom participation are another key indicator of reform success. This transformation is clearly evident from 128 class hours of classroom observation records, Yu Classroom platform data, and student feedback. The mandatory use of in-class exercise workbooks has virtually eliminated mobile phone use and empty-handed listening in class. Classroom observation records show that the head-up rate in theoretical classes of the reform class stabilized above 85%, compared with approximately 50%-60% in the control class during the same period. In practical training classes, due to differentiated data tasks for each group, group discussions and modeling calculations around personal computers have become the norm, transforming the classroom from a passive listening venue into an active workshop and decision simulation room.

Yu Classroom platform data showed that the average number of course material views per student was 12.6 in the reform cohort, compared with 8.3 in the comparison cohort, representing a relative increase of 51.8%. The preview completion rate was 78.8% in the reform cohort and 56.2% in the comparison cohort, representing a difference of 22.6 percentage points. In the anonymous questionnaire, 82.8% of respondents (24/29) agreed that "learning by completing a real project makes goals clearer and more fulfilling." Representative student feedback included: "Group division and role rotation ensure everyone participates—no more free-riding. Though challenging, completing a full report brings great satisfaction" and "Dynamic Excel models are highly practical; changing one parameter updates all results automatically, which is far more efficient than manual calculations. This will be valuable for graduation projects and future work."

4.4 Preliminary Exploration of Teaching Outcome Continuity

The effectiveness of teaching reform should not end with course completion but should be reflected in its long-term impact on students' subsequent learning and development. This round of reform has made preliminary attempts in this regard and achieved positive feedback. This semester, 2 student groups (8 students in total) formally applied to further expand and deepen their "Feasibility Study on the Renovation of Unfinished Buildings" completed in this course as the topic for their graduation design (thesis). Although only 2 groups (25% of all groups) with a small sample size, this marks the initial opening of the connection channel between course teaching and graduation design. This "course-to-graduation project" through-train model allows students to avoid hasty topic selection in the graduation season and conduct more in-depth exploration based on a real project with solid preliminary research foundations.

Despite the limited number of outcome transformations at present, this preliminary attempt demonstrates the possibility of extending teaching reform outcomes—course teaching consolidates foundations, and graduation design deepens innovation, forming a virtuous cycle of continuous competency construction. Future research will further improve the tracking mechanism, expand the sample size, and explore effective paths to transform more high-quality course project outcomes into graduation designs, discipline competitions, or college student innovation and entrepreneurship projects.

5 Reflections on the Limitations of the Teaching Reform

Despite the remarkable achievements of this teaching reform, there are still three deep-seated limitations that require continuous optimization in subsequent practices.

First, the reform imposes higher requirements on students' prior knowledge reserves, which has exacerbated the "Matthew effect" in academic performance to a certain extent [11]. Teaching practice shows that students with weak economic and mathematical foundations face the greatest difficulties in the financial evaluation modeling phase (Practical Phase 3), which requires the comprehensive application of Excel functions, financial logic and data linkage capabilities. Data show that approximately 12.9% of students (4/31) in the 2024 reform class required repeated one-on-one guidance from teachers during Excel formula writing and dynamic model construction, taking more than 40% longer to complete tasks than the class average. In contrast, students with stronger foundations not only finished core tasks ahead of schedule but also proactively explored advanced technologies such as BIM and Python. To address this issue, this study implemented an intra-group peer tutoring measure where students with stronger foundations served as technical assistants. However, due to limited teacher capacity, the coverage and depth of tutoring remained insufficient. Additionally, project-driven teaching places high demands on students' self-directed learning abilities, and some students accustomed to passive knowledge reception struggle to adapt to this learning model, often falling behind in progress. Therefore, designing more graduated learning scaffolds for students at different starting points and developing micro-courses on prerequisite knowledge are key directions for future reforms.

Second, the transformation of the teaching model has posed severe challenges to teachers' comprehensive literacy and workload [5]. Project-driven teaching requires teachers to shift from "knowledge transmitters" to "project designers, process guides and resource coordinators", demanding not only a solid theoretical foundation but also rich engineering practice experience. Currently, only 30% of the teaching team for this course have more than 3 years of work experience in engineering cost consulting enterprises, which cannot fully meet the demand for developing high-quality project cases. In terms of workload, compared with traditional teaching, the total workload of teachers under the project-driven teaching model has increased by approximately 2.5 times, mainly reflected in four aspects: real project case development (30%), differentiated parameter design and preparation (20%), full-process guidance for students' practical activities (35%), and diversified assessment and evaluation (15%). Furthermore, teachers need to flexibly switch between intensive theoretical lectures, group collaboration, individual tutoring and classroom discussions, allocate time reasonably, and simultaneously manage the complexity arising from varying progress among different groups, which places higher demands on classroom management capabilities.

Third, the sustainability and generalizability of the reform are constrained by both resource conditions and institutional factors. First, there is a lack of a stable school-enterprise cooperation mechanism for case updates. The unfinished building renovation project case in Zhaoqing City used in this reform mainly relies on the personal research project of the course leader, and a regular case co-construction mechanism with local engineering cost enterprises has not yet been established. The case update cycle is as long as 2-3 years, making it difficult to keep up with the rapid changes in industry technologies and policies. Second, the workload of formative assessment is mismatched with the incentive mechanism. Formative assessment accounts for 40% of the total grade in this course, requiring teachers to review the four-phase deliverables and final reports of 8 groups one by one, and organize classroom presentations and defenses. The workload is 3-4 times that of traditional final examination grading. However, in the current university teaching workload accounting system, such additional inputs are only calculated based on traditional class hours, lacking special incentives, which makes it difficult to mobilize teachers' enthusiasm in the long run. In addition, the promotion of the reform also requires supporting digital teaching platforms and practical teaching environments, which poses a significant challenge for application-oriented undergraduate universities with relatively limited resources.

6 Conclusion

This study addresses the core pain points of the Engineering Economics course in application-oriented undergraduate universities, including the disconnection between theory and practice, low student participation, and single assessment methods. Taking the Engineering Cost major at Guangdong Technology College as a pilot, it constructs an OBE-guided three-in-one project-driven teaching model integrating "modular theory, whole-process project practice, and diversified assessment". Through continuous teaching practice and comparative analysis of three cohorts from 2022 to 2024, the significant effectiveness of this model in improving students' academic performance, practical abilities and learning initiative has been verified. The research shows that the whole-process teaching based on the real local project of renovating an unfinished building into affordable rental housing in Zhaoqing City has effectively solved many dilemmas of traditional teaching. However, this study was only conducted as a pilot in a single major at a single university with a relatively limited sample size. The stability and generalizability of the reform effects still need further verification in different types of application-oriented undergraduate universities, and issues such as the "Matthew effect" in academic performance also require continuous optimization in subsequent practices.

In response to the problems identified in this reform, future efforts should further improve the hierarchical teaching system, develop micro-courses on prerequisite knowledge, and establish a "teacher + excellent student" dual-tutor tutoring mechanism to alleviate the "Matthew effect". It is necessary to strengthen the construction of a dual-qualified faculty team, promote universities to reform the teaching workload accounting system, and establish special awards for teaching reform to mobilize teachers' enthusiasm. A dynamic case library co-constructed through school-enterprise cooperation should be built with a regular case update mechanism. On the basis of comprehensively promoting this teaching model in our university, multi-school parallel controlled experiments should be carried out with several application-oriented undergraduate universities in the province, and advanced technical modules such as Python data analysis and BIM-cost integration should be introduced. We will continue to deepen teaching reform to cultivate more high-quality application-oriented engineering cost talents for the regional construction industry.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

This study was conducted as part of a routine educational teaching reform in the Engineering Economics course at Guangdong Technology College, China. The study involved analysis of anonymized course performance data, classroom observation records, and voluntary anonymous student questionnaires and interviews collected in the context of normal teaching activities. No personally identifiable information was collected or reported, and participation in the questionnaires and interviews had no influence on students' course grades or academic evaluation. All data were analyzed and reported in aggregate form to protect student privacy and confidentiality. Students participating in the questionnaires and interviews were informed of the purpose of the study and participated voluntarily.

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