Construction and Practice of a Project-Based Teaching Model for Junior High School Physics Integrating Excellent Traditional Chinese Sci-Tech Culture

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Abstract. In response to the requirement of fully reflecting excellent traditional Chinese culture in teaching as stipulated in the Compulsory Education Physics Curriculum Standards, this paper addresses the problems existing in current junior high school physics teaching, such as formalized utilization of cultural resources and superficial cultural transmission, and constructs a project-based teaching model integrating excellent traditional Chinese sci-tech culture. Taking real scenarios as the carrier, this model consists of four progressive stages: project initiation, implementation, presentation, and evaluation. Through links such as theme design, group cooperation, experimental inquiry, and achievement presentation, it promotes the in-depth integration of physical knowledge and traditional sci-tech culture. Taking the teaching of "lever" in Grade 8 of the People's Education Press version as an example, an inquiry activity based on the traditional tool 桔槔 (Jiegao, a traditional Chinese water-lifting device) is designed to guide students to understand the principle of leverage while experiencing the wisdom and creativity of ancient working people, thereby enhancing cultural identity and improving scientific and cultural literacy. The research also points out that there are still problems in current practice, such as unsystematic resource sorting and insufficient design of interdisciplinary tasks, and proposes corresponding improvement directions, providing a feasible path for the organic integration of traditional sci-tech culture and subject knowledge in junior high school physics teaching.

Keywords: Excellent traditional Chinese sci-tech culture, Junior high school physics, Project-based teaching

1. Introduction

The Compulsory Education Physics Curriculum Standards issued by the Ministry of Education in 2021 states: "Organically integrate major thematic education such as socialist advanced culture, revolutionary culture, excellent traditional Chinese culture, national security, and life safety and health into the curriculum to enhance the ideological nature of the curriculum." [1] As an important part of excellent traditional Chinese culture, integrating excellent traditional Chinese sci-tech culture into physics courses is not only an inevitable requirement for implementing national policies but also an important embodiment of the educational value of physics. However, in the current junior high school physics curriculum, insufficient attention is paid to the integration of traditional sci-tech culture: first, formalization—its integration with physics mostly stays at the level of phenomenon explanation and application examples, ignoring the educational value and literacy feedback carried by physics [2]; second, superficiality—teachers focus on knowledge indoctrination and repetition, lacking in-depth excavation and creative application of excellent traditional Chinese sci-tech cultural resources [3]. Project-based teaching emphasizes enabling students to construct knowledge in real scenarios through problem-driven learning, collaborative learning, inquiry-based practice, etc [4]. On the one hand, problem-oriented learning can transform cultural elements from superficial examples into core inquiries, prompting students to independently construct physical knowledge and cultural cognition in the process of solving real scenario tasks, thereby solving the problem of formalized integration. On the other hand, through inquiry-based practice and collaborative learning, students learn in the process of "doing" and think in the process of "collaborating", solving the deficiency of superficial integration in the process of in-depth exploration and understanding of the physical principles behind cultural resources. Based on this, this study constructs a physics project-based teaching model integrating excellent traditional Chinese sci-tech culture, promoting students to form cultural identity and physical concepts in model restoration and principle explanation, and cultivating innovative talents with both scientific spirit and cultural literacy.

2. Overview of excellent traditional Chinese sci-tech culture and project-based teaching

Excellent traditional Chinese sci-tech culture is an important part of Chinese civilization, which can be systematically elaborated from three levels: material, institutional, and spiritual. Its multi-level structure has a high degree of compatibility with project-based teaching.

2.1. Connotation of excellent traditional Chinese sci-tech culture

As an important component of Chinese civilization, excellent traditional Chinese sci-tech culture can be explained from three dimensions: material, institutional, and spiritual. The material level is represented by artifacts such as the Armillary Sphere, Jiegao, and Water Clock, which embody the wisdom of ancient people and are the concrete manifestation of the scientific and technological level and physical knowledge at that time. The institutional level focuses on astronomical observation institutions and weights and measures standards, forming a complete knowledge system and social system to ensure the systematic research, effective application, and cultural inheritance of knowledge. The spiritual level contains philosophical concepts and exploration spirits such as "harmony between man and nature" and "investigating things to gain knowledge". Its pursuit of truth and exploration of natural laws are the fundamental driving forces for scientific and technological creation. These three aspects are interdependent, jointly constructing a system of excellent traditional Chinese sci-tech culture that connects the past and the present.

2.2. Project-based teaching

The explanation of "project" in the Modern Chinese Dictionary is "a category into which things are divided". Extended to teaching, this concept means dividing the knowledge content that students need to learn into several tasks that need to be discussed and solved, allowing students to independently construct strategies and paths for problem-solving with tasks and seek answers to problems in practice [4]. Project-based teaching is a concept developed from "Project-based

Learning (PBL)", and its main characteristics are enabling students to construct knowledge in real scenarios through problem-driven learning, collaborative learning, inquiry-based practice, etc [3].

2.3. Feasibility of integrating excellent traditional Chinese sci-tech culture with project-based teaching

Excellent traditional Chinese sci-tech culture and project-based teaching are deeply compatible in structure and core. Structurally, its material culture (such as the Armillary Sphere and Water Clock) provides real inquiry and practice carriers for project-based teaching, meeting the requirements of "real scenarios + hands-on practice". The systematic knowledge and collaborative models of institutional culture (such as astronomical institutions and weights and measures systems) provide method references for students' "collaborative learning + standardized inquiry". In terms of core, the problem-driven exploration spirit of "investigating things to gain knowledge" is logically consistent with the "problem-driven" principle of project-based teaching. This integration can simultaneously deepen the cultivation of scientific and technological literacy and cultural inheritance, enabling students to recognize traditional scientific and technological wisdom and making ancient philosophy empower contemporary education, which has high feasibility.

3. Construction of a project-based teaching model for junior high school physics integrating excellent traditional Chinese sci-tech culture

The project-based teaching model for junior high school physics integrating excellent traditional Chinese sci-tech culture is an innovative model that achieves educational goals through two paths: cultural infiltration and practical construction [5,6].

This teaching model is implemented in four progressive steps: the bottom layer "project initiation" is guided by excellent traditional Chinese sci-tech culture, laying the foundation for cultural infiltration through theme design, group formation, and plan formulation; the middle layer "project implementation" focuses on the integration of culture and knowledge, deepening cognition through experimental inquiry and subject integration; the third layer "project presentation and evaluation" strengthens cultural identity through achievement inspection and model replication; the whole process relies on the "improvement - reflection - summary" mechanism to optimize practice.

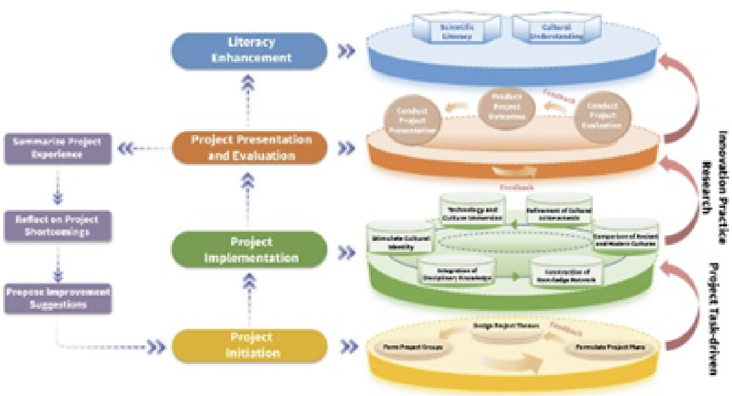


Figure 1. Project-based teaching model for junior high school physics integrating excellent traditional Chinese sci-tech culture

4. Application practice of the project-based teaching model for junior high school physics integrating excellent traditional Chinese sci-tech culture

Taking the teaching of the "lever" section in Grade 8 physics of the People's Education Press version as an example, the specific application and practice model of the project-based teaching integrating excellent traditional Chinese sci-tech culture in junior high school physics classrooms are shown below.

4.1. Designing project themes

4.1.1. Situation introduction and role division

Teachers first start with real-life scenarios and put forward guiding questions: "What tools did ancient people use to save effort when facing 'powerlessness' such as lifting water, moving stones, and hoisting in production and life such as farming, irrigation, and construction?" Combining students' existing historical and life experience, initial discussions are triggered. Subsequently, teachers play the short video Jiegao: The Labor-Saving Wisdom of Ancient People, showing its application scenario in agricultural water lifting during the Spring and Autumn Period, and analyze the working mechanism of Jiegao with the help of a schematic diagram marked with fulcrum, force arm, counterweight, and water bucket (Figure 2). Students can not only intuitively understand the physical principles of "heavy at the back and light at the front" and "using stones to balance water" but also feel the practicality and ingenuity of ancient sci-tech culture, establishing the connection between traditional wisdom and modern mechanics.

On this basis, teachers further ask: "Why can Jiegao save effort? What common machinery is it similar to?" to guide students to associate the concept of "lever" and encourage them to compare with daily tools such as crowbars and seesaws, naturally transitioning to the initial cognition of the lever principle. Finally, students are divided into groups for role-playing: "ancient engineers" analyze the structural advantages, application scenarios, and social value of Jiegao at that time; "modern technology consultants" draw on its labor-saving ideas to design improved water-lifting tool schemes for current scenarios such as water-saving irrigation and water supply in disaster areas. By designing improved tools based on the principle of Jiegao, the integration of ancient and modern thinking is promoted, laying the foundation for in-depth exploration later.

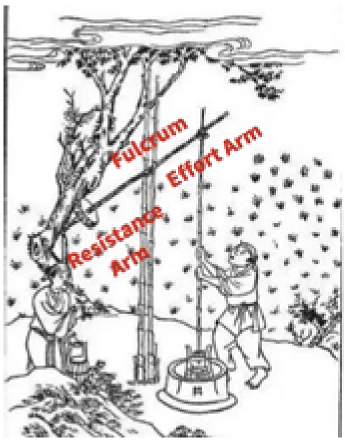


Figure 2. Water-lifting tool designed based on the principle of Jiegao

4.1.2. Core question inquiry and sub-question chain

In the core question inquiry link, teachers first guide students to observe physical models or structural images of Jiegao, put forward the core question "Why can Jiegao save effort when lifting water", and guide them to focus on the physical essence of the lever principle. Around this, teachers design three progressive sub-questions to build a cognitive ladder: "How does the crossbar structure of Jiegao achieve labor saving" guides the analysis of functions, identification of lever elements and action mechanisms; "How does the different position of the fulcrum affect the labor-saving effect" promotes the transition from qualitative understanding to quantitative exploration of variable relationships; "Can similar labor-saving structures to Jiegao be found in modern machinery" promotes the transfer and application of principles. Through question scaffolding, students experience a complete thinking process from intuitive observation to theoretical analysis, and from abstract induction to practical application, deepening their understanding of the lever principle and its practical value in active exploration.

4.1.3. Theme generation and achievement presentation

Combining the knowledge of this course, teachers determine the project theme Ancient Jiegao and Modern Levers - Exploring the "Way of Labor Saving", and set up a "time-space dialogue wall" (with pictures of ancient farm tools hanging on the left and a writing area on the right) to connect the previous scenarios and core tasks.

Figure 3. Teaching process development

4.2. Forming project groups and formulating plans

This part first investigates students' interests through questionnaires or interviews to determine the project direction; then groups students according to their interests and strengths, formulates project plans, refines task division, and conducts overall planning to lay the foundation for subsequent research; finally, improves the closed loop through project interest feedback to promote the integration of excellent traditional Chinese sci-tech culture (Figure 4).

4.2.1. Student interest survey

Teachers design questionnaires to investigate students' interests (including dimensions such as "connection with life experience" and "cognition of key labor-saving factors", see Table 1), distribute and collect them before class, and adjust teaching according to the results (for example, 75% of students believe that "ingenious structure" is the key to labor saving, so the teaching of lever structure can be strengthened).

Table 1. Questionnaire on labor-saving tools in rural areas

Questions	Options
Have you ever seen a rural hand pump or seesaw? (Connecting with life experience)	Yes/No
What do you think is the key to saving effort?	Light materials/Ingenious structure/Large force
……	……

4.2.2. Group formation and plan formulation

① Role assignment adopts the principle of "students' independent choice + teachers' fine-tuning" to ensure full participation of all students.

② Teachers reasonably arrange time and design a schedule (example table).

Design intention: Divide labor and cooperate according to the strengths of different students. For example, students with strong hands-on ability can make models; the time arrangement for completing tasks should fully consider the time nodes to avoid delays.

Figure 4. Plan explanation

Table 2. Role assignment

Roles	Responsibilities	Ability Training Objectives
Cultural Researcher	Consulting ancient books such as Tiangong Kaiwu (Exploitation of the Works of Nature)	Information retrieval and cultural understanding
Physics Analyst	Experimental design and data analysis	Scientific inquiry and mathematical application
Model Designer	Making Jiegao models or improvement schemes	Hands-on practice and innovative thinking
Achievement Presenter	PPT production and achievement presentation	Language expression and team cooperation

Table 3. Task list

Stages	Time	Tasks	Forms of Achievements
Cultural Research	Days 1-3	Collecting historical data of Jiegao	Literature excerpts + PPT
Principle Exploration	Days 4-6	Completing lever experiments and recording data	Experimental reports + charts
Model Making	Days 7-9	Designing improved Jiegao	Physical objects/model drawings
Presentation Preparation	Day 10	Rehearsing reports	Demonstration slides + scripts

4.3. Project implementation

This part presents the circular interaction between culture and knowledge: Stage 1 stimulates identity through cultural integration and comparison, and sci-tech cultural infiltration; Stage 2 integrates subject knowledge through experimental inquiry; Stage 3 constructs knowledge networks through subject integration; Stage 4 compares ancient and modern cultures through knowledge networks; Stage 5 innovates designs and refines traditional sci-tech achievements through the cognition of ancient and modern cultures. Achievements are fed back to the previous links, and culture runs through the whole process to form a cycle, reflecting the interactive sublimation of the two (Figure 5).

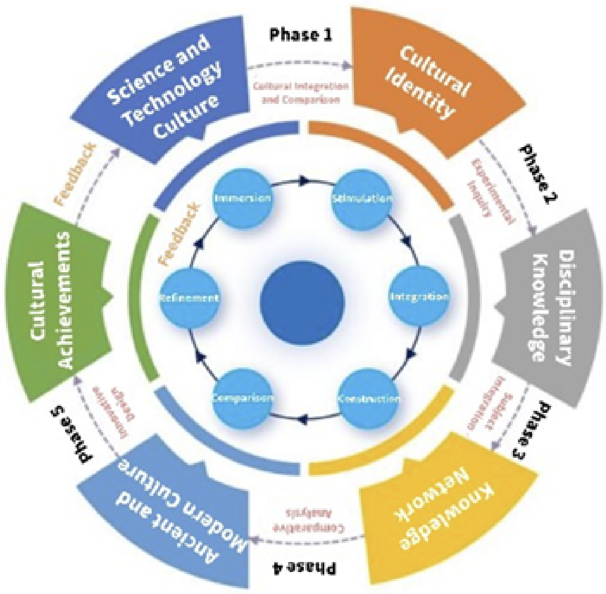


Figure 5. Circular process of interaction between culture and knowledge

4.3.1. Cultural integration and comparison

① Teachers distribute excerpts from Tiangong Kaiwu·Jiegao (vernacular version), and groups cooperate to study ancient books and complete the "Ancient and Modern Dialogue Table" (Table).

(Teachers should note that ancient book materials need to be accompanied by Pinyin and annotations, for example: 功倍 (gōng bèi) - achieving twice the result with half the effort. To help students better understand, additional assistance can be provided.)

② Teachers display the ancient Egyptian "Shaduf" (a water-lifting tool similar to Jiegao) for cultural comparison activities, and put forward the question: What are the common points of labor-saving tools in different civilizations? (Students from different groups can also study only one section of text and then exchange information with other groups for cultural comparison.)

Design intention: Enhance students' sense of identity with traditional culture through ancient book materials. Reflect interdisciplinary integration by combining historical and physical knowledge.

Table 4. Ancient descriptions and modern scientific explanations

Ancient Descriptions	Modern Scientific Explanations
"Hanging stones on the crossbar, achieving twice the result with half the effort"	Counterweights reduce human effort through lever balance
"The fulcrum is close to the water, and it can be lifted with a light shake"	The power arm is long, and the resistance arm is short
.....	......

4.3.2. Experimental inquiry

① Each group of students conducts experiments - simple lever exploration - based on cultural comparison activities and the problems raised.

② Teachers provide students with experimental materials: wooden rulers (marked with scales), brackets, strings, weights (50g each), and spring dynamometers.

③ Students independently design experimental steps, conduct group experimental operations, and record experimental data: first, fix the center of the wooden ruler on the bracket as the fulcrum. Then hang 2 weights (simulating resistance) 20cm away from the left end of the wooden ruler. Finally, pull the wooden ruler to the horizontal position with a dynamometer at different positions on the right side and record the force (example table).

④ Teachers ask: Why is it laborious when the fulcrum is close to the resistance point? What will happen if the fulcrum is moved to the leftmost end? Let students try it themselves, and then teachers give comments.

Design intention: Let students experience the function of levers through hands-on practice; cultivate students' scientific inquiry ability through data recording and analysis.

Table 5. Pressure records at different positions

Experimental Groups	Right Position (Distance from Fulcrum)	Dynamometer Reading (N)	Conclusion (Labor-Saving/Labor-Consuming)
Control Group	10cm	2.0	Labor-Consuming
Control Group	20cm	1.0	Equal-Arm
Control Group	30cm	0.67	Labor-Saving
Experimental Group	15cm	1.5	Labor-Saving

4.3.3. Subject integration

① Teachers guide students to calculate theoretical values using the formula ×=× and compare them with measured values:

1. Control Group (fulcrum at 30cm): 10cm→=2N (measured 2.0N).
2. Experimental Group (fulcrum at 25cm): 15cm→≈1.33N (measured 1.5N).

② Teachers guide students to analyze the causes of errors (such as friction and scale errors). (Teachers provide error analysis guidance.)

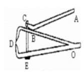
Design intention: Strengthen knowledge application ability through combination with mathematical formulas. Improve engineering thinking by solving practical problems (such as counterweight calculation). Lay a theoretical foundation for the following comparative analysis and innovative design.

4.3.4. Comparative analysis

After students deeply understand the lever principle through experimental inquiry, teachers then display the timeline of lever technology development and pictures of Jiegao, modern cranes, and nail clippers, guiding students to summarize lever types (labor-saving/labor-consuming/equal-arm) by comparing Jiegao with modern tools (Table 6).

Design intention: Understand the universality of scientific principles through comparison between ancient and modern times. Stimulate innovative thinking and encourage students to combine traditional wisdom with modern technology. Lay the foundation for the next stage of tasks.

Table 6. Timeline of lever technology development, jiegao, modern cranes, and nail clippers

Tools	Lever Types	Fulcrum Positions	Power Sources	Mechanical Advantages	Historical Evolution	Pictures
Jiegao	Labor-saving lever	Middle of the crossbar	Stone gravity	Saves 60%-70% effort	Spring and Autumn Period (770-476 BC)	
Crane	Labor-saving lever	Root of the jib	Hydraulic system	Magnifies power by 50-100 times	Modern industry (19th century to present)	
Nail Clipper	Labor-consuming lever	ABC lever: Point B; Blade: Point O	Human power + elastic potential energy	Saves 2-3 times effort + precise cutting	Industrial product in the early 20th century	

4.3.5. Innovative design

Based on students' summaries, teachers require students to add one modern element (such as pulleys and electronic scales) to Jiegao to design drawings and explain its working principle. (Teachers can also provide students with a "design thinking template": 1) Problem: What are the defects of traditional Jiegao? 2) Plan: Add ____ to Jiegao because ___. 3) Result: Using this technology can save ___% of effort and improve the working efficiency of Jiegao by ___%.)

Design intention: Give play to creativity, design innovative drawings, and deepen the understanding of levers; apply the lever principle to the design of mechanical devices and improve design ability.

4.4. Project presentation and evaluation

This part presents the process of project presentation and evaluation: Stage 1 produces and displays project achievements; Stage 2 conducts multi-dimensional evaluation and summative reflection. Each link optimizes achievements through feedback, forming a circular mechanism, realizing a complete process of "production - presentation - evaluation - reflection and improvement", and improving project achievements (Figure 6).

4.4.1. Achievement production and presentation

① Student groups make models according to design drawings and carry out presentations in two ways: physical objects and PPT (reported achievements include historical research, experimental data, innovative designs, etc.).

② Conduct inter-group interaction based on the problems raised by different student groups (such as: How did you calculate the mass of the counterweight in your design?).

Design intention: Exercise students' expression and adaptability through activities and interactions with them.

4.4.2. Multi-dimensional evaluation and summative reflection

① Design an evaluation form according to the project presentation and assessment (Table).

(Using an evaluation form is more in line with students' cognition.)

② Provide project feedback results through teacher comments and student reflections (let students carry out reflections by filling in reflection cards: My biggest gain in the experiment is……. In which aspects can it be further improved?).

Design intention: Adopt a multi-dimensional evaluation method (self-evaluation, peer evaluation, teacher evaluation) to promote students' self-reflection and improvement; clarify the direction of improvement from summary and feedback.

Table 7. Multi-dimensional evaluation (self-evaluation, peer evaluation, teacher evaluation)

Evaluation Dimensions	Evaluation Criteria (Examples)	Student Self-Evaluation (1-5 points)	Teacher Evaluation (1-5 points)
Cultural Understanding	Can accurately explain the historical significance of Jiegao		
Scientific Inquiry	Complete experimental data records and reasonable conclusions		
Innovative Practice	Practical design that can combine modern technology		
Team Cooperation	Clear division of labor among group members and full participation of all		

Figure 6. Plan explanation

5. Summary and reflection

The integrated model constructed in this study takes "Jiegao" as the carrier, guides students to understand physical principles and experience traditional wisdom through cultural infiltration and interdisciplinary practice, realizing the dual goals of physical concept formation and cultural inheritance.

However, there are still some problems in the current teaching practice: on the one hand, many teaching practices lack in-depth and systematic sorting and application of traditional sci-tech resources, only simply juxtaposing relevant cultural materials and knowledge points on the surface; on the other hand, in the design of interdisciplinary tasks, the grasp of subject logic and cultural logic is not in place, resulting in difficulties in achieving appropriate connection and progressive order between tasks. At the same time, it is necessary to build a multi-dimensional evaluation system represented by cultural interpretation and technical ethics to better reflect the development of students' literacy. In this regard, we can combine school-based curriculum development to build a database of examples based on excellent traditional sci-tech, carry out teachers' interdisciplinary learning, and strengthen cultural analysis ability and project design ability.

In view of the time limit of junior high school courses, we can explore a normalized integration model through paths such as "embedding short-cycle projects into unit teaching" and "carrying out thematic practice in after-school services". At the same time, such attempts can provide students with more high-quality and in-depth learning, and provide possible methods and approaches for the effective connection between traditional and modern education, so as to achieve the goal of cultivating students with comprehensive development literacy.

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