



Problem-Based Learning in Chinese K-9 Mathematics Education

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Abstract. With the implementation of education in China, the education sector pays more attention to how to optimize teaching methods to improve the quality of classroom teaching. Problem-Based Learning (PBL) is in line with the concept of “student-centered” education and the basic requirements of high-quality education. This teaching model aims to develop students’ creative thinking, logical thinking, cooperation, and communication competence. This literature review intends to explore the effectiveness of PBL implemented with students from grades 1 to 9 in mathematics classrooms. This review also shows the advantages and intended problems of using PBL in Chinese primary and secondary school mathematics classrooms, which provides some constructive advice for future educational implications.

Keywords: Mathematics education · Problem-Based Learning · K-9 · Primary school · Secondary school

1 Introduction

PBL is an educational approach that aims to develop students’ problem-solving skills. Students’ mathematical thinking is constructed through problem-solving in specific contexts. The ideal classroom is one in which ‘problems’ and ‘activities’ complement each other [1]. In this case, a series of well-designed, richly varied, high-quality, and effective teaching and learning problems are used throughout the teaching and learning process to develop learners’ cognitive abilities and higher-order thinking skills in problem-solving [1]. It can be seen that problem-oriented classroom learning contexts can facilitate students’ learning.

Recently, the traditional state of the teacher-instructed mathematics teaching model in China may have some problems that need to be solved. With the development of technology and the renewal of people’s philosophy in education, the traditional mode of teaching mathematics needs to be changed. At present, the PBL model is not maturely applied in the teaching of mathematics in primary and secondary schools in China. We conducted this systematic literature review to examine specific research that has revealed

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the effectiveness of PBL for student learning of mathematics from primary to middle grades (K-9; ages 7–15), as this is elementary education in China, which has a large influence on students.

This paper intends to apply these findings to the teaching of mathematics in China. This paper has divided the article into three sections. First, it discusses the application of PBL in Chinese primary and secondary schools. Second, it describes the advantages and problems of the PBL teaching model using a literature review method. Third, this paper provides suggestions for responses based on the study.

2 PBL in China

2.1 Previous Research in PBL

PBL is also known as Project-Based Learning. It was originally proposed by John Dewey, an American educator, and psychologist, in 1938. After that, Barrows, a professor of neurology in the United States, tried to apply it for the first time at McMaster University in Canada in 1996. Till now, it has become a more popular teaching method internationally. The PBL teaching mode was introduced in China in 1986 when Shanghai Jiao Tong University School of Medicine and Xi'an Jiao tong University Health Science Center have first implemented the PBL teaching method in China. At present, the PBL teaching mode has gone beyond the medical field, and scholars have also applied it to many aspects such as subject teaching, computer science, and technology, foreign language, writing, etc. There is still much room for development regarding its theoretical construction and practical exploration.

There is no unified concept of PBL after its introduction into domestic translation, which is generally called problem-based learning and problem-oriented learning. The expressions of PBL vary among domestic and foreign researchers, but its essential connotation is quite consistent. After a preliminary summary of the literature, it is roughly divided into three perspectives.

PBL can also be regarded as a teaching strategy. Finkle and Torp hold the view that PBL is a learning strategy that promotes students' active and positive learning. The most authoritative Wikipedia online encyclopedia in the United States defines PBL as a student-centered instructional strategy in which students collaborate to solve problems and reflect on their learning experiences; a large number of scholars engaged in empirical research also prefer the "instructional strategy theory", defining PBL as PBL is defined as "a strategy applied to part of the curriculum".

PBL as a teaching style, the original creator of PBL, Barrows, a professor at Southern Illinois University, and his colleague, Dr. Kelson defined PBL as both a curriculum and a learning style [2]. Feletti argued that "PBL is a curriculum." According to Feletti and Boud "PBL is a way of organizing curriculum, but it also has both teaching strategies and learning processes. There is both the teacher's act of creating problems for students to achieve the teaching objectives and the students' act of continuous learning by solving problems" [3]. As a method, PBL is a creative synthesis of multiple teaching methods.

Most scholars in China define PBL as a teaching model. Domestic scholar Rude Liu thinks that this teaching model is more consistent with the current trend of education reform in China, and it is very enlightening for domestic teaching reform ideas [4]. He

mentions that as a model, PBL is the result of optimizing various teaching models, and this teaching model not only meets the need of promoting quality education in China but also provides the possibility of changing the current status quo of examination-based education in primary and secondary schools in China.

The purpose of PBL is to learn the scientific knowledge behind the problems, develop problem-solving skills, and acquire comprehensive ability development through group work.

2.2 Motivations for the Study

The teaching reform in the context of the new education concept needs to focus on the curriculum and the classroom to build an efficient classroom teaching model. And it happens that the PBL teaching model is very suitable, and the purpose of our literature review study is to explore how far its current development has progressed effectively in recent years to provide a direction to guide our teaching reform in the future.

3 Literature Review

3.1 Analyzing the Application of the PBL Model in Chinese Mathematics Learning

Figure 1 shows the number of published papers from 2000 to 2020, which clearly illustrates that more and more scholars at home and abroad are studying PBL. Its overall trend shows an increase, especially from 2005 to 2015, the slope of the graph is getting bigger and bigger, and the overall tends to level off from 2016 to 2018. In 2019, PBL received great concern from scholars. As can be seen from Fig. 2, the research area on the PBL topic is also very wide, medical education and medical fringe disciplines are

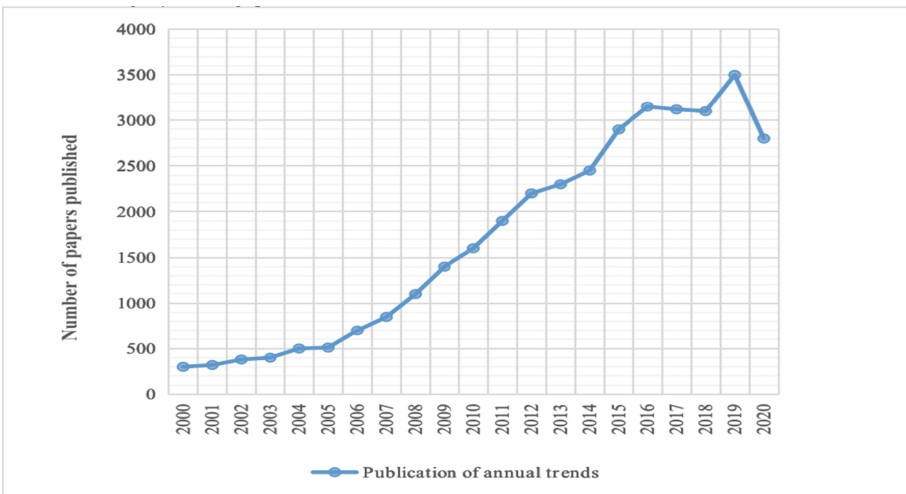


Fig. 1. Number of papers Published on PBL Topics Adapted from [5]

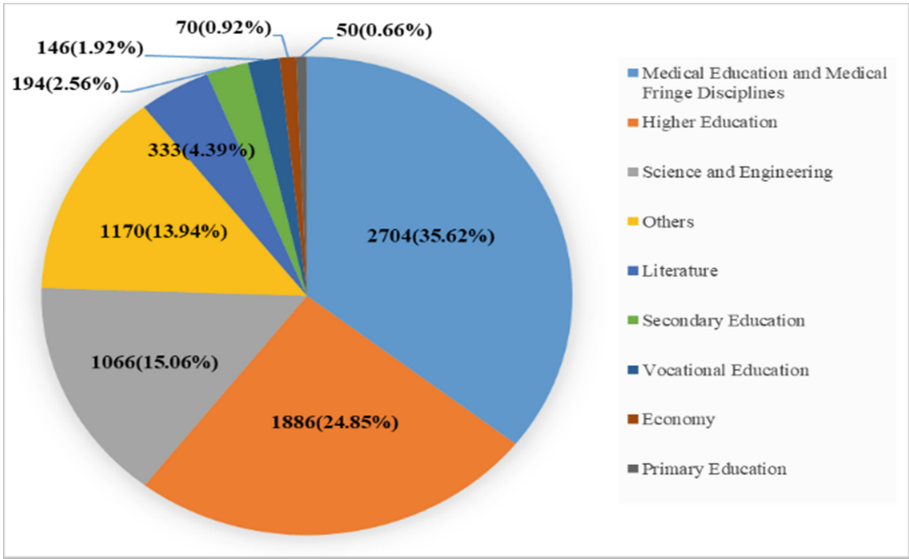


Fig. 2. The Distribution Map of PBL’s Subject Areas Adapted from [5]

the most widely used, accounting for 35.62% of all disciplines. Also, higher education accounts for 24.85%, and PBL in the field of primary education only accounts for 0.66% of the research. Therefore, the main research fields of PBL are still medical education and higher education. In recent years, Chinese scholars have applied it to the field of primary teaching. The educators have actively explored the extension of the PBL teaching method in the field of basic education and have applied PBL integration in the teaching of primary school and secondary school curricula. Some teachers use the PBL model of teaching to improve the graphing and geometry solving skills of primary school students [6]. Some other teachers have applied PBL to a review lesson on “systems of quadratic equations” in junior high school mathematics [7].

Studies have also shown that students using the PBL method do not show significant improvements in performance and competence compared to students using the traditional teacher-led method. According to Wang, there are three reasons for this phenomenon: First, the traditional educational concept of “teachers teach and students learn” has become a strong resistance to the implementation of the PBL teaching method. Second, the learning ability of primary school students often cannot meet the high requirements of PBL teaching. Third, the ability of group cooperation varies, the participation of members is uneven, and some students show a lack of cooperative spirit [8].

3.2 The Advantages of a PBL Model for Teaching Mathematics

In our analysis of the literature, this paper found several advantages of the PBL model for teaching mathematics in K-9 in China: 1) critical thinking; 2) students’ self-directed learning skills, and classroom participation.

3.2.1 Cultivating Critical Thinking Ability

For students, Critical thinking ability is significant in learning mathematics and the PBL model is a good way to develop this ability through problem-setting. Hu found that through the teacher's guidance, students form good mathematical thinking habits in their contemplation of problems so that they can independently explore the intrinsic laws between mathematics and develop an interest in mathematics teaching and learning based on their interest in stimulating creative awareness and thinking about mathematics [9].

Admittedly, the traditional Chinese model of teaching mathematics is based on the teacher's lecture, which is not conducive to the improvement of students' thinking skills. But in the PBL model, students have more chances to express their reviews and work in groups. Grant suggested that PBL constructs a learning environment where students feel free to interact with peers, apply mathematical concepts to real-world issues, and construct new knowledge using their previous knowledge [10]. The process of applying mathematical knowledge to different life situations is also enhancing students' thinking skills.

3.2.2 Enhancing Students' Self-directed Learning Skills and Classroom Participation

The PBL model is a student-centered approach to education. As Du said, with PBL, each student can choose a problem-solving strategy that they understand and have space to work on problems that suit their speed and preference [11]. PBL offers an atmosphere in that students can solve math problems independently without a lot of help from teachers. However, if students face some problems that are difficult to resolve, they can also ask for suggestions from teachers. The acquisition of independent problem-solving skills at primary and secondary school will be a benefit for students in their future studies. Fu indicates that this model guides students to actively participate in the teaching and learning process by setting up good learning and communication contexts based on the actual situation. Students learn more intently and diligently in the mathematics classroom and promote their emotional involvement [12]. Additionally, the PBL model has changed the seriousness of the Chinese math classroom, engaging more students in the class. Compared to the previous, students are more involved in classroom activities, which helps teachers more confident about their teaching and students more conducive to learning mathematics knowledge.

3.3 Problems in PBL

According to Shao, although PBL is a novice teaching method being explored by teachers and researchers in various subjects in the new curriculum reform, it has played a role in developing students' sense of innovation, problem-solving and critical awareness, PBL has not been popularized nationwide because there are still many problems and shortcomings [13]. Two of the more significant issues are as follow.

3.3.1 High Demand for Teachers' Teaching Ability and Students' Learning Ability

Firstly, the PBL teaching model has increased the demands on teachers. For example, the teacher needs to have good classroom control as students will be talking in groups several times. If the teacher is not managed properly, it can lead to chaos in the classroom. At the same time, teachers should spend their break time finding out more information about PBL and creating an appropriate context for students. Secondly, the PBL model also presents a high demand for students' self-motivation to learn. Schmidt argued that students taught using PBL demonstrated superior learning acquisition compared to students taught under controlled conditions [14]. Campbell and Norton also point out that at the beginning, one student in the group has conflicting views on the issue; this stage can be difficult for students who are new to this learning method, as they are not used to expressing their views and may not be willing to argue with other group members [15]. Under this circumstance, PBL is more suitable for those students who are willing to improve themselves.

3.3.2 Elementary PBL Math Teaching

As PBL is not widely used in the Chinese context, the application it presents is not mature. In most schools in China, teachers still use a teaching-instructed model because it can improve students' performance in the short term. Jiang refers that student in China has long been taught in a "fill-in-the-blank" style, they are dependent on traditional education models and lack the motivation and ability to solve problems on their initiative [16]. Some students are only satisfied with getting good "marks", then they find the PBL teaching reform too "time-consuming" [16]. This shows that it will take some time before the PBL model is truly accepted and used effectively by students and teachers.

4 Suggestions

After reviewing the relevant literature at home and abroad, this paper summarizes the following teaching strategies for teachers in need of reference.

4.1 Reality

Based on the teaching objectives required to be achieved by the mathematics curriculum standards, design authentic problems related to real-life experiences with a certain degree of openness and exploration. At the same time, teachers always provide opportunities for students to stand at the center of problem-solving in the process of educating them and giving them the corresponding rights. Instead of relying on teachers, they should cultivate a good habit of learning knowledge and solving problems independently.

4.2 Adaptability

According to students' learning habits and characteristics to form a reasonable "learning community" a learning group, after asking questions, to give students a certain amount of time to think, and then discuss among the group, the teacher should not be rushed to

end the problem, which turns the question into a form. Teachers should also cultivate students' sense of cooperative communication in the teaching process so that students are brave enough to export their ideas to their peers.

4.3 Uniqueness

Teachers should respect the uniqueness of students. It is not encouraged to consistently deny students' unique insights into problems, but to pay attention to students with learning potential, encourage them more, actively participate in the discussion of problems, thereby creating conditions to enhance their self-confidence in learning. When encountering introverted students, teachers can strengthen communication and enlightenment after class, encourage students more in teaching.

4.4 Examinability

The evaluation of the PBL teaching model should be integrated with students' learning process performance. The traditional way of examination should not be discarded to examine the mastery of students' knowledge, especially for designing corresponding attainment tests to examine students. The new examination methods, such as developing the evaluation methods of students' mutual evaluation and inter-group mutual evaluation form, allow students to discover each other's merits and find their deficiencies in mutual supervision and timely correction. In this case, students can develop the habit of writing learning summaries and form effective learning methods. The whole evaluation activity should focus on the results, the process, and the changes in students' emotions and attitudes are shown during the learning process. When conducting evaluation, attention should be paid to the use of expressive evaluation. The presentation form of teaching evaluation can be various, but the evaluation must be timely and give students timely and effective feedback.

4.5 Review

After teaching, we should actively review and reflect on the teaching process: for example, whether we have missed important knowledge points, whether we have mobilized all students, etc. This review procedure is to ensure that after each class, students can learn more knowledge that can be used for their future development under the PBL teaching mode.

4.6 Innovativeness

PBL teaching model does not necessarily have to be applied to a whole class, but can also be applied to a certain unit, a certain classroom session, or a certain knowledge point in the classroom. Teachers should be brave enough to break the stereotypes of PBL teaching mode, be innovative and not stick to the rules.

5 Conclusion

Problem-based learning has been a heated topic in the educational field for a long time in various forms. It can mobilize learners' learning enthusiasm and deepen learners' understanding, which promotes the combination of discovery and acceptance of learning. Even if all the supporting conditions for problem-based learning are met, there are still some natural, inherent, and even insurmountable limitations to problem-based learning. For example, in problem-based learning and teaching practice, the systematic nature of knowledge may be weakened to some extent. Also, it focuses less on the learning outcomes and more on the learning process of the problem or problem organization. Therefore, the balance between focusing on learning outcomes and processes will affect the effectiveness of problem-based learning. This has a direct impact on the quality of problem-based learning education. In addition, in the context of the rapid development of education in China, it is a very challenging issue to better develop problem-based learning in the future.

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