

# The study focuses on reforming college physics teaching and evaluates its effectiveness through demonstration experiments

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**Abstract.** Physics is an experimental-based discipline; however, there is a shortage of demonstration experiments in the instruction of university physics courses. Students now generally believe that the course is hard to understand and boring as a result of this. This article offers a series of university physics demonstration experiments arranged into modules and chapters. The experiments are integrated into classroom instruction in tandem with the different phases of BOPPPS teaching. This method encourages curriculum reform and makes interactive learning easier. A questionnaire survey, scientific method testing, and subject competitions were used to compare the changes between the reformed class and the regular class in order to assess the efficacy of the teaching reform. Research indicates that the use of demonstration experiments in teaching reform can increase students' self-efficacy in learning, specifically in improving their capacity to learn. Additionally, it can foster a scientific mindset by encouraging rational thought and help develop scientific abilities by teaching and practicing scientific methods.

**Keywords:** University physics; Classroom demonstration experiment; BOPPPS; Teaching method.

## 1. Introduction

Although physics is an experiment-based subject, many university physics curricula have overlooked the demonstration experiments' educational value, which makes students view physics as a dry formula and loses interest in the subject. The basic teaching requirements of the University of Engineering Physics course were revised in 2023 by the Department of Education's University of Higher Schools Physics Teaching Steering Committee, who made it clear that "the main components of the university's physics courses should be demonstrated experiments (physical demonstration and multimedia simulation), in which the number of physical demonstration experiments should not be less than 40." [1] Students' ability to observe and investigate is enhanced by the physical demonstration experiment, which provides students with a visual demonstration of physical phenomena. Some universities have been responding positively to the call to explore the teaching reform of demonstration experiments [2-4]. However, we did not find comparative scientific and systematic research on the question, "What kind of physical demonstration experiment should be conducted? How do you combine physical presentation experiments with teaching content?"

## 2. Building a university demonstration experimental project library for physics

We have built the university physical demonstration experiment project library by chapters, a total of 108 demonstration experiments, and the following table shows the demonstration of the mechanical parts. This library was created in conjunction with the practical needs of university physics teaching and was inspired by the book "Physical Demonstration Experimental Tutorial" [5] published by the University of Qinghai.

Table 1. Physical demonstration experiment project library

chapters	number of sections	Demonstration Experiment	Purpose of the presentation
Chapter 1 Description of Motion	1.3 Description of Cartesian Coordinates	Demonstration of Movement Independence	Demonstrate the difference and connection between equations of motion and trajectory equations
		Positioning using Beidou	Explore right-angle coordinate descriptions of position
	1.5 Description of Angular Quantities	angular velocity synthesis	Demonstrate the vectorial nature of angular velocity
Chapter 2 Newton's Laws of Motion	2.1 Newton's Laws of Motion	Galileo's ideal inclined plane experiment	Establishing the concept of inertia
		Impulse Ball Demo	Demonstrate the meaning of the concept of inertia
	2.5 Non-inertial systems Inertial forces	Rollerball Demo Coriolis Force	Demonstration of inertial forces
		Foucault's pendulum	Coriolis force from the Earth's rotation
Chapter 3: Work and Energy	3.2 Conservative forces Potential energy	spring vibrator	elastic potential energy
	3.3 Functional Principles Law of Conservation of Mechanical Energy	Small ball roller coaster model	Interconversion of gravitational potential energy and kinetic energy
		(of a machine) rolling	Demonstrate conservation of mechanical energy
Chapter 4 Impulse and Momentum	4.1 Impulse The Theorem of Momentum	Impulse Ball Demo	Establishing the concept of impulse (time accumulation of forces)
		lit. a boat going against the wind (idiom); fig. you must work harder	Demonstration of the Momentum Theorem
	4.2 Law of Conservation of Momentum	pendulum-carrying cart	Combining experiments with quantitative calculations of examples to investigate the law of conservation of momentum
	4.3 Collisions	Newton's pendulum	Demonstration of an elastic collision
		Hyperelastic collision (vertical impact ball)	Gravitational slingshot effect can be explained visually using demonstration experiments
	4.4 Center of Mass Theorem of Motion of the Center of Mass	Roll on cone	Demonstration of physical phenomena to introduce the concept of center of mass
		Demonstration of center of mass motion (lever)	Exploring the center-of-mass motion theorem

chapters	number of sections	Demonstration Experiment	Purpose of the presentation
Chapter 5 Fixed-axis rotation of rigid bodies	5.2 Laws of fixed-axis rotation of rigid bodies	Comparison of rigid bodies with different mass distributions rolling along the same incline	Verify that the moment of inertia is related to the mass distribution
		Demonstration of the Janibekov effect	Verify the vertical axis theorem
	5.4 Angular momentum and the law of conservation of angular momentum	Whirling Rope Ball	Probe: conservation of angular momentum of a mass when acted upon by a centripetal force
		centrifugal throttle	
		Angular momentum synthesis (angular velocity synthesis)	Angular momentum of a rigid body
		gyros	Verification of the law of conservation of angular momentum of a rigid body
		The "Zhukovsky-like stool" experiment	Conservation of angular momentum: controlling speed by changing the moment of inertia
	5.5 Progress	gyro advance (physics)	Application of the angular momentum theorem to explain the in-motion effect

### 3. Combining demonstration experiments with BOPPPS instruction

The Canadian teacher skill training system ISW, from which the BOPPPS teaching model is adapted, views learning as an experience that integrates "passion," "digestion of knowledge," "absorption," "mastering," and "feedback and correction" into a single, highly regarded program that is used both domestically and internationally. "B-bridge-in," "O-objective," "P-pre-asse," "P-participatory learning," "P-post-assessment," and "S-summary" are the six components of the BOPPPS teaching model [6].

#### 3.1 To pique interest in learning, introduce new lessons through demonstration experiments.

Through a straightforward experiment, the classroom introduction section grabs students' interest, tests their capacity for observation, piques their curiosity, and establishes the groundwork for the lessons that will be covered in class. Showing how the plastic brush charged with static electricity can draw in the tiny water flow, just like in a section of the electrical medium in the static field. The experiment under observation raises awareness, presents a fresh lesson, and promotes inquiry and discovery. Why do water columns tend to be drawn to the bristle with statistics? A pen is hidden for the polarization of learning and the classification of the rear electrical media.

#### 3.2 Develop concrete ideas via demonstration experiments to overcome abstract understanding

Phenomena is the most significant aspect of physics. Most of the ideas in physics are derived from phenomena. [7] "Physics can be demonstrated experimentally because many physical concepts are abstract, and some are even supposed to be described for convenience. For example, homemade

experimental instruments display a black body model. When an object absorbs a certain percentage of light without reflecting any, at room temperature, it appears black. This phenomenon is known as black body. Little holes are made in the air cavity, allowing for a more visual discovery of the colors of the ink dots' perforated pores and small pores.



Fig. 1 Black body model, homemade demonstration experimental device

### 3.3 Encourage scientific thinking by showcasing experimental investigations of physics' laws.

Scientific investigation led to the discovery of the laws of physics, and during the teaching process, we creatively convert the demonstration experiment into an exploration experiment.

First question: Hypothesize that the force of amputation—that is, the impact of the magnetic field on the current—is what propels wire-circle cannons by examining the wire-circle cannon model's structure. However, from what source is the bullet's current coming? conjecture: concerning variations in the magnetic fields produced by wires. Design experiment 1 involved inserting and removing a wire magnet; experiment 2 involved replacing a bar magnetic repeat experiment 1's power screw tube. Confirm theories: The circuit will produce a responsive current in response to altered magnetic fields  $\phi$ .

Second question: What is the best way to accelerate a wire-circuit cannon bullet? By raising the sensing current, amputation can be increased. Experiment 4: The wire circle is approached by the magnet both quickly and slowly; Experiment 5: The conductor cuts the magnetic sensing line both quickly and slowly. Summary Rule: Using the following formula, the sensed electrical momentum increases with a faster change in magnetic flow and vice versa:  $\varepsilon \propto \left| \frac{d\phi}{dt} \right|$ .

Third Question: How can the bullet's direction be changed? The sensing current has the ability to change the direction. Experiment 6: The closed-door aluminum ring will stop the magnet from moving near or away from it when it is in close proximity to it. Experiments 7: Cut the conductor of the magnetic sensing line movement; the directions of motion are different; the indicator of the flow deviates in different directions. The law of Faraday's electromagnetic sensing is summed up by solving three problems:  $\varepsilon = -\frac{d\phi}{dt}$ .



Fig. 2 Explore the Law of Electromagnetic Induction

### 3.4 Strengthening the application of scientific methods through demonstration experiments

In order to help students successfully complete their post-class exploration tasks, the task group built a student's own innovative laboratory, providing them with practical fields and experimental equipment. To enable students to demonstrate their findings fully, it reformed the classroom teaching model and opened a "five-minute physics" teaching link, in which students can present their research results in the form of academic reports and exchange exploration with the whole class.

Table 2. Subject of the post-class investigation

Module	Subjects	Contents
Mechanics	Newton's bowls	The vibration of Newton's bowls decreases gradually until the bowls are stagnant, investigating the impact of relevant parameters, such as the number of bowls, the material and the arrangement, on the decrease rate.
	Magic of ruler	If you put a scale on the side of the table and throw a ball at its free edge, the scale will fall. However, if you cover a part of it with a piece of paper and repeat it, it will remain on the table, and the ball will be bounced by it, explaining the phenomenon and exploring the relevant parameters.
	Table tennis rocket	Put a ping-pong ball in a container filled with water, and when the container falls, the ping-pong ball will be launched to a very high height. Try up to 2 liters of water. What is the maximum height you can reach?
	Why can't we shoot into the sky?	Shooting training rules strictly prohibit shooting in the sky. Assuming that in a wind-free environment, shooting straight into the sky, the bullet will fall in the direction of the relative position of the person, which will cause a mistaken injury.

#### 4. Evaluation of the impact of teaching reform

In order to test the effectiveness of the curriculum teaching reform, after reference to the Guidelines for the Evaluation of the Teaching of the Courses of the University of Wuhan, in combination with the attributes of the physics discipline, the task force started with the scientific spirit, thinking, and methodology to design questionnaires, test subjects, and conduct testing

##### 4.1 Scientific spirit

"Scientific spirit" refers to "the values, standards, thinking, and behavioral manifestations formed by students in learning, understanding, and applying scientific knowledge and skills, specifically the basic elements of rational thinking, critical questioning, and the courage to explore" [8].

The evaluator scores 5 degrees based on their real feelings: 1 is very disagreeable, 2 is more disagreeable, 3 is neutral, 4 is comparative agreement, and 5 is very agreed. Rational thinking, critical questioning, courage to explore the score, and the scientific spirit of the overall score—the higher the score, the higher the scientific spirit with which the subject is tested.

In Table 3 of the results of the questionnaire's credibility analysis, the credibility coefficient is 0.893, which indicates that the quality of the study data is very high. For the " $\alpha$  coefficients that have been deleted," there is no significant rise in the credit coeffice after the deletion of an arbitrary item, indicating that the design of the item is reasonable.

Table3. Credibility analysis of the "Scientific Spirit" questionnaire

Itmes	CITC	Eliminated coefficients $\alpha$	$\alpha$
I believe that the most significant aspect of science is its reproducibility.	0.329	0.907	0.893
I recognize that phase-based truths are subject to error, and that what we currently believe to be true may turn out to be untrue in the future.	0.677	0.883	
I was able to notice the flaws in the other people's theoretical conclusions and experimental designs more clearly after listening to "Five Minutes of Physical Sharing".	0.809	0.870	
I'm good at logical reasoning, controlling variables, summarizing, etc.	0.730	0.876	
The teacher's answer, if I have any doubts, I'll do it again.	0.747	0.882	

Itmes	CITC	Eliminated coefficients $\alpha$	$\alpha$
If I don't agree with the teachers in the classroom, I will speak up and ask to talk about my ideas with the teachers and other students.	0.741	0.876	
I always wanted to try a different way to solve the problem.	0.697	0.878	
Better than a teacher's solution is what I'd like to find.	0.683	0.879	
My first instinct is to check if there are any new experiments available when it comes to demonstration experiments in the classroom.	0.517	0.890	
Every minor alteration in an experiment, in my opinion, has the potential to produce a surprising result.	0.678	0.881	

Questionary exploration factor analysis such as table 7: KMO value is 0.727, P value is unlimited close to zero, rational thinking, critical questioning, and the courage to explore the three factors differential interpretation values are 32.258%, 27.339%, and 26.452%, and after rotation, the cumulative variance interpretation rate is 86,050% >50%, respectively, meaning that the questionnaire can effectively extract information and has good effectiveness.

Table4. Validity analysis of the "Scientific Spirit" questionnaire

Items	Coefficient of factor load		
	Rational thinking	Critical questioning	Dare to explore
Value of the feature root (after rotation)	2.581	2.187	2.116
Differential Interpretation Rate % (after rotation)	32.258%	27.339%	26.452%
Cumulative differential interpretation rate % (after rotation)	32.258%	59.597%	86.050%
KMO value	0.727		
Bart spherical value	147.625		
df	28		
p value	0.000		

Additional analysis of the differences in the three dimensions of rational thinking, critical questioning, and courage to explore. The results of the independent sample t test showed that there were significant differences ( $p < 0.05$ ) between the overall score of scientific thought, rational thought, criticism, and discernment in the class and that the rational mind of the class (average 17.68, standard difference 2.06) was significantly superior to the normal mind (average 16.43, standard difference 2.50).

Table 5. Differential analysis of the “scientific spirit” between the teaching classes and the ordinary classes

Item of analysis	Class	Amount of sample	Average value	Standard difference	t	df	p
Rational thinking	1.0	31	17.68	2.06	2.103	57.000	0.040*
	2.0	28	16.43	2.50			
Critical questioning	1.0	31	8.61	1.33	1.036	57.000	0.305
	2.0	28	8.14	2.10			
Dare to explore	1.0	31	16.90	2.82	1.273	57.000	0.208
	2.0	28	15.75	4.08			

## 4.2 Scientific Methods

Tests and China Undergraduate Physics Tournament competition(CUPT) are the two main tools used to test scientific methods.

The test questions like follows:

We know that gravity  $\vec{F} = G \frac{m_1 m_2}{r^2} \vec{e}_r$  is very similar to that of a coulomb  $\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \vec{e}_r$ , and the interaction between the two mass points and the two charges is inversely proportional to the square of the distance.

(1) Please write the gravitational force of the point of gravity  $g$  according to the strength of the electrical field of a point of charge; (2) Please write the force of gravitation of the quality point based on the voltage of the charge point. (3) In fact, in the course of the establishment of the Law of Coulomb, physicists had only boldly speculated on the basis of empty tank experiments that electricity would also be subject to the law of square inversion. Because Newton's mechanics proved that if gravity is subject to the square inverse law, the equal shell of matter should have no effect on objects in the shell. (4) Please solve the equal distribution of gravitational fields of the material globular shell according to the Gauss theorem.

The CUPT competition tested the ability of the competing team to apply scientific methods to solve physical problems; the learning self-effectiveness of the transformation class is better overall; and the class attendance rate in the CUPT school competition reached 74.19%, far above the ordinary class. At the same time, the training practice of the “five-minute physical” activity, in the application of the scientific method, significantly improved, eventually winning the group first-rate prize in the school contest, a student promotion area competition, and the “best opposite” in the region competition.

## 5. Summary

In order to solve the problem of “what demonstration experiments are opened in university physics courses?” The university has created an innovative physical demonstration experiment library. To solve “how to combine demonstration and teaching content?” The BOPPPS teaching model will integrate demonstration into teaching: introducing new lessons through demonstration, stimulating learning interest, building physical concepts through demonstrations, breaking abstract knowledge points, cultivating scientific thinking through demonstrative examination of the laws of physics, implementing classroom post-examination by demonstrating experiments, and strengthening the application of scientific methods. In solving the problem “How to determine the effect of teaching reform?” the scientific preparation of questionnaires, by predicting the collection of data and using the SPASS software for credibility and effectiveness analysis, has formed a set of “scientific spirit” questionnaires. The results showed that the introduction of the experiment into the classroom to help students establish physical concepts and explore physical laws can cultivate the spirit of science, especially in the cultivation of rational thinking.

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