Teaching Reform and Practice of OBE in the Course "Engineering Geological Numerical Simulation" under the Background of Engineering Education Accreditation: A Case Study of the Institute of Disaster Prevention

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Abstract: Under the framework of engineering education accreditation, to address the deviations in traditional teaching of the "Engineering Geological Numerical Simulation" course—namely teacher-centered instruction (teaching replacing learning) and outcome-over-process bias (emphasizing results over process)—this paper, guided by the OBE philosophy and taking the Geological Engineering program at the Institute of Disaster Prevention as a case study, implements course teaching reform and practice. By reconstructing a three-dimensional (knowledge – ability - literacy) course objective system and establishing a quantifiable support matrix aligned with graduation requirements; constructing a progressive three-tiered teaching content framework (basic theory → software technology → engineering application); innovating a hybrid "online-offline + virtual-real integration" teaching methodology; and designing a three-dimensional dynamic evaluation network (process-ability-ethics), two rounds of teaching practice demonstrate: student classroom interaction increased by 297%, course objective attainment reached 0.83–0.88, engineering ethics awareness completeness doubled. The reform achieves a paradigm shift from teaching-centered to learning-centered pedagogy, providing a reusable OBE practice model for similar courses in application-oriented undergraduate institutions.

Keywords: Engineering Education Accreditation; OBE Philosophy; Engineering Geological Numerical Simulation; Teaching Reform; Process Evaluation; Competency Attainment

1. Introduction

Currently, global engineering education is undergoing a conceptual reconstruction centered on Outcome-Based Education (OBE)[1-4]. Since China officially joined the Washington Accord in 2016, engineering education professional accreditation has become an authoritative standard for measuring the quality of engineering talent cultivation in higher education institutions. The accreditation system emphasizes three core principles: "student-centered, outcome-oriented, continuous improvement," requiring the curriculum system to directly support the achievement of graduation requirements, with particular emphasis on students' ability to solve complex engineering problems[5-8]. Against this backdrop, "Engineering Geological Numerical Simulation," as a core course in our Geological Engineering program, has shifted its teaching objectives from traditional "knowledge transmission" to "competency development," becoming a key supporting element for cultivating "complex engineering problem-solving skills" under accreditation standards [9-13].

Despite its critical status, the current teaching model faces severe challenges, manifested as dual cognitive deviations: Teaching-subject deviation: "Teacher-centered, student-supplementary." Current classrooms predominantly adopt a "cramming" approach with one-way lectures, where students passively receive numerical simulation theories and software operation procedures, lacking active participation and deep thinking. Teaching-process deviation: "Emphasizing results over process." Course assessment long relies on a dual structure of "regular assignments + final exams," neglecting formative evaluation of students' modeling thinking, parametric sensitivity analysis, and critical evaluation of results [14,15].

This paper, anchored in engineering accreditation standards and considering the characteristics of application-oriented undergraduate education, constructs a tripartite reform path: "objective restructuring → content scaffolding → evaluation enhancement." By reshaping the syllabus, developing a tiered practical training system, and building a dynamic evaluation network, it achieves a paradigm shift from teaching-centered to learning-centered pedagogy, providing a reusable reform model for similar institutions[16-22].

2. OBE-Driven Course Objective Restructuring and Graduation Requirement Support

The primary task of this course reform is to deeply integrate the OBE philosophy into the top-level course design, achieving a fundamental shift from "what to teach" to "what abilities students should attain," ensuring course objectives precisely support professional graduation requirements. The OBE philosophy emphasizes the reverse design principle of the educational process: first clarifying the core competencies students should possess five years after graduation (graduation requirements), then decomposing them into cultivation tasks to be undertaken by the course (course objectives), realizing outcome definition as the guide; teaching design consistently revolves around "what students can do," with teachers transforming from knowledge transmitters to guides and assessors of competency development, emphasizing student development as the center; establishing a dynamic cycle mechanism of "setting goals → implementing teaching → evaluating attainment → feedback improvement," achieving a closed loop of continuous improvement. For the "Engineering Geological Numerical Simulation" course, traditional objectives focused on "mastering the principles of the finite element method." According to the OBE philosophy, course objectives are transformed into "ability to establish slope stability models using appropriate numerical methods based on geological survey data and evaluate their reliability." On this basis, course objectives are reconstructed.

2.1 Course Objective Restructuring Based on Three-Dimensional Competency Orientation

Based on the Institute of Disaster Prevention's educational positioning of "serving regional disaster prevention and mitigation," and aligned with geological engineering professional accreditation standards and industry demands, a knowledge-ability-literacy integrated course objective system is reconstructed (Table 1).

Table 1. Restructured Knowledge-Ability-Literacy Integrated Course Objective System

Dimension	Objective Description	Corresponding Complex Engineering Problem Characteristics
Knowledge	Master theories such as constitutive model selection for rock/soil masses, boundary condition setting, parametric sensitivity analysis	Multi-factor coupling
Ability	1. Apply FLAC3D software to complete 3D geological modeling and calculation (supporting geohazard prevention); 2. Analyze discrepancies between simulation results and field monitoring data and propose optimization schemes; 3. Design numerical simulation solutions for typical problems such as slope deformation and seismic loading High comprehensiveness;	Solution innovativeness
Literacy	1. Demonstrate collaboration spirit and responsibility awareness in group projects (teamwork); 2. Maintain scientific critical thinking in result analysis (engineering ethics)	Social responsibility dimension

2.2 Construction of Course Objective-Graduation Requirement Support Matrix

Course objectives need to establish support relationships with graduation requirements. Based on the three-dimensional competency-oriented design, a quantifiable and traceable support relationship matrix is established to clarify the contribution of the course to professional graduation requirements (Table 2).

Table 2. Support Relationship between Course Objectives and Graduation Requirement Indicators

Course Objective	Graduation Requirement Indicator Support	Strength	Evaluation Evidence
Ability Objective 1: Software modeling ability Graduation	Requirement 2.3: Ability to select and use modern engineering tools for simulation and analysis of complex geological engineering problems	H (Strong support)	Special training reports, model files
Ability Objective 2: Result analysis and optimization	Graduation Requirement 3.2: Ability to identify and verify influencing factors of complex engineering problems based on scientific principles M (Medium support) Parametric	M (Medium support)	sensitivity analysis reports, group optimization scheme defense
Ability Objective 3: Solution design	Graduation Requirement 4.2: Ability to design systems, units, or processes meeting specific needs	H	Comprehensive training design manuals, engineering case simulation reports
Literacy Objective 1: Team collaboration	Graduation Requirement 9.1: Ability to undertake individual, member, or leader roles in multidisciplinary teams	L (Weak support)	Group project contribution peer review, collaboration process records
Literacy Objective 2: Engineering ethics	Requirement 8.2: Understand the impact of engineering practice on public safety and environment, comply with professional ethics	M	Ethical discussion in scheme comparison, environmental impact assessment of simulation results

2.3 Syllabus Restructuring: Textual Implementation of OBE Philosophy

The new syllabus, as a programmatic document implementing the OBE philosophy, abandons traditional vague expressions such as "understand" or "comprehend" in objective statements. Instead, it uses observable action verbs to precisely define competency objectives. For example, "master basic principles of the finite element method" in the original syllabus is redescribed as "ability to establish a 2D slope stability calculation model using the finite element method based on geological profiles (including mesh discretization and boundary setting)." This directly links teaching objectives to specific abilities students need to demonstrate, corresponding to higher cognitive levels of "application" and "analysis" in Bloom's taxonomy.

Simultaneously, teaching content is modularly reorganized, breaking textbook chapter limitations to construct a three-tiered progressive module: "basic theory → software technology → engineering application." Basic Theory Module: Focuses on principles of numerical methods. Software Technology Module: Through modular training units, covers 3D modeling and meshing, geotechnical parameter assignment and sensitivity analysis, and extraction/visualization interpretation of calculation results. Engineering Application Module: Integrates real cases, requiring students to complete comprehensive training spanning from digitalization of geological conditions to prevention scheme design.

The syllabus design emphasizes strong linkage between assessment evaluation and objectives, establishing a dual-track "process-summative" evaluation system to ensure assessment directly verifies course objective attainment.

Through restructuring in these three aspects, the syllabus highlights the goal orientation of "learning," clarifies learning outcomes, strengthens the proportion and design of process assessment in grading, and implements the OBE philosophy textually.

3. Core Paths of OBE-Based Course

Teaching Reform

Geological numerical simulation teaching must confront three challenges: "profound theory, difficult practice, variable geology." After defining course objectives, based on the outcome-oriented education philosophy, course teaching reform unfolds across three dimensions: content restructuring, methodology innovation, and evaluation reform. Through "modular decomposition of knowledge → scenario-based training of abilities → data-driven improvement," it strives to resolve cognitive deviations in traditional teaching models, transforming abstract accreditation standards into operable classroom practices, and providing a paradigm for cultivating new engineering talents who "understand geology, master numerics, and excel at problem-solving."

3.1 Teaching Content Restructuring: "Knowledge→Ability→Engineering" Three - Tiered Progressive System

Breaking down textbook chapter barriers, course content is reorganized into three core modules: Basic Theory, Software Technology, and Engineering Application.

Basic Theory Module (16 credit hours): Principles of numerical methods and criteria for selecting constitutive models of geological bodies.

Software Technology Module (16 credit hours): Includes three specialized trainings—geological modeling, parametric analysis, and post-processing (Table 3)—covering adaptive 3D mesh generation, structural plane mesh generation, parametric sensitivity experiment design, inverse algorithm application, multi-field coupled result visualization, and monitoring data-simulation result comparative analysis.

Engineering Application Module (16 credit hours): Primarily includes a constructed typical case library covering slope instability, seismic wave propagation, foundation pit stability, and support. Through these modules, students' ability to handle complex geological problems is strengthened.

Table 3. Construction of a "Basic Operation → Specialized Skill → Integrated Innovation" Three-Tiered Practice System for Stepwise Competency Enhancement

Tier	Training Content	Key
Basic Operation	Software interface familiarity / simple model replication	Tool utilization ability
Specialized Skill	Parametric sensitivity analysis / mesh convergence verification	Scientific analysis ability
Integrated Innovation	Full-process simulation solution for real engineering problems	Complex problem-solving ability

3.2 Teaching Methodology Innovation: Creating a "Online-Offline + Virtual-Real Integration" Hybrid Ecosystem

In teaching methodology, emphasis is placed on the virtual-real integration of online platforms and offline practice. An "Intelligent Geological Body Parameter Recommendation System" is developed to automatically generate parameter ranges from lithological descriptions. "FLAC3D Operation Technique" videos are produced to address students' questions anytime. In offline teaching, engineering-problem-driven pedagogy is adopted, allowing students to experience stages of independent exploration, followed by group collaboration, and finally teacher refinement. For online-offline integration, "Rain Classroom" is utilized to set bullet-screen questions and push group tasks, distributing differentiated modeling tasks to each group to enhance student competency.

3.3 Assessment Evaluation Reform: Constructing a "Process-Ability-Ethics" Three-Dimensional Evaluation Network

To resolve the traditional evaluation pitfall of "emphasizing results over process," this course constructs a three-dimensional evaluation system integrating process tracking, ability verification, and ethical literacy into a comprehensive evaluation framework.

Process Evaluation (50% of total score): Focuses on competency development throughout the learning cycle. It includes four core assessment tasks: geological modeling standardization assessment, parametric sensitivity analysis assessment, group engineering project assessment, and classroom dynamic contribution assessment, emphasizing student evaluation during the learning process.

Summative Ability Integration (50% of total score): Includes complex engineering simulation assignments and engineering ethics defense, emphasizing comprehensive ability verification in complex engineering scenarios.

Concurrently, a continuous improvement mechanism is upheld in evaluation, adopting a "collection-diagnosis-closed-loop" approach. Through standardized data collection, application of attribution analysis tools, and threshold-triggered improvement, specialized teaching interventions are activated when course objective attainment falls below 0.7, dynamically adjusting the proportion of teaching modules based on attribution results.

4. Preliminary Outcomes of Reform Practice

After two rounds of teaching practice (2023–2024 academic year), the OBE-based course reform has achieved significant multidimensional results. Quantitative data comparison, competency attainment analysis, and student feedback validate the effectiveness of the reform path.

4.1 Enhancement of Student Learning Efficacy: From Passive Reception to Active Construction

Rain Classroom data monitoring shows a significant increase in classroom interaction: average bullet-screen questions per class hour rose from 3.2 pre-reform to 12.7, a 297% increase. Group task completion rate increased from 68% to 94%; case library access frequency grew by 215%. This reflects a shift in student learning efficacy from passive reception to active construction.

4.2 Breakthrough in Course Objective Attainment: Precise Support for Graduation Requirements

Attainment of core objectives: η_1 (Modeling Ability) = 0.88 → Strongly supports Graduation Requirement 2.3 (ability to select and use modern engineering tools for simulation and analysis of complex geological engineering problems);

η_2 (Analysis Ability) = 0.83 → Key breakthrough: comparative analysis scores for station data increased by 31%, supporting Graduation Requirement 3.2 (ability to identify and verify influencing factors of complex engineering problems based on scientific principles).

4.3 Manifestation of Engineering Literacy: Cultivation of Ethical Awareness and Collaboration Ability

"Public safety discussion completeness rate" in ethics defense reached 87% (pre-reform: 42%). For example, one group proposed in a campus slope report: "Safety factor 1.1, but slope toe is a dormitory area; recommend adding monitoring points," adopted by enterprise experts.

5. Conclusion

By constructing an OBE closed loop of "objective restructuring → content progression → dynamic evaluation," the dual cognitive deviations of "teaching replacing learning" and "emphasizing results over process" are resolved, achieving a paradigm shift from "knowledge transmission" to "competency development."

The three-tiered progressive system significantly enhances students' ability to solve complex engineering problems, with course objective attainment exceeding 0.83. Through designs such as parametric sensitivity analysis and ethics defense, engineering literacy is manifested and quantified.

Developed tools such as the "Intelligent Geological Body Parameter Recommendation System" and "Dynamic Evaluation Threshold Trigger Mechanism" provide reusable technical pathways for similar application-oriented undergraduate institutions. Cross-disciplinary collaboration cases confirm their promotion value in multidisciplinary engineering education.

Future efforts will continue optimizing the virtual-real integrated teaching resource library, deepening the cultivation of the "simulation → monitoring → optimization" competency chain, and strengthening alignment with regional disaster prevention and mitigation needs.

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