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Case Analysis of Junior Middle School Mathematics Teaching Through Project-Based Learning

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Abstract: In recent years, the growing disconnect between traditional education and labor market demands has become increasingly evident. Conventional classroom teaching methods are no longer adequate to meet the needs of modern talent development. As a result, project-based learning, a new teaching mode distinct from traditional classroom teaching, has received extensive attention in the education field. Based on the constructivist learning theory and the mastery learning theory, this paper employs a literature review to conduct an in-depth analysis of two "interdisciplinary - project-based" cases in junior high school mathematics teaching. It also explores their implementation status, main characteristics and existing problems. This research reveals that project-based learning can effectively promote the integration of interdisciplinary knowledge, enhance students' mathematical literacy, autonomous learning ability and comprehensive practical ability. However, it also faces practical difficulties such as a shortage of teachers, large individual differences among students and limited hardware facilities. Furthermore, the current evaluation mechanism is mainly based on mutual evaluation between teachers and students, lacking diversity and scientificity. Meanwhile, issues such as procedural design and unreasonable time arrangement in task design are noted.

Keywords: Project-based learning, mathematics teaching, case analysis, interdisciplinary

1. Introduction

Against the backdrop of the rapidly developing knowledge economy, there is a growing societal demand for talents with practical problem-solving skills and well-rounded competencies [1]. This trend aligns closely with the core competencies required for 21st-century learners—including mathematical literacy, critical thinking, data literacy, and problem-solving abilities—among which mathematics education plays an irreplaceable role in cultivating these essential capacities [2].

Project-based learning (PBL), as an instructional approach that engages students in solving real-world problems within authentic contexts, has garnered widespread attention in the educational field [3]. Abe's research demonstrated that PBL can effectively enhance students' mathematical performance and comprehensive competencies [4]. Furthermore, Wang Yu has also indicated that PBL positively contributes to the development of students' core attainment [5]. However, some scholars have found that not all instructional scenarios achieve satisfactory outcomes when implementing PBL, as its application in interdisciplinary teaching may potentially compromise final project presentations and assessments [6].

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Based on the aforementioned theoretical findings, this study combines case analysis with literature research to systematically investigate the implementation status of project-based learning in secondary school mathematics education and its distinctive characteristics. This study aims to provide educators and relevant researchers with practical references and improvement recommendations.

2. Theoretical basis

Project-based learning is essentially a constructive teaching paradigm. Its core lies in that teachers design learning tasks through projects, guide students to conduct inquiry-based learning in real situations, and ultimately achieve problem-solving and outcome construction [7]. It should be noted that the theoretical basis of project-based learning mainly stems from constructivist learning theory and mastery learning theory.

2.1. Constructivist learning theory

Constructivist learning theory holds that learning is a process in which an individual actively processes information based on existing experience and constructs a knowledge system [8]. This theory emphasizes that due to the differences in learners' knowledge backgrounds, individuals will construct knowledge in different ways for the same cognitive object. As a result, their learning outcomes present subjective characteristics. As a systematic learning theory, constructivism has significant guiding significance for teaching practice. Its core viewpoints can be summarized as follows.

Firstly, knowledge is not absolute truth but has relative correctness and continuously evolves along with social progress. Secondly, learning is not the passive acceptance of knowledge, but an active process of meaning construction by individuals. Secondly, teaching should focus on cultivating students' subjectivity and creativity [9]. These viewpoints are intrinsically consistent with the concept of project-based learning. Project-based learning also adheres to the educational concept of "student-centeredness", promoting the development of students' rational thinking and problem-solving abilities through the creation of interactive situations by teachers. It can be seen from this that project-based learning is essentially an implementation path of knowledge construction, and the constructivist learning theory provides a solid theoretical support for project-based learning.

2.2. Mastering learning theory

Mastering learning theory is another theoretical basis of project-based learning. In the 1960s, in response to the educational quality issues exposed during the "Restore Foundation" education movement in the United States, the renowned educational psychologist Bloom proposed the Mastery learning theory. This theory points out that under the condition of providing ideal educational conditions and sufficient study time, the vast majority of students can fully master the prescribed learning content and achieve the expected learning goals [10]. Bloom's mastery learning theory emphasizes that teaching should fully consider the individual differences of students. Before instruction begins, teachers must establish specific learning objectives based on the unique qualities of each student and the course's learning objectives. They must then create matching lesson plans and evaluation strategies. Based on this, mastering learning theories and project-based learning have inherent commonalities. Teachers must also create project activities that take into account students' cognitive development stages, prior knowledge, and experience when implementing project-based learning. This will help students achieve meaningful learning outcomes., ensuring that students can obtain substantive learning outcomes.

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3. Application of project learning in mathematics teaching: case analysis

3.1. Background

"Interdisciplinary - project-based" is an innovative form of teaching organization that can promote the development of students' core literacy. Although the study of a single discipline is conducive to the vertical deepening of professional knowledge, the integration of multiple disciplines can better promote the transformation of students from the core literacy of a single discipline to comprehensive scientific literacy, and help students establish the connection between disciplinary knowledge and real life [11]. Based on this, this study selected two teaching cases that combine interdisciplinary and project-based learning for analysis. Case A, "Physical Activity and Heart Rate", is based on the concepts of linear functions and graph knowledge that students have already mastered. It integrates mathematics with physical education and biology to explore the laws governing the changes in center rate during exercise. Case B, "Protecting the Banyan Tree and Locating Its Area", centers on the theme of "Tree Protection on Campus" and designs pre-class practical assignments based on the mathematics inquiry activity in Chapter 7 of the People's Education Edition of Grade 7, Lower Semester [12].

3.2. Case study

3.2.1. Case A: sports and heart rate

This case is based on the knowledge level and physical and mental development characteristics of the learners. With linear functions as the core teaching content, it integrates the knowledge of mathematics, biology and physics, aiming to achieve the learning goals while cultivating students' scientific literacy and comprehensive ability. Project implementation is divided into three stages.

The first stage is to determine the scheme. The teacher first introduced the project background to the students, guided them to put forward hypotheses around the relationship between "physical exercise and heart rate", and provided reference directions to expand the dimension of thinking. After determining the conjecture, the students discussed the experimental plan in groups and selected a certain factor affecting heart rate as the independent variable.

In the second phase of implementation plan, each group collected data according to the established plan and formulated a scientific method for heart rate measurement. The teacher followed up on the progress of the experiment throughout and guided the students to adjust the research methods in a timely manner.

In the third stage of evaluation scheme, students observed and analyzed the experimental data. Under the guidance of teachers, they used computer software to establish function models and draw fitting curves.

Finally, each group reported their research results, allowing teachers to facilitate reflections on the feasibility of the experimental design, the scientific nature of data collection, and other dimensions to deepen their understanding of the knowledge.

The project is designed for implementers to address 12 key issues related to sexual health, specifically focusing on the changes in heart rate. This includes exploring the maximum heart rate range and seven core problems associated with it. These questions not only relate to subject knowledge but also expand the project's connotation, enabling the thematic content to break through the limitations of linear functions and mathematics, physical education, and biology, thereby meeting the teaching needs of all stages of compulsory education.

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3.2.2. Case B: protecting the big banyan tree and locating the area

This case adopts a teaching method that combines pre-class assignments with in-class exhibitions and evaluations. The pre-class assignment section consists of three progressive tasks.

Firstly, students were required to locate the banyan tree in groups within the campus and determined its position coordinates by establishing a plane rectangular coordinate system. The teacher then issued guiding question chains in advance through the task group to assist students in completing the tasks. Secondly, students used measuring tools to calculate the area occupied by the banyan trees on the spot. Finally, based on the biological characteristics of the banyan tree such as its growth period and expanded area, students designed a plan for the best planting location and protection range of the banyan tree that met the requirements of the school's Arbor Day. During the classroom exhibition and evaluation session, students systematically sorted out the project achievements and completed the project proposal writing. Through a combination of group mutual evaluation and teacher evaluation, the achievements were evaluated in multiple dimensions. Finally, students were required to write personal learning reflections.

The teaching innovation of this case is reflected in the deep integration of information technology means, such as implementing online progress monitoring and building an interactive platform between teachers and students. Through the group exploration mode driven by the problem chain, it effectively stimulates students' autonomy and simultaneously promotes teachers to carry out interdisciplinary teaching research activities.

3.3. Discussion

Both of the above two cases emphasize the autonomy of students' learning during the design process. Whether it is the guiding assistance provided by the teacher in Case A or the learning approach driven by the problem chain in case B, they both reflect the importance attached to the cultivation of students' autonomous learning ability.

Case A has achieved remarkable results in practical teaching applications. The results of the student project-based teaching feedback questionnaire and teacher interviews show that this project has effectively improved students' thinking quality and comprehensive ability. However, the interview also points out that the project needs to reasonably set time limits to optimize the efficiency of classroom management and ensure the orderly progress of the teaching process. Furthermore, although the teaching value of this project has been recognized by teachers, due to practical factors such as insufficient teaching staff, significant differences in students' foundations, and limited school hardware conditions, mathematics teachers still rarely involve interdisciplinary integration or adopt project-based teaching methods when preparing lessons at present [11]. Case B guides students to apply the mathematical knowledge learned in class to real-life situations, embodying the concept of "big concept" teaching.

Although Case B has not entered the actual teaching stage, it innovatively divides the learning objectives into three levels. The first level focuses on the mastery of basic mathematical concepts, such as the establishment of coordinate systems; The second level emphasizes the application of spatial concepts and the ability to solve practical problems, such as the calculation method of the protected area of banyan trees. The third level focuses on students' comprehensive ability to deal with complex real-world problems [12]. It is worth noting that this case adopts the follow-up method of online teacher supervision, which may affect the learning effect due to the insufficient efficiency of interaction between teachers and students.

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4. Practical implications of project-based learning

At present, project-based learning has achieved remarkable results in reflecting students' subjectivity and promoting active learning, but there are still several limitations that need to be improved urgently.

From the perspective of project design, some projects overly emphasize the process-oriented task design and fail to fully consider the complex factors in the actual teaching situation. For instance, the activity design fails to effectively take into account the differentiated needs of students at different learning levels, or there are problems such as overly long task duration, excessive emphasis on students' autonomy while weakening the guiding role of teachers [7]. In terms of the evaluation mechanism, the current evaluation method mainly relies on mutual evaluation between teachers and students. Although it helps promote teaching reflection, there is still room for improvement in the diversity of evaluation subjects and the scientific nature of the evaluation system. It is suggested to introduce multiple evaluation subjects such as domain experts and parents to assess the comprehensive ability development of students more comprehensively [13].

To optimize the implementation effect of project-based learning, it is suggested that in the design stage focus on several key aspects. First, attention should be paid to the actual needs of students, improving the learning efficiency through the application of information technology under the guidance of teachers. Additionally, it is crucial to strengthen the risk assessment before the project implementation, systematically predicting possible problems. This approach will enhance the organizational efficiency of teaching activities and ensure a more rational arrangement of tasks.

5. Conclusion

This article, through the analysis of two "interdisciplinary - project-based" teaching cases, indicates that project-based learning can promote the integration of interdisciplinary knowledge and the development of students' core literacy. Case A adopts a combination of teachers' questioning guidance and students' independent exploration, which not only cultivates students' practical innovation ability but also stimulates their interest in interdisciplinary learning. Case B enhances students' mathematical abstraction and geometric intuition abilities by connecting subject knowledge with real life and through activities such as observing the location of banyan trees on campus and drawing maps. Research has found that project-based learning can not only break through disciplinary boundaries and enhance the ability of knowledge transfer, but also effectively improve students' learning autonomy. However, combined with existing studies, it is evident that the current implementation of project-based learning encounters practical challenges such as insufficient teachers, large individual differences among students, and limited hardware resources. The scientific rigor of its evaluation mechanism and the rationality of task design require enhancement.

However, there still exists some limitations. For instance, the literature review does not fully incorporate the latest domestic and international research on PBL. Future studies should address these limitations by expanding the literature base and investigating a wider range of disciplines and educational stages.

With the rapid development of the era of artificial intelligence and the continuous deepening of educational reform, future research will focus on exploring the deep integration of project-based learning and artificial intelligence technology, providing support for building a more intelligent and rational educational model.

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