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Course-Level Teaching Reform in Soil Mechanics Based on Engineering Decision Making

Yuan Chang

School of Civil Engineering, University of Science and Technology Liaoning, Anshan, Liaoning, 114051, China

Abstract: Soil Mechanics is usually taught as a chain of related topics, yet a student can finish the calculations and laboratory exercises without ever connecting them to engineering judgment. This paper proposes a course-level teaching framework that ties soil behavior, evidence, decision making, and review together across eight core modules: soil classification, seepage, stress and effective stress, consolidation and settlement, shear strength, earth pressure, bearing capacity, and slope stability. Each module opens with a physical representation of the problem and then asks students to weigh assumptions, calculations, test results, and observations before settling on an engineering recommendation. Assessment draws on concept checks, numerical work, laboratory interpretation, short decision memos, and a cumulative coursework portfolio that preserves feedback and revision. A seepage lesson demonstrates the classroom process, moving from identification of a failure mechanism to the selection of control and monitoring measures. The paper also outlines a staged implementation and evaluation approach that rests on scenario assessments, student coursework and its revisions, and rubric-based evaluation.

Keywords: Soil Mechanics; Curriculum Reform; Engineering Decision Making; Formative Assessment; Engineering Education.

1. Introduction

Soil mechanics deals with a natural material whose behavior shifts with composition, stress history, water conditions, and loading [1-2]. Reproducing equations is not enough; a student also has to judge whether a model fits the problem, choose the evidence behind the analysis, and recognize when uncertainty warrants further investigation or monitoring. Geotechnical education has long used problem- and project-based formats to put these judgments inside realistic design constraints [3-7]. Active-learning research points the same way, showing that participation becomes valuable when activities are tied to explicit learning goals [8].

Most syllabuses follow the same conceptual order—classification, seepage, effective stress, consolidation, shear strength, earth pressure, bearing capacity, and slope stability [1-2]—and the order itself is defensible. Yet students often meet each chapter as nothing more than a new set of formulas. Classification stays unconnected to the parameters chosen later, laboratory results never reach design values, and stability calculations have no visible link to monitoring. The difficulty is therefore one of connection: the course has to give students repeated chances to travel from soil behavior and evidence to an engineering judgment.

This paper puts forward a course-level reform framework for eight core Soil Mechanics modules. Learning outcomes, classroom activities, and assessment tasks line up behind one chain of reasoning: explain the governing mechanism, examine the calculation and test evidence, make an engineering decision, and review that decision when conditions change. The design builds on soil mechanics textbooks [1-2], constructive alignment [9], formative assessment [10-11], and reported experience with active and problem-based engineering education [3-8,12]. A worked seepage lesson shows how the framework operates within one topic, and a plan for course implementation and evaluation follows.

2. Literature and Design Rationale

The conventional ordering of Soil Mechanics topics mirrors real conceptual dependencies. Classification guides the parameters that later appear in design; seepage alters pore-water pressure and effective stress; consolidation and shear strength shape settlement and stability; and those links underpin the analysis of retaining structures, foundations, and slopes [1-2]. Teaching each topic correctly matters, but the connections between topics have to surface in what students actually produce.

The reform keeps the disciplinary sequence and superimposes a uniform reasoning process on all modules. A student first represents the physical problem, then compares that representation against calculations, laboratory results, or field observations. The evidence is then used to defend a parameter, a model, or a control measure, and to state the condition under which the judgment would need to be reconsidered. Equations, derivations, laboratory work, and standard problem solving stay at the center of the course, since they supply the basis for every decision.

Engineering cases are bounded deliberately. Each one carries enough information for students to work with the target concept, yet leaves chosen uncertainties open for discussion. Direct explanation and worked examples build the initial conceptual model; guided inquiry enters once students possess the theoretical and computational tools the case requires. In this arrangement the systematic study of soil mechanics, not the casework itself, remains the center of the course.

Constructive alignment supplies the organizing principle for the redesign: learning outcomes, teaching activities, and assessment tasks demand the same form of understanding and performance [9]. Selecting a shear-strength parameter illustrates the point. More than recalling a value, a student must trace where the data came from, what drainage and stress conditions apply, and how the parameter will be used in engineering before defending the choice [1-2]. The work

submitted then displays both the answer and the reasoning behind it.

Problem-based learning attaches practical purpose to disciplinary knowledge by embedding it in a defined engineering situation [12]. Geotechnical courses have relied on project work, failure cases, and design problems to bring theory against constraints and to build evaluative skills [3-7]. The same studies caution that student performance differs across tasks and outcome measures [5]. Within the present design, engineering problems exist to draw out observable reasoning—reasoning that can be discussed, revised, and ultimately assessed.

Formative assessment earns its place when feedback steers the next step of learning [10-11]. A sign error sends a student back to the stress or force diagram. An unjustified parameter choice forces a second look at test conditions and data provenance. A control measure that misses the identified mechanism demands a fresh causal explanation. None of this is visible unless the initial response, the feedback, and the revision are all recorded.

Continuity across topics is the backbone of the course. Concepts met early reappear in later engineering decisions, and every classification, parameter, failure mechanism, or recommendation has to be backed with appropriate evidence. Assumptions and revisions are recorded along the way, so that students and instructors alike can watch the reasoning develop over the semester.

3. Course-Wide Reform Framework

Eight commonly taught modules fall under the framework, held together by a cumulative coursework record. Classification yields a short memo backed by test evidence. Seepage links mechanism analysis to control and monitoring. Stress analysis carries sign, boundary, and limiting-case checks. Consolidation states the drainage and parameter assumptions inside a settlement prediction. Later assignments ask students to defend shear-strength parameters, earth-pressure states, bearing-capacity failure models, and slope-stability measures. Because each product builds on earlier ones, classification, permeability, effective stress, compressibility, and strength return again and again instead of dissolving into isolated chapters.

Each module starts from a physical representation—a soil profile, a phase relation, a force diagram, a stress path, a flow path, or a deformation mechanism. Variables and sign conventions are attached to that representation before any calculation begins. Only then does the student compare the model with laboratory data, field observations, units, limiting cases, and plausible alternatives. Where the information at hand will not support a single explanation, the student is expected to say what additional evidence would be required.

In the engineering task itself, students select a model or parameter, identify the governing limit state, and spell out the safety or serviceability consequences of the choice. The response must also name an observation that would support or undercut the judgment. Early assignments keep this step small—a counterexample or a changed condition; later work grows it into a monitoring plan or a revised design memo.

Applying one reasoning process throughout the course gives students a consistent entry into unfamiliar problems and gives the instructor a common yardstick for comparing how the same student handles evidence and uncertainty across topics. Transfer can then be tested with later assignments that change the soil profile, drainage condition, loading, or available test information, rather than by repeating an earlier calculation.

Laboratory work is where engineering interpretation gets its evidence. Grain-size distribution and index tests back up classification while exposing parameter uncertainty. Permeability tests constrain seepage assumptions, consolidation tests constrain the magnitude and rate of settlement, and direct shear or triaxial tests constrain strength parameters under stated stress and drainage conditions [1-2]. Laboratory reports therefore record specimen condition, test boundary, unit consistency, and an account of how each result bears on the engineering case.

A learning platform keeps successive versions of student work and makes feedback available between classes. Students submit an initial judgment before group discussion, revise it once evidence or feedback arrives, and explain why they changed their minds. The instructor chooses the cases, teaches the underlying theory, corrects misconceptions that bear on safety, and determines when the available evidence is sufficient. Requiring an individual response before discussion also preserves a written record of each student's first reasoning.

Assessment brings together short concept diagnostics, conventional calculations, laboratory interpretation, decision memos, and a cumulative coursework record. Examinations keep derivations and numerical problems but add selected items on assumptions, model choice, and how a changed condition would alter the answer. Coursework record tasks are judged not only on the correctness of the final answer but on disciplinary reasoning and the use of evidence.

A single rubric is proposed for reviewing student work across the eight modules. The shared dimensions cover accuracy of the mechanism, consistency of calculations and units, relevance of the evidence, correspondence between analysis and decision, and quality of revision. Because evidence that supports soil classification is not the same as evidence used in slope-stability analysis, each module also needs its own descriptors. The common dimensions carry continuity; the module descriptors protect disciplinary precision.

Feedback always points to the next move in the analysis. A bearing-capacity solution built on an unjustified failure model sends the student back to the soil profile and loading conditions. A consolidation prediction that overlooks drainage length is referred again to the physical model. A slope-stability proposal without monitoring gets revised around the pore-pressure or movement uncertainty that actually governs the decision [1-2]. Each prompt ties the feedback to the technical point that needs reworking.

Where generative AI is allowed, it enters only after a student has finished an initial model, calculation, or recommendation. The generated response is then checked against course sources, supplied data, units, boundary conditions, and a counterexample; its use is disclosed; and personal, confidential, or unpublished project information is never uploaded. Responsibility stays with the student to explain why the final response applies to the soil and boundary conditions under study [13-15].

4. Proposed Implementation and Evaluation

Seepage makes a natural starting point: a single lesson can hold force equilibrium, hydraulic gradients, effective stress,

failure mechanisms, control measures, and monitoring at once. The proposed lesson opens with an excavation scenario—a soil profile, water levels, and a few selected observations. Students first identify the immediate risk, list what information is missing, and sketch the flow and force conditions; only then do they carry out the calculation.

The analysis combines a force diagram, a hydraulic-gradient calculation, a unit check, and an effective-stress explanation [1-2]. Students then set the calculated condition against the observations and sort out whether they are looking at flowing-soil instability, piping, a transition between mechanisms, or a situation where the evidence is simply insufficient. Discussion centers on the evidence for each reading of the case, not on matching a label handed out by the instructor.

From there students prepare a control proposal, drawing on an appropriate mix of cutoff, seepage-path extension, pressure relief or drainage, and filter protection [1-2]. Every measure is tied to the hydraulic or mechanical condition it is meant to alter, and each comes with a limitation and a monitoring indicator. A short revision note records how calculation, observation, or peer critique changed the original proposal. The same pattern transfers later to settlement, shear strength, earth pressure, bearing capacity, and slope stability.

Implementation is staged. The first step is a curriculum map that shows where lectures, laboratory sessions, assignments, and examinations already produce evidence of the intended learning outcomes. Instructors then introduce one decision task per major module and build concise rubric descriptors from representative student responses. During the trial, class time, marking workload, access to digital resources, and the reliability of the learning platform are all recorded, and the findings determine the number and length of coursework record tasks.

Evaluation starts with an entry diagnostic and an equivalent end-of-course scenario assessment. In both, students interpret a soil profile, select relevant evidence, justify a model or parameter, and react to a changed condition. Samples from the coursework record show how reasoning develops during the course; delayed tasks test whether the process transfers to a new topic. Rubric scores, recurring error patterns, revision quality, and student explanations supply complementary evidence of learning.

The evaluation record keeps participation, instrument wording and timing, missing data, implementation changes, and scoring procedures on file. A second scorer reviews a selected sample so agreement on the rubric can be checked. Pre- and post-course comparisons describe change within the assessed cohort; they are not intended to establish a causal effect of the reform. Comparative or staged implementation designs could yield stronger evidence later. Qualitative analysis preserves coding decisions and representative examples so that every interpretation can be traced back to student work.

5. Discussion and Limitations

The course-level design confronts a familiar risk: that related topics get taught and assessed in isolation. The pathway runs from the behavior of soil and water through calculations and test evidence to engineering judgment and review. Classification, permeability, effective stress, compressibility, strength, and stability are treated as parts of a single disciplinary system. Equations, derivations, laboratory tests, and numerical solutions stay in view throughout and give every decision its technical footing.

The chief contribution is the correspondence forged among course outcomes, classroom work, and assessment. Every case yields a specific piece of student work, and every piece of feedback names the technical action that revision requires. The cumulative coursework record, in turn, offers evidence of how precisely a student states assumptions, deploys evidence, and revises a judgment across different Soil Mechanics topics.

Workload, institutional resources, and uneven student participation or prior experience will all shape implementation. Staged rollout, selected portfolio artifacts, concise rubrics, focused peer review, and routine checks of submission completeness help keep these demands manageable. Local trials should log marking time and access to laboratory and digital resources so task count and length can be adjusted.

The framework has not yet been tested in the classroom, so its feasibility and educational value remain to be examined through student work, scenario assessments, transfer tasks, and implementation records. A staged trial would let the cases and rubric descriptors be refined before they are used across all modules.

Course structure, class size, laboratory capacity, and accreditation requirements all bear on implementation. A shared rubric may behave differently across modules, and portfolio performance can be colored by writing skill or group interaction—factors that should be weighed when results are read. Classroom cases give students practice in reasoning under uncertainty; professional geotechnical decisions, of course, still rest on site investigation, standards, accountability, and experienced engineering judgment.

6. Conclusion

This reform links eight core Soil Mechanics modules through one consistent process: explain soil behavior, examine evidence, make an engineering judgment, and review that judgment as conditions change. Constructive alignment ties these actions to learning outcomes and assessment, and formative feedback returns students to the physical model, the data, or the assumption that needs attention.

The seepage lesson shows the process at work within a single topic and demonstrates how the resulting product can feed a semester-long coursework record. Staged implementation, concise rubrics, and scenario-based assessment provide a practical route for testing and extending the design across the whole course. The reform puts calculation, laboratory evidence, and engineering responsibility inside one learning process.

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