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Application of PBL Teaching Method in High School Mathematics Unit Teaching: A Case Study of "Spatial Vectors and Solid Geometry"

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ABSTRACT
This study, titled "Application of PBL Teaching Method in High School Mathematics Unit Teaching: A Case Study of 'Spatial Vectors and Solid Geometry'," analyzes the construction and implementation of the Problem-Based Learning (PBL) teaching model in high school mathematics. Through literature analysis, it explores the characteristics of PBL and its design and practice in the "Spatial Vectors and Solid Geometry" unit. The research indicates that the PBL teaching method, through problem-driven and situational design, can effectively enhance students' core mathematical competencies, including deep understanding of knowledge, problem-solving abilities, and collaboration skills. This teaching method also demonstrates strong adaptability and operability in practice. The findings suggest that PBL has significant value in promoting student development and advancing mathematics teaching reform, providing important references for future teaching.

KEYWORDS
PBL Teaching Method; High School Mathematics; Spatial Vectors

1 Introduction

1.1 Research Significance

1.1.1 Theoretical Significance

During the research process, it was found that although numerous papers discuss the PBL teaching method, most focus on its application in medical education. There is limited research on its application in high school teaching, particularly in high school mathematics. Few scholars have conducted specific and in-depth studies on the current state of PBL teaching design in this context. This study, from the perspective of teaching design, broadens the research field of the PBL teaching method, enriches the research on PBL teaching design theory, and encourages educators to adopt innovative educational concepts and methods.

1.1.2 Practical Significance

Throughout the practice of the PBL teaching method, students gradually establish a theoretical knowledge system through experiential learning. By engaging in independent exploration and collaborative communication, they gain a deeper understanding of the essence of knowledge and enhance their comprehensive abilities. This approach fosters students' analytical and problem-solving skills, fully leveraging their active participation in the learning process.

1.2 Research Content

By studying relevant domestic and international literature on the PBL teaching model, this research gains an in-depth understanding of the latest trends and developments in this teaching method. It constructs and analyzes high school mathematics classroom teaching designs under the PBL model, focusing on elucidating the connotation of the PBL teaching model based on its current development status globally. Discussing aspects of PBL educational theory, such as the rationale for problem formulation, the value of applying the PBL model in high school mathematics classrooms, and the theoretical foundations supporting this approach. Detailing the construction of the PBL teaching model in high school mathematics and illustrating the feasibility of implementing classroom teaching designs through specific units.

1.3 Key Issues to Be Addressed

The research identifies a scarcity of studies on the application of the PBL teaching method in high school education, with existing work primarily in preliminary stages of theoretical discussion and practical exploration. Building upon previous research, this study conducts both theoretical and practical mathematics, aiming to enrich the theoretical framework and provide investigations into the application of the PBL teaching method in high school practical guidance for educational practice.

2 Current Status of PBL Teaching Model Development Domestically and Internationally

2.1 Development of PBL in Medical Education

Problem-Based Learning (PBL) was first introduced in the 1960s by the Faculty of Medicine at McMaster University in Canada, aiming to shift away from the traditional teacher-centered knowledge transmission model. In medical education, PBL has evolved into a well-established system encompassing problem design, student grouping, teacher facilitation, and diversified assessment methods. The successful application of PBL in the medical field has laid a solid foundation for its adoption in other disciplines.

2.2 Research Trends and Theoretical Advancements

International research on PBL has gradually expanded from teaching practice to the construction of theoretical frameworks. For instance, in 1993, Schmidt proposed the Problem-Based Learning Environment Model, emphasizing students' proactivity and collaboration in the knowledge construction process[1].

2.3 Initial Exploration of PBL in China and Its Application in Basic Education

Initially, Chinese academia concentrated on exploring and implementing detailed applications and procedures of Problem-Based Learning (PBL) strategies in medical education. Recent studies have demonstrated that PBL methods significantly enhance the practical skills and teamwork efficiency of medical interns in clinical teaching environments. Recently, the practice of Project-Based Learning (PBL) in basic education has increasingly highlighted its unique value. The highly abstract and integrative knowledge domain of "spatial vectors and solid geometry" provides an ideal context for PBL pedagogy. It not only stimulates students' interest and ability in solving complex problems, but also effectively promotes a deep understanding of core concepts and the development of practical application skills[2].

3 Connotation and Characteristics of the PBL Teaching Model

3.1 Connotation of the PBL Teaching Model

The Problem-Based Learning (PBL) teaching model is a student-centered instructional approach driven by problem-solving. Its core involves presenting open-ended problems, placing students in "problem situations," and guiding them to complete learning tasks through collaboration and inquiry. Compared to traditional teaching models, PBL places greater emphasis on the authenticity and exploratory nature of the learning process[3].

3.2 Characteristics of the PBL Teaching Model

The central feature of PBL is "problem-driven" learning. Problems are typically derived from real-world contexts, characterized by complexity and openness, prompting students to engage in deep thinking and active exploration. PBL underscores the active role of students in the learning process, requiring them to participate proactively in problem analysis, information gathering, and solution design. Through collaborative group work, students engage in communication, discussion, and division of labor to solve problems collectively. This approach enhances students' communication skills and collaborative awareness, fostering the integration of diverse perspectives.

4 Application Value of the PBL Teaching Model in High School Mathematics Classrooms

4.1 Application Value of PBL in High School Mathematics Classrooms

4.1.1 Enhancing Students' Mathematical Core Literacy

The core objective of high school mathematics education is not merely the unidirectional transmission of knowledge but the cultivation of students' mathematical core literacy. This process emphasizes abstract thinking ability, logical reasoning, and the capacity to apply mathematical models to solve practical problems. In the "Spatial Vectors and Solid Geometry" module, we employ the PBL strategy by constructing real and challenging contextual problems, thereby enhancing students' mastery and application of mathematical abstract theories.

4.1.2 Stimulating Learning Interest and Intrinsic Motivation

The PBL teaching method constructs real-world problem situations related to students' daily lives and future careers,

significantly boosting their learning motivation and exploratory enthusiasm. This approach not only deepens students' understanding of theoretical knowledge but also hones their problem-solving skills, teamwork awareness, and critical thinking abilities, leading to more efficient achievement of educational objectives and promoting students' holistic development.

4.2 Theoretical Basis of PBL in High School Mathematics Teaching

4.2.1 Constructivist Learning Theory

Constructivist learning theory asserts that knowledge is not passively received but actively constructed by learners[4]. The PBL teaching method aligns with this theory, as students actively construct the knowledge structure of "Spatial Vectors and Solid Geometry" by solving real-world problems.

4.2.2 Social Constructivist Theory

The group collaboration emphasized in the PBL teaching method highlights the social nature of learning, which aligns closely with social constructivist theory. In teaching "Spatial Vectors and Solid Geometry," discussions and exchanges among students can trigger deeper thinking. For example, when solving the problem of "how to use vector methods to prove whether two lines intersect," group members can analyze the problem from different angles and supplement each other's insights, resulting in a more comprehensive solution[5].

5 Construction of the PBL Teaching Model in High School Mathematics and Feasibility of Classroom Teaching Design Implementation

5.1 Construction of the PBL Teaching Model in High School Mathematics

5.1.1 Core Concept of Problem-Driven Approach

The core of the Problem-Based Learning (PBL) teaching model lies in designing open-ended problems that stimulate students' learning interest and are closely aligned with teaching objectives. These problems guide students in in-depth exploration. For instance, the question "How can vectors describe and analyze geometric relationships in space?" can lead students to actively construct their knowledge system.

5.1.2 Refining Teaching Objectives

Under the framework of Problem-Based Learning (PBL), educational goals do not only focus on acquiring individual knowledge content but also emphasize the development of skills and the formation of values. The analysis of the "Spatial Vectors and Solid Geometry" topic can be broken down into the following dimensions: Learning Goals: To proficiently master the operation rules of spatial vectors and their geometric interpretations; to possess the ability to use vectors to solve basic problems in three-dimensional geometry. Developmental Goals: To enhance students' ability to analyze problems and construct models to solve them, fostering logical reasoning and abstract thinking. Through teamwork and solving practical problems, the aim to cultivate students' collaboration spirit and exploratory mindset.

5.2 Feasibility of Implementing PBL Teaching Model in Classroom Design

5.2.1 Classroom Design Example for the "Spatial Vectors and Solid Geometry" Unit

(1) Pre-class Preparation

Educational professionals need to analyze and refine concepts in depth. In the "Three-Dimensional Vectors and Solid Geometry" chapter, educators must carefully analyze the textbook content and break it down into a series of problem contexts closely tied to practical operations. These include basic spatial vector operations, such as dot product and its geometric significance, and problem construction driven by real-life scenarios. Students should read related textbooks and supplementary materials in advance to establish a solid theoretical foundation for participating in classroom discussions.

(2) Classroom Implementation

Phase 1: Pose the Problem

The teacher introduces the key points through a scenario. In PBL, scenario introduction becomes one of the core steps of course delivery. For example, in the "Spatial Vectors and Solid Geometry" chapter, teachers can plan and execute scenario introduction as follows:

Example 1: Drone Flight Path Planning Problem

At the beginning of the lesson, the teacher plays a video of a drone flying through city buildings, showing its flight path. Then the teacher asks, "If the drone needs to travel from point A to point B while avoiding obstacle C, how can its flight path be planned?"

Core Question: The teacher uses this scenario to introduce a mathematical problem: "How can spatial vectors be used to analyze the drone's optimal path?" Students need to apply their knowledge of spatial vectors (e.g., dot product to calculate angles, vector addition) to solve this real-world problem.

Theoretical Basis: This scenario design aligns with the core idea of constructivist learning theory[6], helping students actively construct knowledge through real-life situations. The problem is open-ended, encouraging students to compare and select the best solution among various path options.

Example 2: Building Projection Problem

Scenario Description: The teacher presents an image of a building's shadow under sunlight and asks, "If we know the direction of the sunlight, can we use mathematical principles to accurately calculate the length and position of the building's shadow?"

Core Question: In this teaching scenario, the teacher poses a mathematical challenge: "How can the principles of spatial vectors be used to calculate the projection of a three-dimensional object in a specific dimension?" Students should apply vector projection formulas and basic spatial geometry principles to solve this problem.

Theoretical Basis: According to social constructivist theory, the process of exploring projection calculation techniques in group discussions can deepen students' understanding of three-dimensional space and vector concepts, while also effectively promoting teamwork and communication skills.

Phase 2: Group Inquiry

Students are divided into groups to conduct autonomous investigations, focusing on specific topics. Team members collaborate by assigning roles: one person is responsible for data collection, another focuses on model construction, and the remaining members write the report. During this phase, educators monitor the groups and provide guidance as needed[7].

Phase 3: Presentation of Results

Each group presents its research findings. For example, by using vector models to calculate and determine the optimal flight path for a drone, and explaining the underlying mathematical principles. Educators evaluate each stage of the presentations, highlighting the advantages of each solution and discussing potential limitations.

5.2.2 Feasibility Analysis

The "Spatial Vectors and Solid Geometry" unit in high school mathematics textbooks contains clear knowledge points and rich application scenarios, making it easily adaptable to PBL teaching with problem-based contexts. The core concepts of the "Spatial Vectors and Solid Geometry" module are highly logical and operational. By using a problem-driven approach, students can better understand abstract concepts and improve their mathematical application skills.

6 Conclusion

The Problem-Based Learning (PBL) teaching method, with its problem-centered approach and student-centered advantages, creatively establishes a teaching framework that integrates group collaboration and self-driven learning. This paper takes the "Spatial Vectors and Solid Geometry" chapter as an example to thoroughly analyze and evaluate the application value and feasibility of the PBL model in high school mathematics teaching. In exploring the teaching practice of this chapter, we use real-life applications such as drone path planning as guiding cases. This learning method not only deepens students' understanding of core concepts in spatial vectors and solid geometry but also encourages them to apply theoretical knowledge to practice, effectively solving complex real-world problems.

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