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Exploring the Innovation and Practice of College Physics Experimental Teaching in Xizang's Colleges and Universities

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Abstract: This study aims to address the challenges in physics experiment courses at universities in Xizang, including students' insufficient foundational knowledge, a monotonous teaching mode, and limited teaching resources, through targeted teaching innovations to enhance the learning outcomes. A mixed-methods approach combining action research and a case study was employed. The teaching reforms were implemented across the college physics experiment course at Xizang University. The innovations encompassed comprehensive reforms spanning course content, teaching methods, the learning environment, and the evaluation system. The effectiveness was evaluated through a questionnaire survey administered to a cohort of 65 students enrolled in the course, supplemented by a comparative analysis of teaching records before and after nearly three years of reform practice. Quantitative and qualitative analyses demonstrated remarkable results. Students' final exam scores significantly increased from a pre-reform average of 66.96 to a post-reform average of 87.0. Questionnaire results indicated that student satisfaction ratings across all reform dimensions ranged from 4.25 to 4.43 (on a 5-point Likert scale). One-sample t-tests confirmed that all ratings were significantly above the neutral level ($p < .001$). The reforms effectively stimulated students' learning interest and enthusiasm and significantly improved their operational skills and innovative capabilities. The innovative teaching model developed in this study not only aligns with the specific educational context of Xizang University but also provides an operational, replicable, and adaptable paradigm for reforming physics laboratory instruction in other remote-area institutions.

Keywords: College Physics Experiment, Demonstration, Virtual Simulation, Innovation, Teaching and Learning.

1. Introduction

College physics experiment courses are among the most essential foundational courses offered in science and engineering universities throughout China. They play a crucial role in training undergraduates to understand the entire scientific experimentation process, master scientific thinking and experimental skills, and gradually develop the ability to independently conduct experiments and apply learned knowledge to solve practical problems in their field. However, in the unique educational environment of Xizang University, physics experiment instruction faces numerous challenges. For example, students often lack sufficient foundational knowledge in physics. Due to the diverse background of the student population, many students have limited exposure to and understanding of physics before entering university, resulting in weak foundational knowledge and difficulty in grasping theoretical concepts. Theoretical knowledge in physics is inherently profound and abstract, requiring experimental verification for full comprehension. This combination poses particular challenges for students with weak foundational knowledge, often leading to learning difficulties. The experimental teaching model is excessively dependent on traditional methods, which emphasize procedural guidance while neglecting the analysis of underlying principles. This results in students focusing primarily on executing experimental steps mechanically, thereby stifling the development of innovative thinking and practical skills, ultimately hindering improvements in teaching effectiveness. Limited teaching resources: Constrained by experimental equipment, facilities, and other resources, students have insufficient opportunities for hands-on practice, and their experimental skills are not adequately developed. Additionally, traditional experimental teaching resources are often limited to textbooks and experimental manuals, lacking diversity and richness and thus unable to meet students' diverse learning needs.

In response to the aforementioned teaching issues, the course needs to innovate its teaching methods based on Xizang University students' actual circumstances and talent cultivation needs, thereby constructing a physics experiment teaching model suitable for Xizang University students. Through the paradigm of teaching experiment research, the effectiveness of teaching innovation should be analyzed to clarify its promotional value.

2. Research Methodology

2.1. Research Design

The study employs a mixed-methods design combining action research with case studies. This approach aims to address authentic educational challenges by iteratively designing, implementing, and evaluating instructional interventions within real teaching contexts. It seeks to gain deep insights into the implementation process and outcomes of these interventions specifically within the physics laboratory course at Xizang University. This study, through an in-depth exploration of the plateau ethnic regions as a representative case, aims to address a more universal question: "How can education be effectively delivered when ideal conditions are not present?" The answer to this question holds significant reference value for higher education institutions in numerous non-elite, non-central regions worldwide.

2.2. Participants and Sampling

The study subjects comprised 65 sophomore science students enrolled in the "University Physics Laboratory" elective course at Xizang University during the 2024-2025 academic year. These students were majoring in Physics and Civil Engineering.

Employing cluster sampling, the research utilized natural teaching classes as the unit of analysis. The sample size was determined by the actual class size, aiming to facilitate in-depth case analysis rather than pursue statistical generalizability.

2.3. Data Collection

The self-developed "Feedback Questionnaire for Teaching Reform in University Physics Laboratory Courses" was employed. This questionnaire comprises 12 structured questions using a five-point Likert scale, aims to evaluate the effectiveness of teaching reforms across four dimensions: Course Content (Questions Q1-Q3): Assessing demonstration experiments, virtual simulations, and video resources. Teaching Methods (Questions Q4-Q6): Evaluating problem-based, blended, and personalized teaching approaches. Teaching Environment and Resources (Questions Q7-Q8): Assessing open laboratories and modernized experimental facilities. Teaching Evaluation (Questions Q9-Q10): Assesses the diversified evaluation system and the proportion of formative assessment.

2.4. Data Analysis Methods

The data analysis followed a structured process to comprehensively address both the distribution and the statistical significance of the students' responses.

We first calculated the percentage for each option in all questionnaire items. This provides a clear picture of the response distribution. For each item on the 5-point Likert scale, we computed the mean (M) to represent the average level of agreement or satisfaction, and the standard deviation (SD) to indicate the variability or consensus among responses.

To determine if the students' evaluations were statistically significantly above a neutral level, a one-sample t-test was conducted for each questionnaire item. The neutral test value was set at 3, the midpoint of the Likert scale. A statistically significant result ($p < .05$) would allow us to conclude that the average response was not neutral but positively skewed.

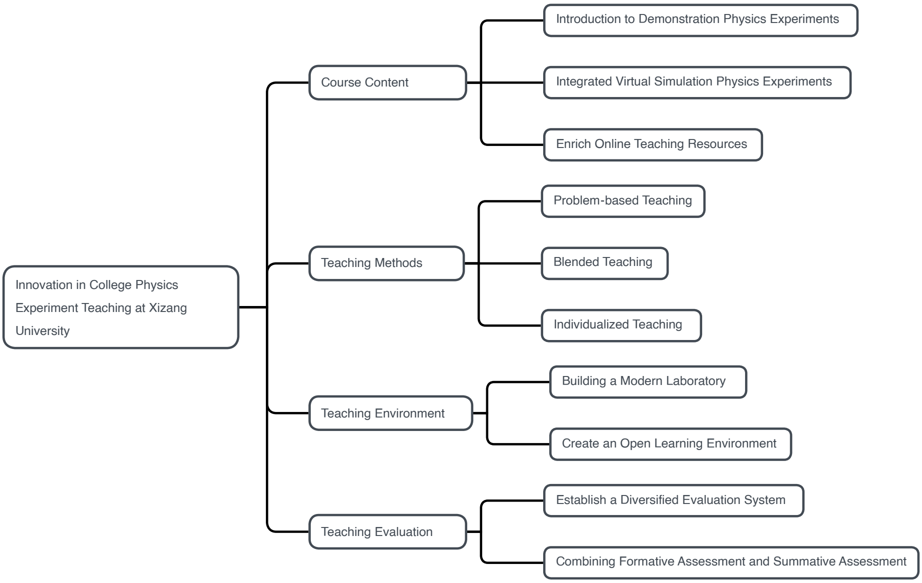
2.5. Ethical Considerations

Prior to the study's commencement, all participants were informed of the research objectives, procedures, and their rights, including the right to withdraw from the study at any time without suffering any adverse consequences. To ensure confidentiality, all data underwent anonymization and was securely stored. Only the research team had access to the data, and any personally identifiable information had been removed from the dataset.

3. Pedagogical Framework

The teaching team for the "College Physics Experiment" course at Xizang University conducted an in-depth teaching reflection and proposed innovative teaching approaches tailored to Xizang University. These innovations encompass comprehensive reforms in course content, teaching methods, teaching environments, and teaching evaluations, as illustrated in Figure 1.

Figure 1: Innovative Teaching Approaches.



The course team restructured the course content by introducing demonstration physics experiments, integrating virtual simulation physics experiments, and enriching online teaching resources. They innovated teaching methods by adopting problem-based, blended, and personalized teaching. They created a teaching environment by building modern laboratories and fostering an open learning atmosphere. They reformed teaching evaluation by using a diversified evaluation system that combines process evaluation and summative evaluation.

4. Innovative Measures and Practices in College Physics Experiment Teaching

To address specific teaching challenges in the physics laboratory courses at Xizang University, this study designed and implemented innovative methods that precisely correspond to these issues. Specifically: To overcome students' insufficient physics knowledge base, we introduced demonstration experiments and short video resources. These aim to lower cognitive barriers through intuitive and engaging physical phenomena, bridging theory with sensory understanding to stimulate learning interest and compensate for background knowledge gaps. To resolve the issue of monotonous teaching modes, we adopted problem-based and blended learning approaches. This transformed instruction from passive “follow-along” to active “inquiry,” while integrating online and offline methods to overcome classroom limitations and enhance teaching flexibility. To overcome constraints of limited teaching resources and scarce hands-on opportunities, we integrated virtual simulation experiments and established open laboratories. Virtual platforms eliminate equipment and space limitations, offering unlimited practice sessions, while open labs extend practical training time. Finally, to address the neglect of competency and process assessment, we established a diversified evaluation system centered on formative assessment. This shifts the focus from outcomes to the process, emphasizing students' experimental attitude, adherence to operational standards, and innovative capabilities. This approach guides them toward prioritizing the development of comprehensive competencies.

4.1. Reconstructing Course Content

4.1.1. Introduction to Demonstration Physics Experiments

Demonstration experiments can help students observe physical phenomena, increase their knowledge through sensory experience, and enhance their interest in learning (Nikitin et al., 2025). Demonstration experiments are essential in stimulating students' interest in learning and cultivating their observation skills, thinking abilities, spirit of exploration, and good learning habits. In encouraging students' enthusiasm for learning and nurturing their various talents, it is imperative to incorporate fun into demonstration experiments (Kácovský & Snětinová, 2021).

Demonstration physics experiments have been incorporated into the course, with a dedicated module of 6 class hours allocated to demonstration experiments scheduled for the first three weeks. This aims to spark students' curiosity about physical phenomena and help them establish connections between physical phenomena and theoretical concepts. Students can observe physical phenomena directly through demonstration experiments and actively think about related principles and concepts. Visually presenting abstract knowledge facilitates students' understanding of abstract concepts and stimulates their interest in learning. Additionally, the demonstration experiment's operational steps and techniques are relatively simple, enabling students to master them quickly and enhance their confidence in this course.

When selecting demonstration experiments, prioritize those closely related to course content that are engaging, representative, and reflective of regional characteristics. For example, conducting the high-altitude boiling point experiment allows students to directly observe how liquid boiling points are influenced by atmospheric pressure, making it easier to understand the relationship between phase transitions and atmospheric pressure. This experiment utilizes Xizang's unique high-altitude, low-pressure environment, highlighting the close connection between science and daily life through heating water to boiling. Demonstrating the high-altitude air refractive index experiment, the difference in air density between high-altitude regions and inland areas results in variations in air refractive index. This experiment visually demonstrates the differing degrees of laser deflection, helping students understand the impact of atmospheric pressure on light propagation. Demonstrate the experiment of igniting paper using a Fresnel lens. The lens's concentric circular structure refracts parallel sunlight to a focal point, creating a high-temperature spot where the paper absorbs sufficient energy to reach its ignition point and catch fire. This experiment visually demonstrates the principles of optical focusing and energy conversion. It cleverly leverages high-altitude regions' high solar radiation intensity, highlighting the scientific value of high-altitude environments.

4.1.2. Integrated Virtual Simulation Physics Experiments

Physical, virtual simulation experiments achieve a high degree of realism by closely replicating real physical experimental instruments and processes, thereby ensuring the experiments' authenticity and the output results' reliability (Bogusevschi, Muntean & Muntean, 2020; Li, 2024; Verawati, Handriani & Prahani, 2022). Research indicates that the scientific inquiry skills and experimental proficiency students gain in virtual experiments can be transferred and applied to real-world experimental work, laying a foundation for future research. Virtual simulation experiments can supplement offline experimental teaching, enriching students' learning experiences and enhancing learning outcomes (Hamed & Aljanazrah, 2020; Martyniuk et al., 2021). Some virtual simulation physics experiments have been integrated into the curriculum to address the limitations of traditional experimental teaching methods.

In recent years, with the strong support of the Xizang Autonomous Region Department of Education and schools, the Experimental Center completed the construction of the "Xizang University Physics Simulation Experiment Platform" in 2024. The virtual simulation platform includes 56 common physics experiments. By adjusting the viewpoint in the observation window, students can observe phenomena from different angles / throughout the experimental setup. The experiment supports multiple working, learning, and assessment modes to meet different learning requirements. The learning mode guides students through the experiment with prompts to ensure smooth completion. The assessment mode automatically records student operations and evaluates performance, allowing students to self-assess their mastery of the experiment. The experiment interface is user-friendly and highly intuitive. The system provides intelligent guidance, automatically offering relevant instructions based on the student's current experiment step to assist in successful completion. During the experiment, the system automatically records student performance and evaluates results. After completion, students can review their performance, identify issues, and reinforce learning targeted at those areas. Teachers incorporate virtual simulation physics experiments into pre-class preparation and post-class assignment activities. Students conduct pre-experiment simulations on the platform before class to reduce cognitive load during class and enhance the effectiveness of experimental teaching; after class, they review experimental steps on the platform to reinforce knowledge application, forming a complete learning loop of "pre-simulation-practical training-extension." While the platform reduced equipment-related errors, it introduced a new challenge: the "simulation-reality gap." Students sometimes found that experiments which worked perfectly in simulation were difficult to replicate with real apparatus, leading to a new form of frustration and doubt about their understanding. Instructors used this as a prime opportunity to discuss the value of practical skills and the complexities of the physical world. They guided students to compare the idealized simulation with the real-world conditions, turning the discrepancy into a deep-learning exercise about uncertainty, calibration, and the scientific method.

Students use a virtual simulation physics experiment platform to simulate experimental operations, observe experimental phenomena, and analyze experimental data on a computer, thereby gaining a deeper understanding of experimental principles and processes. At the same time, virtual simulation physics experiments can also provide personalized teaching and guidance based on students' actual circumstances, helping them gradually enhance their experimental design thinking and abilities. Learning data from the virtual simulation platform—such as operation records and test results—provide a data foundation for teachers to conduct precise stratification, thereby better enabling "teaching tailored to individual needs."

4.1.3. Enrich Online Teaching Resources

Modern network resources are an essential medium for teaching in the new era, and digital courses are the trend in education (Chen, 2025). Teaching short videos present the key points, difficulties, and questions of course knowledge to students in a fragmented and thematic manner through self-directed learning based on course objectives and student needs (Aragoneses & Messer, 2020; Chen et al., 2024), aiming to broaden learning channels and improve teaching quality (Østereng, 2022).

The course team launched the "Xizang University Demonstration Physics Laboratory" official account on a short video app, leveraging the rapid and widespread dissemination advantages of short videos to expand the influence and reach of physics experiment teaching. Over 30 short videos of demonstration physics experiments have been uploaded to the platform, covering topics such as experimental procedures and principle explanations. These short video learning resources are abundant and convenient, allowing students to independently schedule their studies during their free time and learn and reinforce knowledge anytime, anywhere. Students can also leave comments and ask questions in the comment section, engaging in discussions with peers and teachers. This fosters an active learning environment, enhancing students' interest and enthusiasm for learning.

Teachers will continue to update and improve the platform, with plans to launch more high-quality video resources to provide students with a more comprehensive and systematic online learning platform. This will help students gain a deeper understanding of physics experiments, enhance their independent learning abilities, and further optimize the effectiveness and quality of college physics experiment teaching.

4.2. Innovative Teaching Methods

4.2.1. Problem-based Teaching

Traditional physical experiment teaching models typically focus on guiding students to follow the steps outlined in the experiment manual, essentially replicating classic experiments. In such a learning process, students lack active thinking and exploration opportunities. Now, a problem-based teaching approach has been adopted (Gumartifa et al., 2023). The problem-based teaching methodology designed in this study is deeply rooted in constructivist learning theory. From a constructivist perspective, learning is not passive reception but an active process where students construct knowledge while solving real-world problems, such as "how to measure with one-thousandth precision". The teacher's role shifts from knowledge transmitter to facilitator and guide of students' meaning-making. Before the experiment, students are presented with questions to prompt them to think about how to solve the problem. They are then organized into groups for discussion, solutions are developed, and virtual simulation software is used to simulate the experiment and verify the feasibility of their solutions. Finally, they conducted actual physical experiments and exchanged ideas about the results. For example, in the Wheatstone bridge resistance measurement experiment, students are asked: "What method should be used to achieve measurement accuracy to the thousandth decimal place? How should the bridge be designed?" Students then think about how to solve the problem and customize the experimental plan. They then conduct simulated experiments on the virtual simulation physics experiment platform. They perform physical experiments based on the designed circuit diagram if the plan is feasible. After completing the experiment, students analyze the results and discuss their findings with each other. Group discussions are not merely about dividing tasks; they are a process of peer learning where students collectively construct knowledge through debate and sharing ideas.

This process is no longer simply a reproduction of experiments from the textbook but rather a student-centered approach in which teachers guide students in their exploration. Students use questions as a starting point to independently explore solutions to problems and complete the lesson, thereby gaining a deeper understanding of the principles behind the experiments and developing their problem-solving skills (Nicholus, Muwonge & Joseph, 2023).

4.2.2. Blended Teaching

A blended learning approach combines online teaching resources with in-person classroom instruction (Cui, 2024; Deng et al., 2025; Ji & Shi, 2025). Pre-class assignments are assigned, with students using online teaching resources for previewing, including watching relevant experimental videos and simulating experimental procedures on a virtual physics simulation platform. In the in-person classroom, students share and discuss their preview results before conducting hands-on experiments. After class, students can utilize online teaching resources to review and complete assignments. This model combines the flexibility of online teaching with the interactivity of in-person instruction. For challenging experiments, students can repeatedly watch and practice online. The online platform also enables students to share high-quality teaching resources widely. This enhances the efficiency of offline classroom instruction and reinforces its role as the primary channel for learning.

4.2.3. Individualized Teaching

Due to differences in the distribution of educational resources, the cognitive load of language conversion, and cultural diversity, students in the Xizang University district need to gradually improve their cultivation of basic scientific skills. In contrast, students from outside the region benefit from long-term access to high-quality educational resources and possess a comparative advantage in terms of experience in inquiry-based learning. To address students' diverse needs and circumstances, personalized teaching methods are employed (Suwastini et al., 2021; Zheng, 2022). Experimental content and difficulty levels are categorized into a foundational tier (mandatory) and an advanced tier (optional), enabling dynamic alignment between instructional objectives and student capabilities. This approach ensures that all students meet basic skill requirements while providing advanced exploration opportunities for those with additional capacity. Students may independently select and complete optional experiments after fulfilling mandatory requirements. For example, in the experiments on adjusting optical paths and measuring lens focal lengths, students must complete the convex lens experiment and may optionally complete the concave lens experiment. In the Wheatstone bridge experiment for measuring resistance, students must measure resistance accuracy to the nearest hundredth and may optionally measure resistance accuracy to the nearest thousandth.

After students complete their operations on the virtual simulation physics experiment platform, teachers can provide personalized guidance based on the students' performance. Students are also encouraged to design and innovate experiments based on their interests and strengths to cultivate innovative thinking and higher-order skills (He, Zhang & Wang, 2025). Teaching should target students' "zone of proximal development," setting appropriate, challenging goals and content to transform students' potential developmental levels into new current developmental levels, continuously creating new "zones of proximal development" to meet students' developmental needs (Lei & Abu Bakar, 2025). Through preliminary assessments and ongoing observation, we identify each student's Zone of Proximal Development to provide scaffolding support. Foundational experiments ensure all students meet basic requirements—their current developmental level—while advanced challenges guide them toward leaps toward their potential developmental level.

4.3. Create a Teaching Environment

4.3.1. Building a Modern Laboratory

During the early years of the school's establishment, each laboratory was designed to be 60 square meters, with 10 physics laboratories. However, with the expansion of higher education enrollment, if each class has 45 students, the average space per student is less than 1.4 square meters, which is far below the higher education laboratory construction standard requirement of 5-7 square meters per student, resulting in overcrowded laboratories. Due to experimental equipment and facilities limitations, students have insufficient opportunities for hands-on practice, and their experimental skills are not adequately developed.

To provide students with a good experimental environment, Xizang University is actively constructing and renovating laboratories. Advanced experimental equipment and instruments have been introduced, and the layout and facilities of the laboratories have been optimized to create a safe, comfortable, and modern experimental environment for students. As shown in Figure 2, the demonstration physics laboratory is already in use, while the physics innovation laboratory is currently under construction with the support of the University Physics Course Teaching Guidance Committee and partner schools. The construction of modern laboratories improves students' experimental efficiency and accuracy and enhances their experimental experience and interest.

Figure 2: Demonstration Physics Laboratory and Physics Innovation Laboratory.

4.3.2. Create an Open Learning Environment

The laboratory emphasizes fostering an open learning environment, encouraging students to actively engage in experimental learning and exploration, and utilizing their free time to design experiments and pursue innovation independently. The laboratory provides students with opportunities for collaboration and exchange, such as organizing experimental groups and conducting experimental competitions. The laboratory is open to students who may use laboratory equipment after class for experimental needs. Students participating in undergraduate innovation projects may receive funding ranging from 5,000 to 15,000 yuan, resulting in high-quality academic achievements, such as published papers and granted patents. This has enhanced students' innovative capabilities and comprehensive practical skills.

4.4. Reforming Teaching Evaluation

4.4.1. Establish a Diversified Evaluation System

Traditional course assessments primarily focused on operational skills and exam results. After the reform, the evaluation system shifted to a diversified approach. In terms of knowledge, the assessment mainly evaluates students' theoretical understanding of experimental principles and procedures. In terms of ability, it assesses students' operational skills and innovative capabilities through experimental procedures, creative design, and data analysis. In terms of literacy, it focuses on scientific attitudes, rigor, and teamwork. Evaluating students from multiple dimensions not only emphasizes the accuracy of data and conclusions but also prioritizes the development of abilities and the enhancement of competencies, which promotes students' comprehensive development (Liang, 2023; Tremblay-Wragg et al., 2021), improves the fairness and scientific rigor of evaluations (Sulaiman & El-Nasir, 2025), and achieves the educational objectives of "promoting learning through evaluation" and "promoting innovation through evaluation."

4.4.2. Combining Formative Assessment and Summative Assessment

Evaluating broad learning outcomes, learning motivation, attitudes, and performance during the learning process is called formative assessment; the review of the achievement of course objectives is called summative assessment of the course (Ismail et al., 2022; Khaled & El Khatib, 2020; Morris, Perry & Wardle, 2021; Qadir et al., 2020). Traditional evaluation methods in the past primarily focused on summative assessment, with a higher proportion of exams. Nowadays, there is a greater emphasis on formative assessment, which is combined with summative assessment to evaluate students' learning outcomes comprehensively. Formative assessment accounts for 70% of the total evaluation, while summative assessment (exam scores) accounts for 30% of the total evaluation.

Formative assessment accounts for 70% of the total grade, aiming to comprehensively and objectively evaluate students' overall performance throughout the learning process. This evaluation system comprises five core dimensions, each with clearly defined performance indicators and quantifiable scoring criteria: Classroom Participation (15% of total score): Scored primarily based on the initiative and quality of student engagement in class. Grades are: Excellent (13-15 points): Proactively raises insightful questions and actively participates in discussions; Good (10-12 points): Effectively responds to teacher questions and participates in collaboration; Passing (6-9 points): Only passively participates; Failing (0-5 points): Significantly insufficient participation. Attendance (10%): Quantified using a deduction system. Full marks are 10 points. One deduction of 3 points for each unexcused absence, and one deduction of 1 point for each instance of tardiness or early departure, until the maximum deduction is reached. Laboratory Attitude (15%): Assessed through preparation, operational rigor, and initiative in maintaining the laboratory environment. Excellent (13-15 points): Requires thorough preparation, meticulous execution, and proactive maintenance of cleanliness. Good (10-12 points): Demonstrates generally careful operation and adherence to rules. Passing (6-9 points): Meets basic requirements but requires reminders. Failing (0-5 points): Involves careless operation or violation of safety protocols. Experimental Procedure (20%): Primarily evaluates students' adherence to standard protocols and independence in completing experimental steps. Excellent (18-20 points) indicates independent, standardized completion of all steps with problem-solving ability; Good (14-17 points) indicates completion of major steps with minimal prompting; Passing (10-13 points) indicates completion with substantial guidance; Failing (0-9 points) indicates inability to independently complete core operations or major errors. Quality of Experiment Report (40%): Comprehensive rating across four dimensions: data recording, analytical depth, standardization, and reflective capability. Excellent (36-40 points): Original, authentic, and complete data; standardized and professional charts/graphs; profound analysis of physical principles with logically clear discussion of error sources; rigorous report format with fluent language; innovative reflections or improvement proposals. Good (30-35 points): Data is fully recorded with clear charts; correctly analyzes principles and explains major errors; report format is standardized with clear expression; provides appropriate summaries related to the experiment. Passing (24-29 points): Data recording is generally complete, though minor omissions may exist; experimental phenomena and basic conclusions are described, but analysis is superficial; report format is largely standardized with no significant scientific errors. Failing (0-23 points): Data is missing or fabricated, charts are disorganized; analysis is ineffective or conclusions are erroneous; report format is non-standardized, or contains substantial plagiarism.

The final assessment accounts for 30% of the total grade and is conducted as a written exam primarily consisting of short-answer questions. It primarily evaluates students' in-depth understanding of experimental principles and data processing skills. To ensure scoring objectivity, we employ a structured rubric evaluating responses across four dimensions: 1. Knowledge Understanding and Exposition: Assesses accurate articulation of core concepts, principles, and instrument mechanisms. 2. Principle Application and Analysis: Evaluates logical reasoning in applying theory to novel contexts and analyzing experimental validity. 3. Data Processing and Calculation: Focuses on formula selection, computational rigor, and proper unit usage. Fourth, Conclusions and Argumentation, which evaluates the quality of reasoning in drawing conclusions based on theory and data and providing reasonable explanations for phenomena. Each question will emphasize one or two of these dimensions and has a clearly defined maximum score. Graders will score each question based on the corresponding grade-level descriptors: Excellent ≥85%, Good 70%-84%, Passing 60%-69%, Failing <60%. The final written exam score is the sum of all actual question scores, which is then proportionally converted to constitute 30% of the overall course grade.

Emphasizing formative assessment offers multi-dimensional advantages, overcoming the limitations of traditional summative assessment. It stimulates students' intrinsic motivation and alleviates the pressure of summative exams.

5. Results

5.1. Teaching Achievements

After nearly three years of teaching practice, the "College Physics Experiment" course has developed a multi-dimensional innovative teaching model suitable for students at Xizang University and has achieved remarkable results.

Students' interest in learning and enthusiasm for participating in experiments have significantly increased. This is reflected in a more lively classroom atmosphere, with demonstration experiments featuring novel and eye-catching phenomena. Students are more focused, and the classroom is no longer dominated by the teacher's monotonous lectures with disengaged students. Students are also willing to take the initiative to conduct demonstrations, enhancing interaction between teachers and students and between teaching and learning in the classroom. Attendance rates for course instruction have also improved significantly, with students generally finding the experimental classes interesting and willing to attend. The comment sections of short videos also feature many lively discussions among students about the knowledge covered.

To quantitatively evaluate the effectiveness of the teaching reform, we compared students' final exam scores before and after the reform. Prior to the reform, the average score was 66.96 (SD = 14.17), with only 2.5% of students achieving an excellent score (≥90 points). Following the reform, the average score significantly increased to 87.0 (SD = 6.43), while the percentage of students achieving excellent scores rose substantially to 40.54%.

Students' experimental skills and innovative abilities have significantly improved. Now, more students proactively propose their own innovative experimental design plans. After online previews, students have become more proficient in experimental operations and make fewer mistakes. Both experimental and theoretical grades have improved, and course pass rates and student satisfaction have significantly increased. Students have won multiple awards in the National University Physics Experiment Competition, and our university has received two Outstanding Organization Awards. Students participating in the Undergraduate Innovation and Entrepreneurship Training Program achieved excellent results in project evaluations, published papers, and obtained related patents.

The course has been certified as a first-class undergraduate course at the university level and is actively applying for certification as a first-class undergraduate course at the autonomous region and national levels, demonstrating its promotional value and influence.

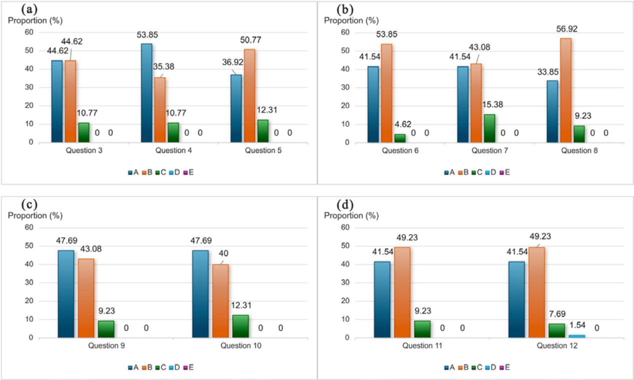
5.2. Distribution of Student Feedback

A questionnaire was conducted on 65 sophomore and junior students from different majors. The questionnaire included four sections: feedback on curriculum reform, feedback on teaching method innovation, feedback on teaching environment and resources, and feedback on teaching evaluation reform. Overall student feedback across the four reform dimensions was highly positive, with detailed response distributions visualized in Figure 3 and corresponding item descriptions provided in Table 1.

Table 1: Student Feedback.

Options Core Description	A	B	C	D	E
Question 3: Attractiveness of demo experiments	Very strongly	Moderately strongly	Neutral	Slightly	Not at all
Question 4: Helpfulness of virtual simulations	Extremely helpful	Moderately helpful	Neutral	Slightly helpful	Not helpful
Question 5: Satisfaction with video resources	Very satisfied	Moderately satisfied	Neutral	Slightly dissatisfied	Very dissatisfied
Question 6: Improvement from problem-based teaching	Significant improvement	Slight improvement	No effect	Slight decline	Significant decline
Question 7: Efficiency of blended teaching	Highly efficient	Moderately efficient	Neutral	Slightly inefficient	Very inefficient
Question 8: Satisfaction with personalized teaching	Fully met	Mostly met	Neutral	Partially met	Not met
Question 9: Enhancement of innovative thinking	Significant enhancement	Slight enhancement	No effect	Slight limitation	Significant limitation
Question 10: Satisfaction with modern labs	Very satisfied	Moderately satisfied	Neutral	Slightly dissatisfied	Very dissatisfied
Question 11: Comprehensiveness of evaluation system	Very comprehensive	Moderately comprehensive	Neutral	Slightly lacking	Very lacking
Question 12: Reasonableness of assessment weighting	Very reasonable	Moderately reasonable	Neutral	Slightly unreasonable	Very unreasonable

Figure 3: Student Feedback.



5.2.1. Feedback on Course Content

Students responded very favorably to the new course elements. The attractiveness of demonstration experiments (Q3) and the helpfulness of virtual simulations (Q4) were particularly well-received, with approximately 90% and 89% of students, respectively, giving positive or highly positive ratings. While satisfaction with online video resources (Q5) was also high, its proportion of top-tier ("very satisfied") ratings was comparatively lower, indicating a relative area for improvement.

5.2.2. Feedback on Teaching Method

Reforms in teaching methodology garnered strong endorsement. The vast majority of students perceived improvement in independent problem-solving from problem-based teaching (Q6, 95.4% positive) and found the blended learning approach efficient (Q7, 84.6% positive). Personalized teaching (Q8) was also successful, meeting the learning needs of 90.8% of respondents.

5.2.3. Feedback on Teaching Environment and Resource

Investments in the physical and open learning environment were validated by student feedback. Nearly all students reported that the open laboratory enhanced innovative thinking (Q9, 90.8% positive) and expressed satisfaction with the modernized labs (Q10, 87.7% positive).

5.2.4. Feedback on Teaching Evaluation

The revised assessment system was viewed as fair and comprehensive. A high percentage of students found the diversified evaluation system to be comprehensive (Q11, 90.8% positive) and considered the increased weight of formative assessment reasonable (Q12, 90.8% positive), signaling broad acceptance of the evaluation reforms.

5.3. Descriptive Statistics and Results of the One-Sample t-Test from Student Feedback

As shown in Table 2, students' average ratings for each dimension of the teaching reform ranged from 4.25 to 4.43. Students' ratings across all dimensions were not only positive but also exhibited low to moderate variability (with standard deviations ranging from 0.575 to 0.75). To verify the statistical significance of student feedback, we conducted one-sample t-tests (theoretical value = 3) for all items, with all p < .001. The results indicate that all teaching reform measures received significantly positive evaluations from students, well above the neutral level.

Table 2: Descriptive Statistics and Results of the One-Sample t-Test from Student Feedback(N=65).

Assessment Dimension	Item Description	Mean (M)	Standard Deviation (SD)	t-value	p-value
Course Content	Q3: Attractiveness of demo experiments	4.34	0.668	16.155	<0.001
	Q4: Helpfulness of virtual simulations	4.43	0.684	16.866	<0.001
	Q5: Satisfaction with video resources	4.25	0.662	15.173	<0.001
Teaching Methods	Q6: Improvement from problem-based teaching	4.37	0.575	19.208	<0.001
	Q7: Efficiency of blended teaching	4.26	0.713	14.261	<0.001
	Q8: Satisfaction with personalized teaching	4.25	0.613	16.385	<0.001
Learning Environment & Resources	Q9: Enhancement of innovative thinking	4.38	0.654	17.066	<0.001
	Q10: Satisfaction with modern labs	4.35	0.694	15.718	<0.001
Teaching Evaluation	Q11: Comprehensiveness of evaluation system	4.32	0.640	16.667	<0.001
	Q12: Reasonableness of assessment weighting	4.31	0.683	15.439	<0.001

6. Discussion

6.1. International Comparison and Theoretical Implications

The analysis of student feedback and academic performance confirms the overall success of the reform across all targeted dimensions. These positive outcomes align with and extend contemporary international discourse on pedagogical innovation in STEM education.

Regarding the high effectiveness of virtual simulation experiments (M=4.43), we compare and contrast our results with relevant international studies (Bogusevschi et al., 2020), highlighting how our platform served not only as a resource substitute but also as a cognitive scaffold in our specific context.

Concerning the positive outcomes of problem-based teaching (M=4.37), we reference established literature on PBL (Gumartifa et al., 2023), discussing its adaptation to the demands of university physics laboratories.

Related to our diversified assessment system, we engage with research on context-dependent teaching strategy effectiveness (Tremblay-Wragg et al., 2021), illustrating how our evaluation framework represents a successful contextual adaptation.

In summary, this study not only validates the transferability of key global pedagogical innovations but, more significantly, provides a context-sensitive model for their strategic integration and adaptation. It demonstrates that in non-elite, geographically distinctive institutions, effective reform hinges on tailoring these innovations to address localized challenges such as foundational knowledge gaps and resource scarcity, offering a replicable paradigm for similar settings worldwide.

6.2. Conditions for Successful Adaptation

While this teaching model was developed within the specific context of Xizang University, its core principles hold value for a wider range of institutions. However, successful transferability is not automatic and depends on several key institutional and contextual variables:

Socio-cultural and Geographical Context: This model is particularly suitable for institutions serving student populations from diverse cultural backgrounds or in unique geographical settings. The emphasis on localized content is a transferable principle that can be adapted to other regional characteristics. Student Preparedness: The model's effectiveness in bridging knowledge gaps suggests it is highly relevant for institutions where incoming students have heterogeneous or insufficient prior knowledge in foundational subjects. Its scaffolding strategies are key for such contexts. Resource Availability and Institutional Support: The successful implementation relied on certain resource inputs, such as the development of virtual simulation resources and the modernization of labs. Therefore, the model is most readily transferable to institutions with moderate investment capacity or strong administrative backing for teaching innovation. For resource-constrained settings, we suggest a phased approach, prioritizing low-cost elements like problem-based learning and personalized feedback before moving to high-cost virtual labs.

For educators interested in adopting this model, we recommend the following adaptive strategies:

Conduct a Local Context Analysis: First, identify the specific challenges in your own institution that mirror the ones addressed in our study. Prioritize and Adapt: Do not attempt to replicate the model in its entirety. Instead, prioritize the core components most relevant to your needs and adapt the localized elements. Start with Low-Threshold Innovations: Initiatives like incorporating short instructional videos and reforming assessment rubrics require less financial investment and can serve as a starting point, building momentum for more comprehensive reform.

6.3. Short-Term Outcomes and Long-Term Implications

The empirical data presented in this study primarily captures the short-term outcomes of the teaching reform: a significant rise in exam scores, high levels of student satisfaction and engagement, and improved experimental skills within the course timeframe. These immediate results validate the model's effectiveness in achieving its primary instructional objectives.

Looking beyond the semester, the reform holds promising long-term implications. For students, the emphasis on inquiry-based learning, problem-solving, and the use of digital tools is likely to foster lasting scientific literacy, adaptability, and a positive disposition towards STEM, which could influence their future academic pursuits and career choices. For the institution and similar counterparts, this study provides a validated framework for sustainable pedagogical transformation, demonstrating how strategic innovation can address systemic challenges. At a policy level, the success of this context-sensitive model offers evidence to inform strategies aimed at enhancing educational equity and quality in non-elite or geographically distinctive regions. While confirming these long-term effects requires longitudinal follow-up studies, the strong foundational outcomes established here provide a compelling rationale for their potential realization.

6.4. Limitations of the Study

The study's survey data were collected from only 65 students at a single university, which may limit the generalizability of findings to broader populations. Future studies should expand sample size and include multi-institutional comparisons to enhance external validity.

A limitation of this study is the absence of a control group, which restricts our ability to isolate the causal effects of instructional innovations from other potential confounding factors. However, to enhance the internal validity of the findings, we employed triangulation across multiple data sources—including questionnaires, observations, and lab reports—along with longitudinal comparisons of pre- and post-reform outcomes such as course grades and competition awards. The consistent positive evidence emerging from these diverse data sources provides compelling support for the effectiveness of the instructional model. Future research should employ quasi-experimental designs incorporating control groups across multiple institutions to rigorously isolate the model's causal impact and further validate its generalizability.

6.5. Concluding Remarks

In conclusion, this study, taking the college physics experiment course at Xizang University as a case, has demonstrated the effectiveness of a comprehensive innovation model encompassing course content, teaching methods, environment, and assessment. The practical implementation has proven its capacity to stimulate student interest, enhance operational and innovative skills, and ultimately improve learning outcomes. This research provides a validated, context-sensitive paradigm that offers a valuable reference for reforming STEM laboratory instruction in similar regional or resource-constrained higher education settings.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Conceptualization, Y.Z and X.Q; Methodology, Y.Z.; Investigation, X.Q; Resources, X.Y; Data Curation, X.Q; Writing – Original Draft Preparation, X.Q; Writing – Review & Editing, Y.Z; Visualization, L.L; Supervision, Y.Z; Project Administration, Y.Z; Funding Acquisition, Y.Z.

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Data Availability Statement

Data sets generated during the current study are available from the corresponding author on reasonable request.

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