

# The Applications of Problem-Based Learning Method in China's High Schools Science Teaching

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**Abstract.** In the current educational research, it is crucial to investigate how to reasonably and effectively use teaching methods to complete classroom teaching tasks. The problem-based learning method, which takes “problems” as the carrier, creates problem situations, raises problems, analyzes problems, and solves problems, which is more effective for implementing teaching. This paper reviews the applications of PBL in science teaching in China's senior high schools in recent years. The findings of the thesis are the following: 1) PBL teaching mode not only stimulates students' learning interest and initiative but also improve students' abilities to analyze and solve problems. 2) PBL teaching method improves students' language expressive abilities. 3) adopting PBL teaching method can improve students' critical thinking. Nevertheless, in the process of using PBL there are some shortcomings. From the perspective of most teachers, they are influenced by the traditional teaching mode so it is difficult for them to use PBL. Due to the limited teaching time, the assessment mode of PBL is too simple. Therefore, this study put forward some suggestions to improve PBL classes. First, teachers should look for the life phenomena related to the subject and find some teaching materials. Second, schools need to provide experimental equipment to encourage students to practice. Third, teachers should design questions with difficult coefficients to inspire students' thinking. This paper objectively summarizes the examples of PBL science teaching in Chinese high schools, analyzes the advantages and disadvantages, and puts forward suggestions for improvement, which is conducive to promoting teachers' thinking about PBL science teaching and promoting the applications of PBL teaching mode in Chinese high schools' science classes.

**Keywords:** PBL; Chinese science classes; Improvement methods.

## 1. Introduction

### 1.1 The definition of PBL

Generally speaking, Problem-Based Learning (PBL) is a problem-centered, student-centered educational method. It was first pioneered in 1969 by Howard Barrows, a professor of neurology in the United States at McMaster University in Canada. According to Wu, PBL emphasizes that learning should focus on specific and complex tasks and problems [1]. Students are encouraged to study independently and introspectively, and their advanced thinking ability is cultivated. Wu refers that the core concept of PBL is a learning method that assists students in acquiring knowledge in solving problems, including interdisciplinary learning content, group work, and student-centered learning [1].

### 1.2 The aims and significance of research

The traditional teaching method limits students' development in innovation and exploration. By contrast, the PBL cultivates the critical thinking of students based on problems. There are two aims of research: (1) to improve teachers' teaching methods; (2) to promote students' class participation and initiative in learning.

According to the definition of PBL, it is clear that PBL can improve not only teachers' teaching skills but also students' ability to discover and analyze problems, giving PBL theoretical and practical significance. From a theoretical standpoint, this paper analyzes the application of PBL in science teaching and serves as a reference for future PBL theoretical research. From a practical standpoint, this paper identifies and analyzes research gaps in science education and offers suggestions to teachers for designing PBL classes.

## **2. The background, origin, and development of PBL**

### **2.1 The origin of PBL**

PBL was first proposed by Barrows[2]. At that time, it was mainly used in medical teaching. He defined PBL as a learning way triggered by real problem situations, in which students define their own learning goals, collect information through continuous communication and cooperation, and then stimulate thinking through group discussions. Thus, it would help them finally solve problems and develop their skills and abilities in all aspects[2].

Later, after PBL was modified by Don woods, it achieved remarkable results. Since then, PBL had flourished and expanded in lots of fields [3]. Erdogan and senemoglu from the Middle East University of technology applied PBL to English teaching [4]. According to the final experimental data, it can be seen that PBL teaching has a significant impact on improving students' academic performance and self-regulation ability; Pilar and Jorge integrated complex problem situations into traditional teaching and implemented teaching in combination with PBL [5].

The research shows that this kind of mode can encourage students to acquire and recall knowledge. Nurhirani et al. discussed how to improve the scientific literacy of primary school students by developing the learning model of PBL [6].

### **2.2 The background of PBL**

In this era of information explosion, the popularity of the Internet has brought great convenience to humans, but it also weakens their abilities to think and exploring of things themselves. Therefore, critical thinking is very important in the process. It can help us make correct judgments while improving our ability [7]. PBL is a teaching method that can help us exercise critical thinking. Different from the cramming teaching method of traditional education in China, PBL no longer put too much focus on academic performance itself, but instead, it tries to encourage students to explore things that have never been questioned. Based on the generation of various problems, students will be more interested in learning. At the same time, group cooperation can also cultivate students' soft skills, such as social interaction and cooperation [7].

In the process of practicing PBL, its benefits have been confirmed. Kong , for the first time, studied the effect of PBL teaching method on improving the development of learners' critical thinking. The results showed that the critical thinking of nursing students after participating in the PBL teaching course for one year was improved, and it was also found that PBL mode was effective in the training of critical skills of nursing students [8]. Zhang applied the PBL teaching method to students majoring in biochemistry and found that PBL triggered students' interest in this complex subject. At the same time, they were better at analyzing a problem in depth and trying to solve it, thus cultivating their self-learning ability. Besides, the exchange and communication between teachers and students are closer [9].

After doing the questionnaire in mathematics class, it was found that most teachers had gotten rid of the previous "indoctrination" teaching and started to try the PBL method. As around 65.59% of the teachers imitate the PBL teaching method and often set questions to teach in class [10]. From the feedback, the vast majority (82.8%) of the students said that they could not only keep up with their teachers but also better help themselves understand the knowledge in the math class using PBL method. At the same time, 56.99% of the students thought that PBL promoted their interest in learning [10].

According to the results of practice and investigation, PBL can not only satisfy the purpose of cramming teaching methods for imparting knowledge to students but also enable them to equip themselves with independent thinking and the spirit of inquiry. Thus, it changes from passive learning to active learning. When PBL is conducted in the form of teams, students can improve their social and team cooperation skills and become more confident.

### 2.3 The development of PBL in China

Since ancient China, many educators have believed that thinking comes from doubts [11]. The teaching thought of Confucius in ancient times is also the rudiment of “problem-driven” [12]. After asking questions, students are allowed to think on their own. He believed that It is better not to enlighten students until they struggle with problems. It is the earliest problem-oriented heuristic education in China [13]. Tao Xingzhi, a modern educator, also explained the importance of questions. He believed that the reason why animals were not as intelligent as human beings were because they could not ask questions, while wise people were clever than fools [14]. With the deepening and refinement of the research, PBL has been gradually systematized, and many types of problem teaching methods have been derived. PBL is developed on this basis. The other two researchers formally proposed the concept of ‘problem driven’ in the article: mathematics teaching driven by problems [15]. Since then, PBL has been continuously practiced and gradually becoming popular.

## 3. Related applications of PBL in China’s science classes

**Table 1.** Related applications of PBL in China’s science class

Previous studies	Methods	Findings
Chi’ study [16]	<ol style="list-style-type: none"> <li>1. Documentation method</li> <li>2. Questionnaires method</li> <li>3. Observation method</li> </ol>	It can improve students' ability to analyze and solve problems independently and promote students' all-round development. But teachers lack the ability to design problems and guide students, and students lack the confidence to solve problems.
Yan’ study [17]	<ol style="list-style-type: none"> <li>1. Documentation method</li> <li>2. Questionnaires method</li> <li>3. Observation method</li> </ol>	Problem-based learning can stimulate students' interest in learning, enhance students' awareness of autonomous learning and improve students' ability to analyze and solve problems.
Guo’s study [18]	<ol style="list-style-type: none"> <li>1. Literature review</li> <li>2. Questionnaire method</li> <li>3. Case analysis</li> <li>4. Observation method</li> </ol>	The PBL model can improve students’ attention and cooperation awareness, but due to the influence of the traditional teaching mode, teachers cannot do a good job of role transformation, and the evaluation form of PBL model is too simple, the teaching conditions are limited, and this method cannot improve performance underachiever’s learning enthusiasm.
Zhang’ study [7]	<ol style="list-style-type: none"> <li>1. Interview method</li> <li>2. Literature review</li> <li>3. Questionnaire method</li> <li>4. Experimental method</li> </ol>	The multiple dimensions of students’ critical thinking tendencies have been significantly improved, but the practice time and resources are limited, and students’ lack of learning experience in group learning makes them unable to complete independent inquiry.

According to Table 1, it can be concluded that the usage of PBL teaching method can accelerate students’ abilities to analyze and solve problems independently, stimulate students’ interest in learning, promote students’ active learning, improve students’ critical thinking, and even boost students’ all-round development.

#### 4. A case study of PBL science class

Zhang has already done comparative experimental teaching, which was conducted in the new teaching of biology in the first year of high school [7]. After the experiment, a post-test was conducted on the critical thinking tendency of the students in the two classes to analyze whether the PBL teaching mode promoted the critical thinking tendency of the students. The following is a teaching design case based on PBL teaching mode --Taking “Energy Currency of Cells-Adenosine Triphosphate (ATP)” as an example:

The first step is to present and define the problem. The teacher asks students several questions: Why do fireflies glow? Where does the luminous energy come from? Then students need to find out the principle of firefly luminescence. The teacher and students decide to explore the experiment, and the students are divided into groups to experiment. The design intentions are to cultivate students' awareness of problem-solving and their abilities of communication and cooperation.

The second step is the simulation experiment. Students should think about the idea of experimental design, clarify the direction of the experiment, eliminate the influence of irrelevant variables according to the hypothesis, write the experimental process and predict the experimental phenomenon. Next, the teacher confirms the predicted results of the experiments designed by each group and shows the experimental videos and phenomena made by the scientists. Then, students need to conclude that ATP is the direct energy material for the light-emitting process and analyze the shortcomings of the experiment. The teacher indicates that ATP is not only the direct energy material for the process of firefly luminescence but also powers most life activities in cells. And put forward two questions: Does this experiment show that sugars and lipids cannot provide energy for life activities? What are their relationships with ATP? After thinking, students reply that organic matters can provide energy for life activities, but there are certain transformations. Organic matter must be oxidized and decomposed step by step in the cell to release energy. The design intentions are to train students' abilities to connect knowledge, think logically, and fully apply knowledge.

The third step is to construct the ATP model and display achievements. Teachers organize students to use the materials at hand to construct the structural model of ATP. According to the textbook information, students should use paper-cut, rubber paste, toothpick, circular needle, etc., to construct the ATP structure model and mark the chemical bonds of each part. And then present their models. Through the independent reading of textbooks, collating materials, and joint production of ATP business cards, students' abilities to acquire integrated information and master the knowledge they have learned are improved.

The fourth step is to find out how ATP provides energy for firefly luminescence. Students in each group are invited to read ATP-related materials independently and demonstrate the mutual transformation process of ATP and adenosine diphosphate (ADP) using the prepared model. Then write down the equation of ATP hydrolysis into ADP and ATP synthesis by ADP in combination with the equation of the firefly luminescence principle. The teacher raises a question: Is this a reversible reaction? And asks students to discuss and explain between the representatives of the group. After discussion and data analysis, students conclude that the reaction is not reversible. During this process, students not only understand the structure of ADP and the hydrolysis and synthesis process of ATP but also make a systematic analysis of the source and path of the energy.

Zhang indicated that compared with ordinary teaching, PBL teaching mode could improve students' critical thinking tendencies[7]. Therefore, we can also see that the PBL teaching mode has a certain application prospect in high school science classes. It can link the knowledge in books with practical problems, and gradually change from the traditional teacher as the leader to the student as the active explorer.

## 5. Strategies to improve PBL science classes

Based on the previous study, there are some gaps in the progress of experiments. Zhang holds the view that there are three shortcomings in the research: the teacher lacks practical experience, the experiment is only demonstrated by the teacher, and students have little willingness to communicate with group members[7].

Under the condition that most of the teachers often use the traditional teaching method in the class, it is difficult for them to design a perfect question circumstance with critical thinking. Therefore, the teacher fails to control the time and content in the process of the activities being created. Because only the teacher experiments the class, students seldom have the opportunity to do experiments by hand, which limits the development of the PBL methods and hinders the teaching progress from achieving the requirements of openness.

At the same time, most students have become accustomed to the teacher-led learning model, which makes them resistant to learning through their own exploration. Due to the lack of experience in group learning, students do not know how to discuss questions with the group. In addition, Yan argues that as the questions become more and more difficult, the polarization of students' learning progress may arise due to their distinct academic skills[17]. According to the barrier students meet, it is inevitable for teachers to intervene in group discussions.

Besides, the influence of the process of the experiment should be considered in the drawbacks of the research. Chi refers to the imprecise questions of the questionnaire, the short study time of the experiment(only one term), and the monotonous sample types of the research( the author used only one grade as a sample)[16].

To improve the teaching strategies, there are three suggestions can be provided. First, the teacher needs to accurate more and more teaching material from subject-related phenomena in daily life. Ding refers that teachers need to pay attention to the combination of curriculum teaching and real life[19]. Only when the curriculum can be combined with real life can the teacher design the problem situation close to the teaching content and students' life. Besides, the school ought to give material support to students. Doing experiments is an indispensable learning method for students who study science. Thus, the lab equipment must be provided. Different researchers will obtain distinct results in the same experiment. Students can analyze various results to get several conclusions, which is beneficial to them in developing critical thinking. Moreover, satisfactory learning is not to achieve overnight. When students face a dilemma in their studies, teachers should guide them patiently. X. Zhang believes that teachers can fully study knowledge, explore the questioning factors from it, put forward appropriate questions to enlighten students' thinking and guide students to actively engage in learning in teaching practice[20]. For example, in teaching students with distinct academic skills, the teacher should design questions at different levels to cultivate students' abilities to analyze and address problems. Therefore, suitable questions are positive for students in encouraging them to gain pleasure from group learning and ensuring all of them benefit from the PBL method.

## 6. Conclusion

This review paper comprehensively analyzes the application of the PBL teaching method in domestic science courses.

The results of this study are as follows: On the positive side, first of all, this learning mode can stimulate students' interest and initiative in learning, and it also improves students' abilities to analyze and solve problems. Secondly, due to the need for group cooperation and final results displayed in the PBL teaching process, the students' language expression ability is improved, and the dull classroom atmosphere when using traditional teaching methods is improved. Thirdly, using the PBL teaching method can improve students' critical thinking tendencies. However, from the perspective of the shortcomings of the experiments. On the one hand, teachers are affected by the traditional teaching mode, and it is difficult to use the PBL teaching method to design effective problem

scenarios. On the other hand, the use of the PBL teaching method is limited by teaching conditions. Also, due to the limited teaching time, the assessment mode of PBL is too simple.

Therefore, the further work of this research is to analyze and organize more literature materials and try to practice this teaching method for as long as possible and experience the changes brought to students after using this teaching method for a long time.

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