Research on the Reform of Assessment Methods for High Voltage Technology Course Oriented to Engineering Accreditation

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Abstract: *Engineering accreditation requires that the assessment methods for the High Voltage Technology course possess an evaluative system for measurable and traceable ability achievement. However, the current methods exhibit structural deviations in terms of engineering problem coverage, score differentiation, and working condition alignment. Based on the mapping analysis between graduation requirements and course objectives as well as the measurability decomposition of ability indicators, a supporting relationship model between assessment methods and achievement degrees is constructed. To address the coverage blind spots, insufficient differentiation, and lack of contextual authenticity in traditional assessments, a redesigned assessment system is developed, which includes a dynamic weight allocation between formative and summative assessments, a multi-dimensional quantitative evaluation scale for ability indicators, and a closed-loop correction mechanism for achievement degrees. This system uses quantitative ability evidence to drive the systematic alignment of assessment methods with engineering accreditation indicators.*

Keywords: *Engineering Accreditation; High Voltage Technology; Assessment Methods; Evidence of Ability Achievement; Course Objective Achievement Degree*

Introduction

The High Voltage Technology course is a core course in the electrical engineering discipline, covering knowledge modules such as gas discharge, dielectric insulation, overvoltage protection, and high voltage testing, and it plays a critical supporting role in cultivating the ability to solve complex high voltage engineering problems. Engineering accreditation requires that assessment methods not only evaluate the mastery of theoretical knowledge but also measure the achievement levels of multidimensional abilities, including analysis, design, judgment, and innovation. The current assessment methods, which primarily rely on a closed-book final examination supplemented by lab reports and regular homework, have limitations in measuring abilities such as engineering problem definition, multi-scheme comparison, fault diagnosis, and non-standard operating condition analysis. The grading system adopts a linear accumulation model, which makes it difficult to distinguish between knowledge reproduction and application levels, nor can it effectively capture the ability characteristics of the technological innovation dimension. The assessment content is mostly based on ideal conditions or standard waveforms, which are disconnected from typical working condition scenarios such as environmental changes, waveform distortions, and random discharges in actual equipment operation. To address the above structural deviations, this study constructs a reform framework for assessment oriented toward evidence of ability achievement. By restructuring assessment criteria, designing a dynamic weight allocation strategy, establishing a multi-dimensional quantitative evaluation scale, and introducing a closed-loop correction mechanism, this study aims to enhance the validity of assessment results in supporting the indicators of engineering accreditation.

1. Logical Restructuring of the Assessment Criteria for the High Voltage Technology Course Oriented to Engineering Accreditation

1.1 Mapping Analysis between Engineering Accreditation Graduation Requirements and Course Objectives of the High Voltage Technology Course

The graduation requirement of Engineering Accreditation takes "solving complex engineering problems" as a core ability indicator, and this indicator is manifested in the High Voltage Technology course as the comprehensive application ability of knowledge units such as gas breakdown, insulation characteristics of liquid and solid dielectrics, overvoltage protection, and high voltage testing methods. Through a step-by-step comparison between the indicator points of the graduation requirements and the course teaching contents, one can identify two types of mapping relationships: direct support and indirect support. For example, the graduation requirement "being able to research complex engineering problems based on scientific principles and using scientific methods" corresponds to specific objectives in the course, such as the design of high voltage insulation withstand voltage test plans and the analysis of impulse voltage waveforms, thus forming a one-to-one mapping chain.

The course objectives of the High Voltage Technology course usually cover three levels: fundamental theoretical cognition, engineering calculation analysis, and experimental operation with data interpretation. To establish a systematic mapping analysis, one needs to decompose each graduation requirement into several observable ability behaviors and then match them with specific learning outcomes in the course objectives. This mapping analysis is not limited to content correspondence; it should also clarify the support intensity levels, namely strong support, medium support, or weak support. By constructing an objective-indicator point correlation matrix, one can provide a basis for the subsequent assessment weight allocation while avoiding a disconnect or redundant coverage between the course objectives and the graduation requirements[1].

1.2 Decomposing Principles for the Measurability of Ability Indicator Points in High Voltage Technology

The measurability requirement demands that ability indicator points be directly observed and quantitatively evaluated by specific assessment activities. For the ability of "analyzing the breakdown process of an air gap in a non-uniform electric field" in the High Voltage Technology course, one can decompose it into three measurable sub-indicators: identifying the characteristics of the electric field distribution, calculating the inception field strength and breakdown voltage, and judging the polarity effect. The decomposition process follows the principle of hierarchical progression, moving stepwise from knowledge reproduction (e.g., describing the streamer theory) to engineering judgment (e.g., evaluating the insulation withstand level under actual electrode structures), thereby ensuring that each sub-indicator has a clear response format and scoring criteria.

Another principle of measurability decomposition is operationalization, meaning that each sub-indicator must correspond to one or more assessment tools. For example, "selecting an appropriate high voltage test circuit" can be decomposed into three observable behaviors: drawing the schematic diagram of the circuit, calculating the parameters of each component, and listing the safe operation steps. These are measured respectively by a drawing question, a calculation question, and a short-answer question. For indicator points involving abstract physical concepts in High Voltage Technology, such as the effect of space charge accumulation, one can enhance the objectivity and differentiation of measurement by transforming them into tasks of interpreting simulation waveforms or identifying abnormal data under laboratory conditions.

1.3 A Supporting Relationship Model of Assessment Methods for Course Objective Achievement Degree

The supporting relationship between the assessment methods and the course objectives needs to be constructed as a quantitative model. This model takes the course objectives as its orientation and defines the contribution rates of different assessment components (such as classroom quizzes, lab reports, thematic assignments, and closed-book examinations) to each objective. The supporting relationship model is expressed in the form of a matrix, where the rows represent the course objectives, the columns represent specific assessment items, and the matrix elements represent the preset weight coefficients, which reflect the degree of influence of each assessment item on the achievement of the objective. The determination of the weight coefficients is based on the number and depth of the ability indicator points contained in each assessment item.

Under the framework of this model, the calculation of the course objective achievement degree is based on the raw scores of each assessment item, and the weighted achievement score for each objective is obtained through weight aggregation. The supporting relationship model also includes a feedback correction mechanism: when the achievement degree of a particular course objective consistently falls below a threshold value, one systematically adjusts the number or the weight of the assessment items corresponding to that objective, rather than simply increasing the difficulty of the examination questions. This model can reveal the many-to-many mapping relationship between assessment methods and objectives, thereby avoiding the bias of the achievement evaluation being overly influenced by a single assessment format. The data generated during the operation of the model can also be used to identify the weak links in the alignment between course objective settings and assessment methods, thus providing a quantitative basis for subsequent course teaching improvement[2].

2. Structural Deviation Analysis of the Current Assessment Methods for the High Voltage Technology Course

2.1 Coverage Blind Spots of Traditional Assessment Components in Engineering Problem-Solving Ability

The traditional assessment components of the High Voltage Technology course mainly consist of a final closed-book examination, supplemented by a small number of regular homework assignments and lab reports. In the final examination papers, the short-answer questions and calculation questions primarily examine the memorization and formula application of basic knowledge, such as gas discharge theory, dielectric polarization and loss, and impulse voltage generators. This type of assessment component lacks systematic measurement of the sub-processes of engineering problem-solving ability, including problem definition, constraint identification, multi-scheme comparison, and verification. For example, for the typical engineering problem of "suppressing lightning intrusion overvoltage in a substation," the traditional assessment only examines the switching impulse withstand voltage value or the calculation of the arrester residual voltage, without covering the selection of waveform parameters, the verification of the protection distance, or the evaluation of the insulation coordination margin.

The assessment of the experimental session usually focuses on confirmatory experiments, requiring students to complete the power frequency withstand voltage or dielectric loss measurement experiment according to the prescribed steps and fill in the data tables. This assessment method only focuses on the correctness of the operational procedures and the accuracy of the results, while ignoring such aspects as fault diagnosis, abnormal waveform identification, and test circuit adjustment. This assessment design leaves students lacking the ability to cope with open-ended engineering problems, such as troubleshooting when nonlinear changes in test data are found on site. The traditional assessment components have obvious gaps in covering the composite abilities of engineering design, analysis, and judgment, and thus they cannot support the achievement evaluation of "solving complex engineering problems" required by engineering accreditation.

2.2 Insufficient Differentiation of Knowledge Application and Technological Innovation Dimensions in the Grading Method

The current grading system usually adopts a percentage-based linear accumulation model, in which the final examination score accounts for 60% to 70%, and the usual performance score includes attendance, homework, and lab reports. This grading method linearly superimposes the performances of different cognitive levels, making it unable to distinguish students' differences between the two dimensions of "knowledge reproduction" and "knowledge application." For example, if a student receives full marks on short-answer questions but loses many points on calculation problems involving the voltage correction of air gap breakdown, the overall grade only reflects the total score difference, without identifying the weakness in application ability. This grading method leads to a concentration of score distribution, and the marginal difference between excellent and passing grades often originates from the accuracy of answering memorization-based content[3].

The assessment of the technological innovation dimension is particularly lacking in the current evaluation system. The innovation dimension manifests as proposing improvement schemes for existing high voltage testing methods, providing reasonable explanations for insulation characteristics under non-standard waveforms, or conducting preliminary demonstrations of the applicability of new insulating materials. The existing examination questions are all closed-ended problems with unique and pre-determined answers. Even if a course design or a thematic essay is introduced, its scoring criteria mostly focus on format specifications, the completeness of the literature review, and the consistency of the conclusions with the textbook, rather than the judgment of novelty, depth of analysis, and engineering value. This evaluation method cannot distinguish students with innovative thinking from those who merely complete the assigned tasks, nor does it provide an effective measurement basis for the non-technical indicator of "innovation ability" in engineering accreditation.

2.3 Lack of Alignment between Assessment Content and Typical Operating Conditions of High Voltage Equipment

Typical operating conditions refer to the voltage types, environmental conditions, and fault evolution processes that high voltage equipment withstands during actual operation. The existing assessment content focuses on theoretical calculations under ideal conditions or standard test conditions, such as calculating the breakdown voltage of a plate electrode gap in a uniform electric field or the equivalent capacitance of parallel capacitors. In actual operating conditions, the switching overvoltage waveform endured by a power transformer is often accompanied by high-frequency oscillations, multiple polarity reversals, and chopping phenomena, yet the switching wave in the assessment questions is always assumed to be a standard 250/2500 μs waveform; the randomness and dynamic process of partial discharge induced by particles in gas-insulated switchgear never appear in the assessment.

The lack of alignment between assessment content and operating conditions is also reflected in the neglect of environmental factors. The insulation performance of high voltage equipment under conditions such as altitude increase, humidity variation, or contamination deposition significantly deviates from the test values under standard atmospheric conditions. However, the current examination questions either do not involve correction calculations or only require the application of a single formula without analyzing the boundary conditions for selecting correction coefficients. Special operating conditions such as electromagnetic compatibility, superimposed harmonics with impulses, and very fast transient overvoltages rarely appear in the assessment content of the High Voltage Technology course, making it difficult for students to establish a connection between the assessed knowledge and the actual insulation coordination design of equipment. This lack of alignment directly weakens the predictive validity of the assessment results for engineering application ability and also causes the requirement of "considering environmental and operating condition factors" in the engineering accreditation indicator points to remain unmeasurable.

3. Redesign of the Assessment Method System Based on Evidence of Ability Achievement

3.1 Dynamic Weight Allocation Strategy for Formative and Summative Assessments

The collection of evidence of ability achievement needs to run through the entire teaching cycle of the High Voltage Technology course, and the weight allocation between formative assessment and summative assessment should not be preset with fixed ratios. Instead, it should be dynamically adjusted according to the achievement cycle of the ability dimensions corresponding to each course objective and the measurement reliability of those dimensions. The dynamic allocation strategy takes the teaching week sequence as the horizontal axis and the evidence types generated by each assessment event and their corresponding ability levels as the classification basis, thereby setting a sliding weight window. In the early stage of the course, the focus is on the mastery of basic knowledge, such as the fundamental theory of gas discharge and the safety regulations for high voltage testing. At this stage, formative assessments such as in-class timed quizzes and unit assignments account for a higher weight, which is used to capture the students' initial achievement status in understanding basic concepts and principles. In the middle and late stages of the course, as the teaching content progresses toward engineering calculation analysis (such as insulation coordination and estimation of switching overvoltage amplitudes) and comprehensive evaluation of test schemes, the weight of the summative assessment gradually increases, which is used to measure the students' engineering design judgment ability under the integration of multiple knowledge points[4].

The specific implementation of the dynamic weight allocation strategy can adopt an adaptive adjustment mechanism triggered by a cumulative achievement threshold. One presets a minimum formative achievement score threshold for each course objective. When the ability indicator point of a student, calculated based on multiple formative assessment evidence pieces, reaches this threshold, the weight of the corresponding objective in the summative assessment automatically decreases; conversely, the weight increases. This mechanism avoids misjudging the cumulative process ability due to a single summative assessment error under a uniform weight, while also preventing the insufficient measurement of comprehensive application ability caused by an excessively high proportion of formative assessment weight. For practical components in the High Voltage Technology course, such as electrical test operations and discharge data analysis, their weights are iteratively adjusted based on the depth of error source identification and the rationality of waveform interpretation provided in each lab report, thereby enabling the weight allocation to truly reflect the temporal evolution characteristics of the ability achievement process and individual learner differences.

3.2 Construction of a Quantitative Evaluation Scale and Scoring Criteria for Multidimensional Ability Dimensions

Based on the measurement requirements of engineering accreditation for multidimensional abilities such as technical knowledge, engineering analysis, experimental operation, and written expression, the quantitative evaluation scale should systematically cover at least four independent dimensions: the reproduction of theoretical knowledge, engineering calculation modeling, the design of high voltage test circuits with fault identification, and technical documentation writing. Each dimension should be designed with three to five descriptive scoring anchors, thereby abandoning the practice of assigning a single overall score based on an overall impression. Taking the dimension of "high voltage test circuit design and safety analysis" as an example, Level One corresponds to the presence of serious topological errors or missing safety protection in the circuit schematic; Level Two corresponds to a basically correct circuit structure but with unmarked component parameters; Level Three corresponds to a complete circuit with reasonable parameters but lacking descriptions of grounding and overcurrent protection; Level Four corresponds to a reasonably designed circuit with clearly marked safety measures; and Level Five corresponds to a circuit with a redundant protection scheme and an explanation for coping with abnormal operating conditions. This type of graded anchor makes the scoring process repeatable and auditable.

The operational definition of the scoring criteria requires that the performance at each level within each dimension has clear observable behaviors, and that different scorers, following the criteria, can give consistent judgments. For the dimension of electrical safety operation, which is unique to the High Voltage Technology course, the scoring criteria should list specific behaviors that must be verified item by item: checking the connection status and connection sequence of the grounding wire before the test, monitoring the leakage current and partial discharge signals in real time during the voltage boosting process, and performing the discharging and re-grounding procedures after the voltage is reduced and the power is cut off. The weights of the multidimensional ability scale are determined by the contribution coefficient of each dimension to the achievement degree of the course objectives, among which the dimension of engineering calculation and modeling is assigned a higher weight because it directly supports core engineering abilities such as insulation coordination optimization and lightning overvoltage simulation analysis. Although the dimension of technical documentation expression has a relatively lower weight, its scoring criteria still need to specify clear rules, including the citation of term definitions in the test report, the labeling specifications for coordinates of voltage waveforms and breakdown probability curves, the basis for determining the removal of abnormal data, and the level of discussion on error sources.

3.3 A Closed-Loop Correction Mechanism for Course Objective Achievement Degree Driven by Assessment Results

The closed-loop correction mechanism uses the quantitative solution value of the course objective achievement degree as its input variable and the adjustment instructions for the constituent elements of the assessment methods as its output variable, thereby constructing a data-driven continuous improvement loop. This mechanism integrates three functional components: the achievement degree calculation module, the deviation diagnosis module, and the assessment scheme update module. The achievement degree calculation module, based on the established supporting relationship model and the multidimensional scale scoring, calculates the average achievement degree of each course objective and the coefficient of inter-individual distribution dispersion item by item. The deviation diagnosis module sets a lower threshold (recommended as 0.65) and an upper threshold (recommended as 0.85) for the achievement degree. When the achievement degree of a certain course objective falls below the lower threshold, the diagnosis module further identifies the assessment items supporting that objective that have low differentiation or insufficient test-retest reliability, and it simultaneously analyzes the achievement dispersion to determine whether the problem originates from structural defects in the assessment scheme or from individual learning differences[5].

The diagnostic results guide the assessment scheme update module to execute three types of structured adjustment operations: item replacement, weight redistribution, and form addition. Item replacement substitutes the original memorization-based short-answer questions with engineering context analysis questions that have higher differentiation, such as inferring the insulation coordination margin from a given field overvoltage waveform. Weight redistribution increases the frequency of formative assessment for course objectives whose achievement degree consistently falls below the threshold, or raises the score proportion of the examination questions supporting those objectives in the summative assessment. Form addition introduces assessment formats not yet included in the assessment scheme, such as a partial discharge tracing task based on fault tree analysis, or a technical scheme comparison seminar report based on an actual substation insulation coordination case. The updated assessment scheme is then applied to the next teaching cycle, where the course objective achievement degree is recalculated and compared longitudinally with historical data to verify the significance of the correction effect. This closed-loop mechanism relies entirely on quantitative evidence of ability achievement for decision-making, thereby avoiding empirical subjective adjustments, and it can explicitly record the linkage between each assessment reform module and the change in course objective achievement degree, thus providing a traceable technical archive for the continuous improvement of the High Voltage Technology course oriented to engineering accreditation.

Conclusion

This study, focusing on the ability achievement requirements of engineering accreditation for the assessment of the High Voltage Technology course, has completed the logical restructuring of the assessment criteria, the analysis of structural deviations in the current methods, and the redesign of the assessment system based on evidence of ability achievement. By establishing the mapping analysis between graduation requirements and course objectives as well as the measurability decomposition principles, this study has clarified the supporting relationship model between ability indicator points and assessment items. To address the shortcomings of traditional assessments in covering engineering problem-solving ability, score differentiation, and alignment with operating conditions, this study has proposed a dynamic weight allocation strategy for formative and summative assessments, designed a quantitative evaluation scale and scoring criteria covering such dimensions as theoretical knowledge reproduction, engineering calculation modeling, test circuit design and fault identification, and technical documentation writing, and constructed a closed-loop correction mechanism for achievement degree driven by assessment results. Using quantitative ability evidence as the basis for decision-making, this system has achieved the transformation of assessment methods from fixed ratios to adaptive adjustment, from a single total score to multidimensional anchored evaluation, and from static schemes to data-driven closed-loop iteration. Future research can explore trajectory tracking methods for individual ability achievement based on learning analytics technology, in order to establish a refined correlation model between assessment data and teaching interventions; investigate quantitative measurement tools for non-technical ability indicators (such as teamwork and engineering ethics awareness) in the High Voltage Technology course and their pathways for integration into the assessment system; and develop a digital platform that supports dynamic weight adjustment, automated multidimensional scale scoring, and the online operation of the closed-loop correction mechanism.

Fund Projects

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