Journal of Contemporary Educational Research, 2026, Volume 10, Issue 5
http://ojs.bbwpublisher.com/index.php/JCER
Online ISSN: 2208-8474
Print ISSN: 2208-8466

The Construction Strategies for the Project-Based Learning Model in Physics Teaching

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Abstract: With the continuous deepening of education reform guided by core competencies, physics teaching is transforming from "knowledge imparting" to "ability cultivation." As a student-centered, inquiry-based teaching model driven by real-world problems, project-based learning (PBL) is highly consistent with the essence of physics—"derived from life and applied to life." It can effectively solve the pain points of traditional physics teaching and facilitate the cultivation of students' core competencies. Combined with physics teaching practice, this paper starts from the application significance of PBL in physics teaching and the existing problems in its current implementation, systematically discusses its construction strategies, provides theoretical references and practical paths for physics teaching reform, and promotes the improvement of physics teaching quality and the all-round development of students' comprehensive abilities.

Keywords: Physics teaching; Project-based learning; Core competencies; Construction strategies

Online publication: June 9, 2026

1. Application significance of project-based learning in physics teaching

Physics is a natural science based on observation and experimentation, whose main goal is to cultivate students' ability to explore laws and solve problems through inquiry. Project-based learning (PBL) provides an effective carrier for achieving this goal. It breaks through the single mode of "teacher explanation + exercise training" in traditional physics teaching, takes "learning by doing" as the core concept, enables students to complete real projects, integrate knowledge, and strengthen abilities during project implementation. Its application significance is mainly reflected in three aspects.

The *Compulsory Education Physics Curriculum Standards* clearly states that the core competencies of physics include four dimensions: physical conception, scientific thinking, scientific inquiry, and scientific attitude and responsibility. The implementation process of PBL can fully meet the cultivation needs of these four dimensions. In terms of physical conception, students integrate knowledge of mechanics, thermology, electromagnetism, and other modules to solve project problems, which promotes the structuring of knowledge and forms a preliminary understanding of the material world. In terms of scientific thinking, links such as variable control, data modeling, and scheme optimization in projects can effectively train students' logical reasoning and critical thinking. In terms of scientific inquiry, the whole process from problem raising to scheme implementation and result reflection allows students to experience the scientific research method of "conjecture—verification—revision" and improve their experimental inquiry ability. In terms of scientific attitude and responsibility, division of labor and communication in team cooperation, public expression in result display, and projects' attention to social issues can cultivate students' sense of cooperation and social responsibility [1–3].

2. Analysis of problems in the implementation of project-based learning in physics teaching

2.1. Unreasonable project design, deviating from disciplinary essence and students' reality

Project design is the guarantee for the success of PBL. However, there are two main problems in project design for some physics teachers at present. First, projects are separated from physics teaching content, emphasizing fun and practice while neglecting knowledge infiltration, turning projects into "handicraft making" or "activity experience" and deviating from the fundamental purpose of physics teaching. Second, the difficulty setting of projects is unreasonable—either too simple to be challenging and stimulate students' inquiry desire, or too difficult beyond students' current knowledge level and practical ability, making it hard for students to complete and causing frustration. In addition, some project themes lack authenticity and openness, mostly being preset "standard answer" tasks, which fail to leave room for students' independent inquiry and bold innovation, thus restricting the development of students' thinking.

2.2. Vague teacher role positioning, inadequate guidance and support

Project-based learning attaches importance to students' subjectivity, but this does not mean teachers can let go. Teachers are guides, organizers, and facilitators, and their role performance directly affects the implementation of projects. At present, some physics teachers have insufficient understanding of the concept of PBL and unclear role positioning. They regard PBL as a teaching method rather than a teaching model to be promoted, failing to recognize its fundamental purpose—letting students independently discover knowledge and solve problems in the inquiry process [4]. On the contrary, some teachers are too laissez-faire and lack effective guidance and support for students. When students encounter knowledge gaps, experimental difficulties, or team conflicts in inquiry activities, they cannot provide corresponding guidance, resulting in slow project progress, failure to complete projects, and negative impacts on students' learning experience and teaching effect.

2.3. Unbalanced student participation, formalized cooperative inquiry

Project-based learning is mostly carried out in group cooperation to cultivate students' teamwork ability, but some group cooperative inquiries are only formal at present. On the one hand, student participation is unbalanced—high-achieving and hands-on students act as "leaders" of the group and undertake most tasks, while underachieving and introverted students are in a state of "passive participation" or "non-participation," failing to get exercise and improvement in projects. On the other hand, unclear group division of labor and lack of effective communication and cooperation mechanisms lead to disjointed efforts among members, which not only affects project completion quality but also fails to achieve the goal of cultivating teamwork ability [5]. Some students lack the awareness and ability of independent inquiry, rely too much on teachers and other group members, and cannot actively participate in inquiry activities, which is contrary to the purpose of PBL.

2.4. Imperfect evaluation system, difficult to fully reflect teaching effect

A scientific and reasonable evaluation system is an important condition to ensure the effective development of PBL. At present, there are many deficiencies in the evaluation system of PBL in physics teaching. First, the evaluation orientation is single, mostly focusing on the final project results, ignoring students' inquiry process, thinking process, and changes in emotional attitudes during project implementation, failing to fully reflect students' learning gains and ability improvement. Second, the evaluation subject is single, mainly relying on teacher evaluation, lacking student self-evaluation, group mutual evaluation, and external evaluation (parents, engineers), making the evaluation results unobjective and comprehensive. Third, the evaluation criteria are vague without specific and operable evaluation indicators, making it difficult to quantify the evaluation of students' core competencies such as inquiry ability, cooperation ability, and innovation ability, resulting in a formalized evaluation that cannot play the role of diagnosis, motivation, and improvement [6,7].

3. Construction strategies of PBL model in physics teaching

3.1. Optimizing project design, based on disciplinary essence and students' reality

Project design is the foundation of PBL, which should follow the principles of disciplinary compatibility, closeness to students, authenticity, and openness, ensuring that projects can achieve physics teaching goals and stimulate students' learning interest. First, highlight disciplinary essence according to teaching content. Project themes should be designed around core physics knowledge points and teaching key and difficult points, ensuring each project has specific knowledge and ability goals without being separated from disciplinary content. For example, a project of making a simple generator can be designed in the electromagnetic induction unit to help students understand the principle of electromagnetic induction and the relationship between coil turns and current intensity during hands-on production; a project of designing anti-slip schemes for campus stairs can be designed in the friction unit to cultivate students' problem-solving ability, combined with influencing factors of friction [8]. Second, fit students' reality and set a reasonable difficulty. Design moderately challenging projects according to students' knowledge reserve, practical ability, and cognitive rules, enabling students to complete them through effort and stimulating their inquiry desire. Meanwhile, design hierarchical tasks to meet the needs of students at all levels so that every student can develop in projects. Third, attach importance to authenticity and openness to stimulate inquiry vitality. Project themes should come from real life, social hot spots, or cutting-edge science and technology, with authenticity and practicality, allowing students to experience the application value of physics knowledge; at the same time, leave enough space for students' independent inquiry, allow them to put forward different solutions, and encourage bold innovation without the restraint of "standard answers."

3.2. Clarifying teacher roles, strengthening guidance and support

Teachers should correctly position themselves as "guides, organizers, and facilitators" in PBL, neither being too laissez-faire nor excessively interfering with students' autonomy, but providing appropriate guidance and support during students' independent project implementation. First, introduce project themes with situation introduction methods (playing relevant videos, showing life phenomena, raising practical questions, etc.) before project launch, so that students understand the project purpose, task requirements, and implementation process; guide students to group, help them formulate project plans, determine division of labor, time, and resources, laying a foundation for project development. Second, provide support for the inquiry process. During project implementation, teachers regularly check the progress of each group; if students have knowledge gaps, provide necessary key concept explanations and relevant material support to prevent stagnation due to lack of knowledge; when students encounter experimental problems, guide them to analyze the causes and explore different solutions to exercise their inquiry ability; when team conflicts arise among students, organize communication skill discussions to guide students to learn to listen to and accept others' opinions, enhancing teamwork spirit [9–11]. Teachers should not interfere too much in students' inquiry process, leaving enough space for independent exploration so that students can gain experience and improve abilities in practical activities. Third, guide project summary. After project completion, guide students to summarize and reflect on the implementation process, sort out the knowledge learned, inquiry methods, and existing problems, so as to realize the systematization of knowledge and improvement of abilities; meanwhile, carry out result display and exchange activities for each group to report project results and inquiry experience, achieving mutual learning.

3.3. Improving participation mechanism, enhancing the effectiveness of cooperative inquiry

Group cooperative inquiry is the main part of PBL, requiring a sound participation mechanism to ensure every student can actively participate and cooperate with each other, improving the effect of cooperative inquiry. First, group reasonably for complementary advantages. Use heterogeneous grouping to divide students with different academic performance, hands-on ability, and personality characteristics into groups, ensuring complementary advantages within groups; clarify internal division of labor by setting positions such as group leader, experimenter, recorder, and reporter, so that every student can participate in project implementation and prevent free-riding [12]. Second, establish a communication and collaboration mechanism. Promote groups to set up regular communication systems, encourage members to share ideas, exchange experience, and solve problems, cultivate students' communication and expression abilities and teamwork awareness; guide students to learn to listen to others' opinions, respect others' ideas, and negotiate friendly to reach consensus when differences arise, so as to form joint efforts to promote project completion [13]. Third, attach importance to students' subject status and cultivate their independent inquiry ability. Let students look up materials, design schemes, operate hands-on, and summarize reflections by themselves, dare to put forward their own ideas and questions, and cultivate their independent inquiry awareness and innovative spirit. Provide targeted guidance to students with low participation to help them overcome the fear of difficulties and actively participate in inquiry activities, so that every student can get exercise and improvement in projects.

3.4. Constructing a diversified evaluation system, fully reflecting teaching effect

A scientific and reasonable evaluation system can effectively mobilize students' enthusiasm for participating in PBL and improve teaching effect, requiring a process-oriented, multi-subject, and full-coverage evaluation system. First, adhere to process orientation and enrich evaluation content. Evaluation should not only focus on whether the final project results are scientific, innovative and practical, but also on students' inquiry attitude, independent inquiry ability, cooperation ability, innovation ability, problem-solving ability and other aspects during project implementation, fully reflecting students' learning gains and ability improvement; attach importance to the evaluation of students' emotional attitudes and values, pay attention to the difficulties they encounter, efforts they make and progress they achieve in projects, give timely affirmation and encouragement, and stimulate students' learning motivation. Second, enrich evaluation subjects and realize diversified evaluation. Construct an evaluation system combining teacher evaluation, student self-evaluation, group mutual evaluation, and external evaluation. Teacher evaluation focuses on objectivity and professionalism, conducting comprehensive and fair evaluation of students' inquiry process and results; student self-evaluation allows students to reflect on their performance, gains and shortcomings in projects, cultivating self-reflection ability; group mutual evaluation enables students to evaluate each other, learn to appreciate others and find their advantages, improving evaluation ability and teamwork awareness; external evaluation can invite parents and professionals in the field of physics to evaluate project results, enhancing the objectivity and practicality of evaluation [14,15]. Third, determine evaluation criteria and realize operability. Formulate specific, clear and operable evaluation indicators, refine the cultivation requirements of core competencies into specific evaluation contents—for example, divide inquiry ability into indicators such as scheme design, experimental operation and data processing, and divide cooperation ability into indicators such as division of labor and collaboration, communication and expression, ensuring evaluation has rules to follow and basis to rely on, and preventing formalized evaluation.

4. Conclusion

Project-based learning is consistent with the essence of physics and has important application value in physics teaching. It can effectively strengthen knowledge internalization and transfer, stimulate students' learning motivation, and promote their all-round development. At present, the implementation of PBL in physics teaching still has problems such as unreasonable project design, unbalanced student participation, and imperfect evaluation systems, which restrict the full play of its teaching effect. In practice, front-line teachers should deeply understand the core concept of PBL, combine it with physics teaching reality and students' cognitive rules, continuously explore and optimize the implementation path of PBL, integrate it into the whole process of physics teaching, break the limitations of traditional teaching, and promote the in-depth advancement of physics teaching reform.

Disclosure statement

The author declares no conflict of interest.

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