Reform Practice of University Physics Experimental Teaching Based on OBE Concept: Measuring Gravity Acceleration by Single Pendulum Method as an Example

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Abstract

In response to the transition in higher education from teacher-centered knowledge transfer to student-centered competency building, this work proposes an outcome-based education (OBE) approach to university physics laboratory instruction. Using the classical experiment of determining the gravitational acceleration by a simple pendulum as an example, the teaching process is re-conceptualized with real-life physical situations, fundamental concept comprehension and competency-oriented learning outcomes as its core. The instructional design includes the non-linear modelling of the period of a simple pendulum at large angles, which leads the students to examine the applicability of models, carry out error corrections and pursue innovations via extended topics. A multi-dimensional assessment system consisting of four dimensions and six indicators based on Blooms taxonomy and the CDIO engineering education model was developed. Results show that the students have made significant progress in modeling skills, error analysis and interdisciplinary integration. The suggested OBE approach to experiments promotes higher-order thinking and meaningful learning outcomes effectively, offering a reproducible model for the reform of physics laboratory teaching under the new engineering education paradigm.

CCS Concepts

• **Applied computing** → Physical sciences and engineering; Physics.

Keywords

Outcome-Based Education, Simple Pendulum, Physics Experiment, Large-angle Correction, Bloom's Taxonomy, CDIO

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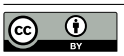

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1 Introduction

1.1 Research Background

With the transformation of higher education from teacher-centered knowledge delivery to student-centered competence development, outcome-based education (OBE) has gained increasing popularity in different disciplines [1]. OBE stresses the ultimate learning results for students, and it requires consistency among educational goals, course design and assessment systems [2]. Such consistency ensures that the contents of instruction match the ILOs. With close integration between instructional activities and ILOs, OBE can strengthen students practical skills and cultivate innovative thinking [3]. In experimental teaching, such an approach transforms the tedious mechanical procedures into inquiry-based, outcome-focused learning processes. This helps to activate the autonomy of students and facilitate the development of higher-order thinking skills.

In this context, problem based learning (PBL) has been extensively used in experimental teaching and engineering education systems as an important way to implement OBE. However, the effective implementation of PBL in engineering and physics courses still faces many challenges in real teaching [4]. The contents of traditional experimental courses are usually closed with fixed operational paths, and they do not have the openness of problem scenario. Students mainly passively complete the experimental procedures, which makes it difficult for them to deeply understand the physical mechanism, theoretical assumption, and error source in experiments. Such operation-oriented instead of thinking-oriented teaching model prevents students from changing their role from executors to explorers, and reflects the inherent contradiction between the teaching philosophy and the target-oriented objective of current physics experimental teaching.

The pendulum method for measuring gravitational acceleration is a classic project in the teaching module of mechanics in physics. Under the traditional teaching pattern, the experimental contents are confined to the periodic measurements under the small-angle approximation condition ($\theta < 5°$). The students simply follow the fixed operation procedures without a thorough understanding of the availability and limitation of the experimental model. The discussion on the nonlinear models, error corrections and real-life complicated situations are also absent [5]. In accordance with the

competence- and outcome-oriented notions advocated by the OBE philosophy, the teaching structure for this experiment should be reshaped in an integrated manner, from the verification training to the inquiry-based, project-oriented tasks that finally generate outcomes. This will enhance the students capabilities in model construction, error analysis and creative expression.

Therefore, the OBE educational conception was reconstructed upon the simple harmonic pendulum experiment. Starting from periodic correction, students were led to comprehend the nonlinear features of theoretical models at large pendulum angles. Through experimental explorations extended beyond physical knowledge, students made formula fitting and measurement, constructing step by step a pathway from elementary cognition to comprehensive application and creative expression. This reflects the essential requirements of outcome-based education.

1.2 Research Questions

Despite the growing adoption of Outcome-Based Education (OBE) principles in university physics laboratories, there are still challenges in effectively implementing these principles to improve student learning outcomes. The main research questions are as follows:

RQ1: How can experimental content be redesigned within the OBE framework to integrate authentic contexts, core physics concepts, and learning objectives?

RQ2: How can virtual simulation platforms enhance the effectiveness of hybrid teaching models in physics laboratories in terms of interactivity, accessibility, and adaptability?

RQ3: Which evaluation frameworks best assess student competencies in OBE-based experimental teaching?

2 Literature Review

2.1 Outcomes-Based Education

Outcome based education (OBE) is now an important paradigm in modern engineering education. The essence of this approach is to plan the curriculum, pedagogy and evaluation strategies based on the outcomes which the students will acquire eventually. Research suggests that OBE helps in developing better practical engineering skills and problem solving capabilities among students by clearly establishing a three level mapping between PEOs, PLOs and CLOs [6]. In computer engineering education, for example, the OBE framework adopts the Washington Accord standards for keeping the course contents industry relevant and employs rubrics and CQI (continuous quality improvement) mechanisms for dynamic teaching quality optimization.

However, the implementation of OBE poses challenges such as teachers adherence to conventional teaching models and the intricacies in devising assessment instruments. Kidd argued that over-structuring may impede teaching creativity [7], Oliveira argued that the lack of digital management tools may lead to inefficiencies in monitoring CLOs and PLOs [8]. In order to overcome these challenges, researchers suggest striking a balance between standardization and teaching flexibility via teacher training, the development of blended learning platforms and the design of AI-powered learning analytics systems, e.g. automated assessment tools.

Future OBE studies may also investigate other complementary effects of interdisciplinary ability integration and international accreditation. For example, integrating CDIO (Conceive-Design-Implement-Operate) into OBE can help develop systems thinking in engineering students [9]. Personalized career portfolio based on learning outcomes may also be developed as another linkage between education outcomes and job market, showing the strategic importance of OBE in nurturing flexible talent for the Fourth Industrial Revolution.

2.2 Bloom's Taxonomy

Blooms Taxonomy of Educational Objectives is a classification system developed by Benjamin Bloom in 1956 to identify educational goals and assess learning outcomes. It consists of six levels of cognitive skills ranging from simple to complex: knowledge, comprehension, application, analysis, synthesis, and evaluation. Blooms taxonomy helps educators design instruction that moves students from basic understanding towards more sophisticated thinking. Adams stresses the significance of Blooms taxonomy in medical education; it enables teachers to formulate specific learning objectives and evaluations that foster cognitive growth at progressively higher levels of complexity [10].

Since its inception, Blooms Taxonomy has evolved to incorporate contemporary educational perspectives. Krathwohl proposed a revised version that articulated the six cognitive categories in terms of active verbs: remember, understand, apply, analyze, evaluate, and create. He also added a second dimension, the knowledge dimension (factual, conceptual, procedural, and metacognitive) [11]. The resulting two-dimensional matrix facilitates the alignment of teaching approaches with assessment methods. Bonaci et al. [12] integrated the taxonomy into the 3Ps model (Presage-Process-Product) and created a unified framework for higher education. They highlighted the synergy between instructional objectives, the learning process, and results. This demonstrates the role of Blooms Taxonomy as both a pedagogical framework and an evaluation instrument to enhance student achievement.

2.3 CDIO Engineering Competency Model

The CDIO (Conceive-Design-Implement-Operate) concept of engineering education was developed at MIT to thoroughly permeate the curriculum with engineering practice and develop student engineering abilities and practical literacy in a systematic way. Nguyen et al. brought CDIO into primary education teacher training in Vietnam to investigate the possibility of using it in curriculum management and teaching methods in their study of educational reform [13]. A questionnaire survey of 296 university managers, teachers and students was conducted to evaluate the performance of five management reform strategies in terms of urgency and feasibility. The results showed that the CDIO framework is very flexible and can promote teaching management innovation. The study also pointed out that the CDIO approach is not only suitable for engineering education, but also suitable for various disciplines such as teacher education because of its competence-based philosophy.

In higher engineering education, the CDIO approach has been an important guide for curricular reform. Loyer et al. described in detail the systematic reorganization of five engineering majors (e.g.,

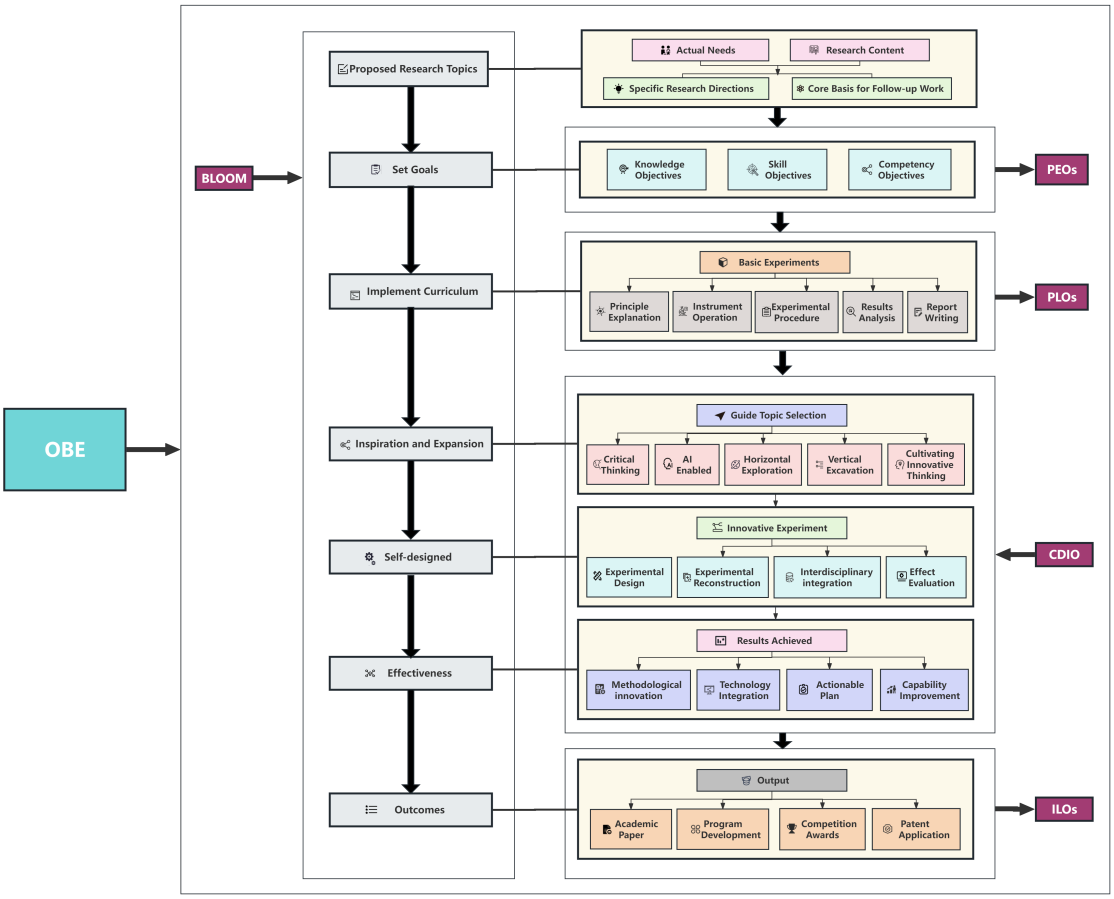

Figure 1: This is a university physics experiment teaching process framework diagram based on the OBE concept, showing a complete set of teaching closed-loop paths from Proposed Research Topics, Set Goals, Implement Curriculum, Inspiration and Expansion, Self-designed, Effectiveness, to Outcomes.

computer science, civil engineering) at the School of Engineering of University of Santa Cruz de Chile (UCSC), based on the CDIO framework [14]. A gradual advancement from conceiving to designing to implementing, together with active and service-learning strategies were used to facilitate students holistic acquisition of engineering competences. This process not only proved the practicability of the CDIO philosophy, but also validated its effectiveness in improving engineering literacy and interdisciplinary teamwork skills. Meanwhile, Lynch et al. discussed the issue from the perspective of educational evaluation, proposing self- and peer-assessment approaches to foster deep learning and critical reflection [15], which is closely related to the student-centered learning principle in the CDIO framework. Such extension of the application scope of CDIO educational principles beyond engineering fields was another contribution.

3 Research Design and Experimental Teaching Process Reconstruction

Inspired by the idea of outcome-based education (OBE), this paper takes the single pendulum method for measuring gravitational acceleration project in the traditional university physics laboratory teaching as an example. It aims at the deficiencies and systematically reconstructs and investigates the teaching processes by matching the teaching objectives with students core competences. At the same time, the paper integrates the OBE idea to design the corresponding teaching model diagram (see Figure 1), which improves the purposefulness of laboratory teaching and the scientificity of effectiveness evaluation.

3.1 Proposed Research Topics

In traditional teaching, students measure the period of a simple pendulum under the conditions of the small-angle approximation($\vartheta < 5^{\circ}$)by varying the length of the pendulum under the guidance of the teacher and by calculating the local gravitational acceleration

(g) using formula:

$$g = \frac{4\pi l^2}{T^2} \tag{1}$$

While this method is simple, it ignores the limitations of the theoretical model regarding the applicable range of angles. This leads to a lack of deep understanding among students regarding the relationship between pendulum angle and period. It also hinders the development of their experimental design and data analysis skills.

In order to overcome these disadvantages, in this work students are guided to study the topic of correcting the period of a simple pendulum for large angles. More concretely, the issue is approached from the perspective that, for not small angles, the conventional period formula leads to substantial errors. What theoretical corrections could be done in order to measure more accurately? This problematization of the issue situates the teaching goals and offers theoretical challenges; it gives a very clear main thread to the subsequent didactic interventions.

3.2 Set Goals

In line with the concepts of OBE, we set teaching goals in three aspects: knowledge, skills and competence. Knowledge goals: understand the dynamic model of the simple pendulum motion, master the derivation process and the applicability of the period formulas of small and large angles; Skills goals: improve the ability of period measurement, data processing, error analysis and theoretical validation; Competence goals: develop critical thinking, problem awareness, independent research and expression ability. These goals are in close conformity with the essential nature of learning outcomes in OBE, and form the basis for systematically fostering students experimental ability.

3.3 Implement Curriculum

At the implementation stage of teaching, the study adopted a modular teaching process consisting of "theoretical instruction, teacher guidance, student design, experimental implementation, data analysis, and results evaluation." During the theoretical instruction stage, teachers guided students in reviewing the derivation process of the small-angle oscillation period and deriving the large-angle period correction formula

$$T_{\text{modification}} = 2\pi\sqrt{\frac{l}{g}}\left(1 + \frac{1}{4}sin^2\frac{\theta_0}{2}\right) = T\left(1 + \frac{1}{4}sin^2\frac{\theta_0}{2}\right) \tag{2}$$

This formula is derived from a second-order approximation of the original periodic differential equation, with the introduction of a nonlinear correction factor to improve the accuracy of periodic calculations.

Firstly, the students are grouped to design experiments and collect data. The experiment is in two phases: the first phase is to use the fixed pendulum length method to measure the average period of 30 oscillations under condition ($\vartheta < 5^\circ$); the second phase is to use the variable pendulum length method to fit the linear relation between l and $(30T)^2$ to derive the value of g.

Next the teacher leads the students to conduct creative experiments, in which students design experiments on their own to investigate large pendulum angles from 5 to 24, measure the actual period, and calculate the relative errors between the measured period and the theoretical period and corrected period to determine the acceptable ranges of objective errors for different pendulum angles.

3.4 Inspiration and Expansion

In the data analysis phase, students calculated the theoretical cycle T, corrected cycle $T_{\text{modification}}$, and measured cycle T_{measured} for small angles, and derived the relative error using the following formula:

$$\varepsilon_{theory} = \frac{|T - T_{\text{measured}}|}{T_{\text{measured}}} \times 100\% \tag{3}$$

$$\varepsilon_{\text{modification}} = \frac{|T_{\text{modification}} - T_{\text{measured}}|}{T_{\text{measured}}} \times 100\% \tag{4}$$

The experimental results indicated that the theoretical cycle error could be greater than 2% at that time, while the error was less than 0.4% after correction. The correction was very effective, with the error reduced by more than 80%. Further verification showed that the correction formula could keep the relative error within 3% in the range, showing good applicability and accuracy of the correction model.

Note that the students did not pose this question themselves, but rather were led there via heuristic questions such as What are the sources of error? and Is the theoretical model always valid?, which took the students from routine data processing to reflection upon the theoretical assumptions. The pedagogy is based around combining periodograms, and during this process the teacher guides the students in a review of the assumptions behind the mathematical modelling of single pendulum motion, with consideration of the systematic deviation in the period measurement results, and discussion of the breakdown of the($sin\vartheta \approx \vartheta$) approximation for large initial pendulum angles. This allows students to make the shift from operational completion of the task to judgement of model validity and strategies for correction, thus setting the theoretical scene for further investigation of error correction and formula validation.

This teaching design deepens the theoretical aspects of the original experiment and awakens the students feeling of active investigation. On this basis, some students tried to merge fitting experimental data and numerical calculation to examine the interval of applicability of the correction formula at different angles and to build a cyclic error versus initial pendulum angle graph which was first constructed by experimental results with research features.

3.5 Self-designed

After completing basic and innovative experiments, the instructor guides students in exploring the results further. In this process, teachers guide the selection of topics, while students leverage their own initiative to explore and independently use tools such as A to conduct in-depth analysis, resulting in the following two interdisciplinary integration projects:

(1) Constructing a dataset of periodicity and pendulum angle data, utilizing regression algorithms (such as SVR, random forest, etc.) to train a periodicity prediction model, and exploring "machine learning-based g-value prediction methods";

(2) Designing a "low-cost physical quantity testing platform" based on the adjustability of the pendulum apparatus, for preliminary testing of new gravitational measurement instruments (such as atomic gravimeters).

Both projects have preliminary plans in place and demonstrate high feasibility. The relevant content is currently being further developed into student research training and competition projects.

3.6 Effectiveness and Outcome

In the OBE experimental teaching reform carried out in this institution, the students complete the experimental works following a five-stage research cycle, which are Proposed Research Topics, Set Goals, Implement Curriculum, Inspiration and Expansion and Self-Design. The students obtained theoretically valuable results with application prospects during the process, and made significant progress in important abilities such as knowledge transfer, interdisciplinary construction and outcome expression. A series of academic and practical results were obtained. Typical results include:

(1) A comprehensive experimental research paper: "Analysis of Gravitational Acceleration Measurement Using the Pendulum Method and Improved Formulas."

In this paper, the students investigate in a systematic way how to determine the gravitational acceleration with a simple pendulum with good precision. They analyze the errors and improve the commonly used small-angle simplified formula. The range of validity of the period formula at various angles was shown by their theoretical derivation and by fitting and verifying the large-angle corrected formula with experimental data combined. Standardized ways of error measurements and graphical presentations are applied to reinforce their results. All these reflect the students integrated skills in theoretical modeling, data analysis and scientific writing.

(2) Two student-led extension projects:

The first one is called Design of a machine learning based period prediction model, which uses various groups of experimental data as training samples, and incorporates regression models like SVR, Random Forest, etc. to fit the non-linear mapping relation between the length of the pendulum and its period. This project follows an intelligent prediction path outside the traditional physical formulae. The other one is called Construction of a low-cost gravity measurement testing platform. Using cheap materials and open-source sensors like Arduino, ultrasonic ranging, etc., the students designed a portable gravity acceleration measurement device that can be used in middle school physics class. These two projects show the students ability of interdisciplinary integration, engineering design, and independent research.

(3) Competition Achievements: They qualified for the preliminary round of the National University Physics Experiment Competition and participated in the campus Challenge Cup selection.

The Innovative Physics Experiment Project based on this experimental topic has qualified for the preliminary round of the National University Physics Experiment Competition (Innovation Category), and also participated in the university level selection for the Challenge Cup Science and Technology Competition as a project. This proved the originality and feasibility of the students project, and showed that in educational reform, the results of students could be transformed from classroom activities into competitions, and from course assignments into research presentations. This embodies the learning-centered idea of OBE.

(4) Development of the "Oscillation Period Visualization Simulation System"

With experimental baseline data, the students developed an initial version of the system. The system has an interactive parameter input interface for variables such as pendulum length, initial angle, mass, etc., and a visualization chart module for period output. Some functionalities have animation simulation of the oscillation trajectory. This project combines physical modeling and program development, showing the students practical skills in technical implementation, system logic design, and visual representation. It also marks a new direction towards integration of traditional experimental teaching and digital tools.

4 Teaching Framework Evaluation and Student Achievement Analysis

4.1 Dimensions of Teaching Evaluation

To systematically assess the capabilities acquired by students via this experimental teaching reform, the research team set up four dimensions of evaluation based on Blooms taxonomy of cognitive objectives and the CDIO engineering competence model (see Figure 2): Basic Understanding Level, Knowledge Transfer Level, Comprehensive Application Level and Innovative Expression Level. The team integrated these dimensions with observations made during the teaching process, the contents of students experimental report and interview feedback to carry out an overall analysis.

Specifically:

(1) Basic Understanding Level: Students generally mastered the principles of the simple harmonic motion of a pendulum, the applicability conditions of the period formula, and sources of error. They could accurately derive the correction model and identify its theoretical advantages under large pendulum angles.

(2) Knowledge Transfer Level: Some students could apply mathematical analysis methods, such as Taylor series expansion, to correct physical formulas, demonstrating good cross-disciplinary knowledge transfer abilities.

(3) Comprehensive Application Level: With guidance, experimental groups successfully replicated the entire experimental protocol, including setup, period data collection, and the error correction process. Some groups used graphical plotting tools to fit error curves before and after correction, demonstrating strong validation capabilities.

(4) Innovative Expression Level: Students incorporated elements such as machine learning, big data modeling, and low-cost platform design into their expanded project designs. This demonstrates their preliminary awareness of scientific and technological innovation and interdisciplinary integration. It also shows their ability to express scientific research.

Compared to students in traditional teaching classes, those participating in this research pathway demonstrated significant advantages in terms of the completeness of experimental protocol expression, depth of error analysis, and rationality of model improvements.

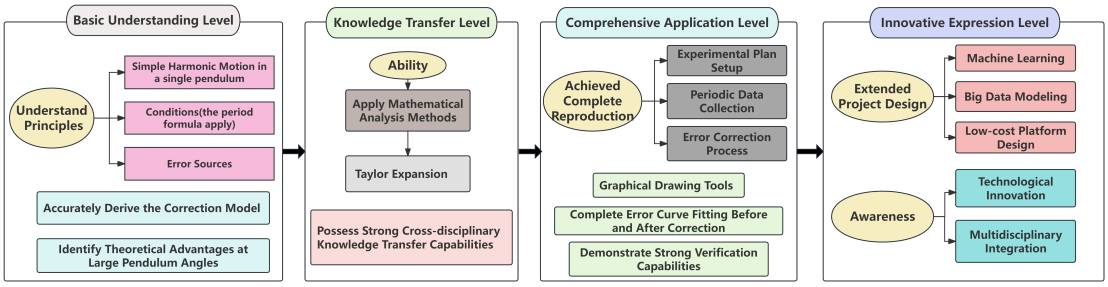

Figure 2: A four-dimensional student competency assessment framework diagram combining Bloom's Taxonomy of Educational Objectives and the CDIO Engineering Competency Model.

4.2 Teaching Evaluation Indicators

Based on the outcomes-based education (OBE) concept and with reference to Blooms taxonomy of cognitive objectives and the CDIO competence criteria, we have devised a multi-dimensional assessment system for the measure gravitational acceleration by means of a simple pendulum project. The system emphasizes students grasp of knowledge and practical skills, their capability of analyzing and solving problems and making innovations in real-life situations (see Figure 3).

The specific evaluation dimensions and indicators are as follows:

(1) Knowledge and Understanding

Students are assessed on their mastery of key theoretical concepts, such as experimental principles, formula derivations, assumptions for small-angle approximations, and sources of error. They must also demonstrate their ability to correctly explain the applicability and logical basis of the correction formula.

(2) Skills and Operations

Evaluate whether students can independently assemble experimental apparatuses and perform basic experimental procedures, such as measuring periods, calculating errors, organizing data, and creating charts.

(3) Application and Transfer

Determine if students can apply the corrected formula to analyses involving different initial angles and if they can use their knowledge to create model frameworks for solving similar dynamic problems by analogy.

(4) Analysis and Evaluation

Focuses on whether students can judge the applicability of models, accurately analyze sources of error, compare effects before and after correction, and propose reasonable suggestions for optimizing models or improving experiments.

(5) Innovation and Expression

Students are evaluated on their ability to expand on the experiment by proposing innovative improvement ideas, such as introducing AI algorithm modeling or developing low-cost simulation systems. They must also produce preliminary research results and showcase their work.

(6) Collaboration and Communication

Emphasizes students' communication and collaboration skills in group experiments, including task division, effective cooperation,

Figure 3: An educational assessment indicator chart based on the OBE idea provides a systematic representation of students learning outcomes in the experimental teaching process in terms of six dimensions, i.e., Knowledge and Understanding, Skills and Operations, Application and Transfer, Analysis and Evaluation, Innovation and Expression, and Cooperative Communication, which is used for an overall measurement of their integrated ability accomplishment.

the logical and systematic structure of report writing, and the ability to express ideas clearly in oral presentations or written materials.

This evaluation system implements a progressive tracking of abilities from "cognition—operation—transfer—innovation," while combining formative and summative evaluation methods to establish a teaching assessment loop that balances formative feedback and summative evaluation, ensuring that students achieve measurable, transferable, and applicable high-quality learning outcomes in the experimental teaching process.

4.3 Analysis of the effectiveness of teaching reforms and capacity building

Based on the philosophy of outcomes-based education (OBE), this study discusses teaching reform and practice for the university physics experiment Measurement of gravitational acceleration with a simple pendulum. In the teaching process, teachers led students to follow a systematic, problem-oriented, target-setting, process-guiding, result-oriented teaching workflow, cultivated innovative

thinking, and improved comprehensive research-based learning ability. Students designed and implemented a machine learning-based periodicity prediction model around the experimental topic. They built a low-cost gravity measurement testbed, developed a single-pendulum visualization simulation system, and applied artificial intelligence (AI) tools to optimize data analysis and model validation.

According to teacher interviews and course evaluations, the students asked questions, verified and enhanced experimental models, and leveraged contemporary technological resources to augment experimental schemes. This represents a departure from the conventional teaching paradigm which emphasizes only upon measuring the period of a pendulum and computing the value of gg. The students acquired knowledge of both the theoretical underpinnings and practical uses of the large-angle correction formula. They were able to perform period measurements, error evaluations, and correction analyses autonomously. Their experimental procedural skills, data analysis capabilities, and scientific communication skills have markedly increased. Low-cost testbeds and visualization simulation systems made experimental experiences more intuitive, and artificial intelligence assisted tools enhanced the efficiency and accuracy of data processing.

Teachers feel that the reformed vocabulary teaching helps to activate students consciousness of problem solving and innovation, and to create an open and personal teaching atmosphere. Students think that the result-oriented teaching methods inspire their interest in learning and exploring. They believe these methods improve their capability of independent learning, teamwork and problem solving. This teaching reform has stimulated the explorative learning and innovation activities among the students. Many proposals for research projects and results of competitions have been obtained which may be applied in practice. In the process of teaching reform, teachers role has changed from knowledge transmitter to learning facilitator and cooperative guide. A healthy atmosphere of cooperation between teachers and students has been established.

In conclusion, the feasibility and effectiveness of the philosophy of OBE in university physics laboratory teaching was examined in this work. Through the gradual guidance of students to innovate, and through the integration of this approach with modern machine learning, simulation, and AI technologies, a reproducible model of teaching reform was established. The content of physics laboratory teaching was enriched, and a practical template and theoretical support were offered for teaching reforms in other science and engineering courses.

5 Research Conclusions and Recommendations for Follow-Up Action

Based on the philosophy of outcomes-based education (OBE), this work centers on a basic experimental project of measuring gravitational acceleration with a simple pendulum. With problem-based instruction design and multi-dimensional competency assessment mechanism, an innovative experimental teaching system has been built with the features of clear objectives, open process and quantified results, and meanwhile interdisciplinary cooperation and engineering education are incorporated. This system will promote the penetration and extension of teaching in four dimensions: Basic Understanding Level, Knowledge Transfer Level, Comprehensive Application Level and Innovative Expression Level. Based on this frame, teaching evaluation and improvement will rotate around six pivotal indicators: Knowledge and Understanding, Skills and Operations, Application and Transfer, Analysis and Evaluation, Innovation and Expression and Cooperative Communication. Setting and adjusting these six indicators scientifically and dynamically, the system facilitates students all-round development in cognition, operation, thinking and communication.

The students involved in this experiment showed their interdisciplinary knowledge application ability. They applied the mathematical methods, e.g., Taylor series expansion, to correct the periodic formulas, and considered the possible applications of data fitting and artificial intelligence in periodic prediction. The outcomes of teaching were experimental reports, formula validation, competition projects, virtual simulation designs, applications of machine learning algorithms, and drafts of research papers, which went over teaching to research quite successfully.

Overall, this teaching reform made positive progress in terms of the depth of the experimental content, openness of the teaching methods, and types of student outcomes. This validates the adaptability and promotional value of the OBE philosophy in university physics experimental teaching.

Based on the effects of implementing the reform, the following suggestions are proposed to promote subsequent teaching reform efforts:

(1) Implement a tiered experimental teaching model. In foundational physics courses, establish a three-tier progressive experimental system comprising "standard," "expanded," and "research-oriented" experiments. This system can accommodate students of varying ability levels and provide categorized guidance and targeted cultivation.

(2) Introduce digital and simulation tools. As virtual simulation platforms develop, online experimental resources, such as the "Simple Pendulum Period Nonlinear Correction Demonstration System," can be created to enhance teaching flexibility and reduce pressure on experimental equipment resources.

(3) Establish a diversified evaluation system oriented toward OBE. Student performance in experimental design, presentation of schemes, analysis of errors, and application of outcomes can be incorporated into evaluation criteria. An integrated model combining formative and summative assessments should be explored to enhance the scientific rigor and motivational impact of evaluations.

(4) Promote the integration of teaching and research. Use teaching reform projects to collaborate with faculty research teams and guide students' research interests toward experimental competitions, course papers, and project incubation. This will establish a seamless connection between teaching, research, and practice.

Future educational reforms can promote problem-driven teaching mechanisms in basic physics experiment modules, such as gravity measurement, optical measurement and electromagnetic experiments to build an innovative experimental teaching system integrating interdisciplinary integration and engineering education characteristics. The system deepens the teaching reform in the physics discipline and has strong interdisciplinary extension ability. It can be extended to many disciplines, such as mechanical engineering, materials science, computer science, etc., to promote

the systematic integration and collaborative cultivation of multi-disciplinary knowledge and skills. This framework is expected to respond to the demand for cultivating compound innovative talents in higher education in the context of new engineering discipline. It transforms the experimental teaching paradigm from a single discipline to an interdisciplinary integration paradigm, which will further improve the talent cultivation quality and innovation ability, and lay a solid foundation for constructing a high-quality talent cultivation system suitable for the new era.

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