

The Impact of Project-Based Learning on High School Education—Based on Systematic Literature Review

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Abstract: Project-based learning (PBL) is a student-centered pedagogical approach that empowers students to actively engage in learning by integrating theoretical knowledge with practical application. It encourages students to synthesize their skills and knowledge to develop practical solutions for real-world problems. Currently, some scholars have begun to explore the impact of the implementation of PBL on high school education. Consequently, a substantial body of literature on PBL in high school education has emerged. A systematic literature review can systematically analyze the research status of the implementation of PBL in high schools, and comprehensively explore the core influencing factors and implementation effects of PBL. In this study, a systematic literature analysis method was employed to compile a total of 47 empirical journals published between 2019 and 2023, focused on the application of PBL in high school education. The analysis served to provide an overview of the research landscape surrounding PBL in high school education. This overview encompassed various aspects, including the number of article publications, sources of journals, research methodologies, academic disciplines, and key factors influencing the of PBL in high school education.

The results showed that the number of publications had been decreasing over the past five years. The analyzed journals predominantly focused on practical subjects like geography, science, chemistry, and physics, with the majority of studies originating from China. Research primarily employed mixed methodologies with sample sizes typically under 100 samples. The predominant research theme centered on STEM subjects. Key factors influencing successful PBL implementation included a relaxed and enjoyable learning environment, a collaborative learning approach, and engaging students through intriguing driving questions. Effectiveness in high school PBL was notably influenced by both students and teachers. In conclusion, this review offered recommendations for PBL in high schools, encompassing various grade levels, preferred databases, optimal search periods, and language considerations. It served as a valuable resource for future research and the development of PBL teaching models in high schools.

Keywords: Project-Based Learning; High School Education; Systematic Literature Review.

1. Introduction

Project-based learning (PBL) is a student-centered pedagogical approach that enables students to conduct active learning, integrate theories and practice, and apply knowledge and skills to come up with practical solutions to a specific problem (Savery, 2006). Since its inception, PBL has attracted global attention and found widespread adoption in the realm of high school education. Some

countries have crafted policies aimed at implementing PBL within high school education. For example, in 2019, China issued the policy document entitled *Guiding Opinions of the Department on Promoting the Reform of Education Methods in Ordinary High Schools in the New Era*. This document places a strong emphasis on the significance of project design within interdisciplinary and comprehensive teaching. Likewise, Spain had proposed an *Organic Law* designed to

elevate the quality of high school teaching and learning. This law recognizes PBL as a valuable tool for enhancing the educational experience of secondary school students (Lopez and Palacios, 2020). Additionally, many scholars from other countries have published a lot of literature on PBL in high school and have demonstrated that PBL can improve high school students' collaborative communication skills (Yamada, 2021; Tyurina et al., 2022; Virtue and Hinnant-Crawford, 2019; Giaffredo et al., 2022; Tian et al., 2023), interests in learning (Chmelárová and Čonková, 2021; Makkonen et al., 2021; Uden et al., 2023), acquisition and understanding of subject knowledge (Somjai and Soontornwipast, 2020; Saleh et al., 2020). PBL with the use of instructional media was also found to significantly increase the effectiveness of PBL implementation in high schools (Suhroh et al., 2020; Sánchez-Cambronero et al., 2021; Somjai and Soontornwipast, 2020; Basilotta Gómez-Pablos et al., 2020; Hossein-Mohand et al., 2021).

While there were numerous published articles on the practical applications and effects of implementing PBL in high schools, there remained a notable gap in examining common characteristics and implementation effects of PBL in this educational context. Hence, systematically analyzing the issue of the effectiveness of PBL implementation in high school education could provide valuable insights into the current development trend and the core influencing factors, which could provide a reference for improving the practice of PBL in high school. Based on this research gap, this study aimed to analyze the empirical journal articles on the application of PBL in high school education which were published from 1 January, 2019 to 1 August, 2023. The study aimed to explore the research status of PBL applied in high school education, sought to assess its implementation effectiveness, and identified potential factors that may influence its efficacy.

1.1. Literature review

Many scholars have focused on a single subject to conduct empirical project-based teaching and learning research in high schools. For example, Gu and Ye (2023)

conducted a PBL activity in chemistry in a high school in China, revealing that high school students felt the work they did was meaningful and valuable during the PBL process, and the driving questions also attracted students' interest in learning. Han and Yan (2023) implemented project-based teaching in high school geography, involving students in creating and conducting street surveys. The findings proved that carrying out geography PBL facilitated students in overcoming difficulties in real social environments, enhancing their communication with diverse individuals, and improving their ability to integrate theory with practice while sharpening problem-solving skills. Additionally, some researchers use information technology for PBL. Suhroh (2020) studied how well 50 vocational high school students learn when using whiteboard animations in English PBL by using quasi-experiments and questionnaires. These findings indicated that high school students who used whiteboard animation in PBL had a significant improvement in English oral expression skills than the students in the control group who used traditional media.

Based on the literature review, it was found that most of the literature studied the practice situation and the implementation of PBL in high school students. There has been a noticeable gap in the availability of systematic literature reviews that comprehensively analyze the effectiveness of PBL in high school education. In response to this gap, the current study endeavors to employ a systematic literature analysis approach to investigate the following three sub-research questions. The aim was to understand the development trend of PBL and the variables that affected the implementation of PBL in high schools, and to improve the practice and research of project-based teaching in high schools in the future.

(1) What was the current state of research on the application of PBL in high school education? (What was the volume of relevant literature issued? What were the journal sources and countries? What were the research methods and total sample size? What were the research disciplines?)

(2) What was the effectiveness of project-based

learning in senior secondary schools?

(3) What factors influenced the effectiveness of project-based learning applications in senior secondary education?

2. Research design and analysis

In this study, the empirical journal literature on "project-based learning in senior secondary education" that was published from 1st January, 2019 to 1st August, 2023 was reviewed and analyzed. The procedures for this systematic review were as follows:

2.1. Identified the searching terms and their English and Chinese synonyms for the literature search based on the research topics

Firstly, this study listed the English and Chinese synonyms of the two keywords, "project-based learning" and "high school education". The Chinese search strings and its synonymous were: ("项目化学习" OR "基于项目的学习" OR "项目式学习" OR "微项目化学习" OR "项目学习" OR "项目化" OR "项目式教学") AND ("高中教育" OR "高中" OR "高中生" OR "高中教师"); The English search strings and the synonymous were: ("PBL" OR "project-oriented learning" OR "project-based learning" OR "micro-project based learning" OR "Project Method" OR "Project-based Learning approach" OR "Project-based Curriculum") AND ("high school education" OR "high school " OR "high school students" OR "high school teachers" OR "secondary school" OR "senior high school" OR "senior middle school" OR "senior school"). The English and Chinese synonym strings were used interchangeably and combined by using OR and AND. The words were inputted into the Web of Science (WOS) and China National Knowledge Infrastructure (CNKI) search fields for relevant literature searches (See Table 1).

Table 1. Chinese and English search strings

Sear ch Tool	Key Terms	Search Strings
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CN	项目化学习 (Chinese terms)	"项目化学习" OR "基于项目的学习" OR "项目式学习" OR "微项目化学习" OR "项目学习" OR "项目化" OR "项目式教学" AND "高中教育" OR "高中" OR "高中生" OR "高中教师"
	高中教育 (Chinese terms)	
WO	PBL	"PBL" OR "project-oriented learning" OR "project-based learning" OR "micro-project based learning" OR "project method" OR "project-based learning approach" OR "project-based curriculum"
	high school education	AND "high school education" OR "high school " OR "high school students" OR "high school teachers" OR "secondary school" OR "senior high school" OR "senior middle school" OR "senior school"

2.2. Determine the database for searching the literature

WOS is the database generally accepted as the most comprehensive and influential data source for various purposes (Haojie and Yaojun, 2009). CNKI is the largest database of academic papers in China, it contains Chinese literature, academic dissertations, educational journals, and so on (Zhengtai Yu and Hao Liu, 2023). This database is frequently utilized by many researchers for conducting inquiries into Chinese literature. Consequently, the core journals extracted from these two databases were authoritative and reliable, and could be used as the data

sources of this study. Hence, in this research, the core journals retrieved from these two databases served as the primary data sources.

2.3. Developed literature exclusion and inclusion criteria

Literature exclusion and inclusion criteria (See Table 2) were developed based on the theme of the impact of PBL in the application of high school education. Determined the language of literature: English or Chinese, and chose the core journals literature, that was published in the CSSCI, Core Collection of WOS and the Peking University core journals. Journal articles published from 1 January, 2019 to 1 August, 2023 were selected. 330 foreign language articles and 88 Chinese articles were obtained. Subsequently, articles that were either in English or Chinese were reviewed, leading to the exclusion of 37 sources that were not in English, were not journal articles, or were written in foreign languages. This screening process resulted in a final selection of 193 English-language literature sources and 88 Chinese-language literature sources for the study.

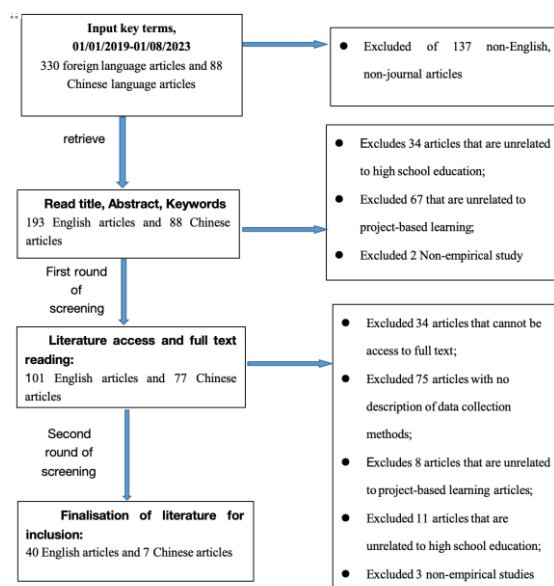
Table 2. Literature inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Empirical research	Non-empirical study
Detailed information on research methods (data collection and analysis methods, sample size, etc.)	No details of research methodology
Available full text	Inaccessible contents
No duplications	Duplicate document
Chinese or English articles	Other languages
Journal papers published	Conference articles, newspaper, review articles, etc.
Upper secondary education	Not high school education.
Project-based learning	Not project-based learning
Publishing time from 01/01/2019 to 01/08/2023	Other publishing time

2.4. Literature screening and process

The initial step of literature screening. The titles, abstracts, and keywords of the remaining literature were read. 92 English literature and 11 Chinese literature which were not empirical research or relevant to high school education, and irrelevant project-based learning were excluded. After that 101 English literature and 77 Chinese literatures were left for the following review. The author further accessed and read the full text of the remaining 178 literature. Among them, 61 English literature and 70 Chinese literature that could not be accessed, did not present sample size or methods of data collection or analysis, were not related to high school education, or project-based learning, or were not empirical studies were excluded. Ultimately, a total of 47 articles, including 40 in English and 7 in Chinese, satisfied all the inclusion criteria and were included in the final review (See Figure 1).

Figure 1. Flowchart of literature screening



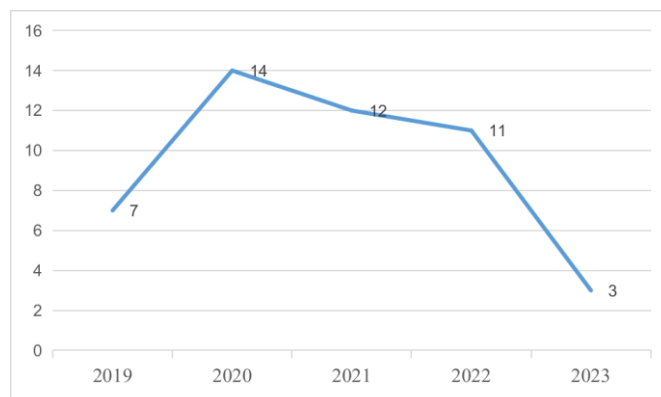
3. Results

3.1. Volume of publications

From reviewing the 47 empirical studies on PBL, it was found that the number of journal articles on "the application of project-based learning in high school education" had increased from seven in 2019 to 14 in 2020, and the number of articles on "the application of

project-based learning in high school education" had decreased from 2020 to 2023. The number of articles published in 2020 was 14, which was the peak of the number of articles published in these five years (see Figure 2). The peak in the number of articles published in 2020 can potentially be attributed to the Ministry of Education revising the *High School Curriculum Standard* in 2017. This revision encouraged high schools to prioritize students' learning process, created real-life scenarios related to students' lives, promoted autonomous, cooperative, and inquiry-based learning, as well as emphasized the process evaluation of high school students' learning. This encouragement largely supported the implementation of PBL: a way of teaching and learning in which learning tasks were project-based and students were allowed to solve problems in real-life scenarios and to learn independently. With the encouragement of PBL, a large number of scholars tended to be focused on PBL and published articles on the application of PBL in high school education (Yang, 2021). However, after 2021, with the promulgation of the *Opinions on Further Reducing the Burden of Homework and Out-of-School Training for Students in Compulsory Education* (2022), as well as there was no further research on PBL in high school. Researchers had shifted the focus of PBL research to compulsory education (Wang, 2023; Haojie and Yaojun, 2009). Thus, the number of publications on PBL in high schools exhibited a declining trend year by year.

Figure 2. Annual trends of publishing the number of articles



3.2. Journal sources and countries

These 47 papers were published in 34 different journals, with the largest number of documents published in the *International Journal of Instruction and Teaching Geography*. The second largest number of documents was published in the *Sustainability* journal and the number of the studies was three. Other journals like *Arab World English Journal*, *Frontiers Psychology*, *Interdisciplinary Journal of Problem-Based Learning*, *Journal of Baltic Science Education*, and *Chemistry Education* all published two documents. Each of the rest of the journals such as the *Journal of E-learning and Knowledge Society*, *International Journal of Technology and Design Education*, *Journal of Nusantara Studies*, *Teaching Statistics*, and so on (See Table 3) published only one article. Articles on PBL in high schools are published mostly in the practical domains within educational sciences, including geography, science, chemistry, and physics. This underscores the importance of educational science journals in disseminating practical research findings

Table 3. Distribution map of journal sources

Journal sources	Number	Percentage	Journal sources	Number	Percentage	Journal sources	Number	Percentage	Journal sources	Number	Percentage
International Journal of Instruction	4	9%	Journal of E-learning and	1	2%	IEEE Transactions on Education	1	2%	Tech Trends	1	2%

n			Knowle dge Society								
Geograph y Teaching	4	9%	Interna tional Journal of Technol ogy and Design Educati on	1	4%	A journal of historical conscious ness, historical cultures, and history educatio n	1	2%	Research on Electro-C hemical Education	1	2%
sustainab ility	3	6%	Journal of Nusant ara Studies	1	2%	Educatio nal Research er	1	2%	The Journal of Research in Science Teaching	1	2%
Arab Wrld English Journal	2	4%	Nation al Researc h Univers ity Higher School of Econo mics	1	2%	TESOL Journal	1	2%	The American Biology Teacher	1	2%
Frontiers Psycholog y	2	4%	Teachin g Statisti cs	1	2%	Apuntes Universit arios	1	2%	Teacher Developm ent	1	2%
Interdisci plinary Journal of	2	4%	TEM Journal	1	2%	America n Society of Civil Engineer	1	2%	Chem Didact Ecol Metrol	1	2%

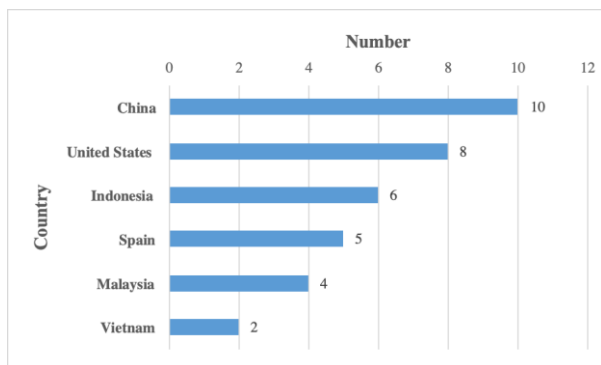
Problem-Based Learning						s.					
Journal of Baltic Science Education	2	4%	Journal of Advanced Academics	1	2%	Social sciences & Humanities	1	2%	International Journal of Science and Mathematics Education	1	2%
Chemical Education	2	4%	International Journal of Engineering & Technology	1	2%	Science of the Total Environment	1	2%	Journal of Science Teacher Education	1	2%
Aula Abierta	1	2%	Humanities and Social Sciences Communications	1	2%						

Regarding countries, we found that China, the United States, Indonesia, and Spain published a majority of articles on PBL. Specifically, China contributed the highest number of publications on PBL, with 10 articles, followed by the United States with eight, Indonesia with six, and Spain with five. Both Malaysia and Vietnam published two literature on PBL. The number of articles focused on the contexts of Portugal, Japan, the Slovak Republic, Austria, and Italy was only one for each country (See Figure 4). This might be due

to that China, the United States, Spain, and Indonesia had formulated educational policies on PBL. For example, in the *Guiding Opinions of the General Office of the State Council on Promoting the Reform of Education Methods in Ordinary High Schools in the New Era* (2019) issued by China in 2019, it was proposed to focus on interdisciplinary and comprehensive teaching approaches, such as "project design". The National Academy of Sciences emphasized that PBL was necessary for student learning (Barbara

Schneider, 2022). Furthermore, both *the Common Core State Standards* and *the Next Generation Science Standards* emphasized the development of conceptual knowledge and deeper learning skills. These requirements also were consistent with the goals of PBL (Barbara Condliffe, 2017). In 2013, in an effort to improve the quality of teaching and learning in secondary schools, Spain proposed " PBL as a tool to enhance the learning of secondary school students " in the *Organic Law* (2020). Therefore, it is known that PBL education in countries such as China, the United States, and Spain is supported by national policies and therefore favors the development of PBL-related educational research and practice.

Figure 4. Country distribution map of research subjects

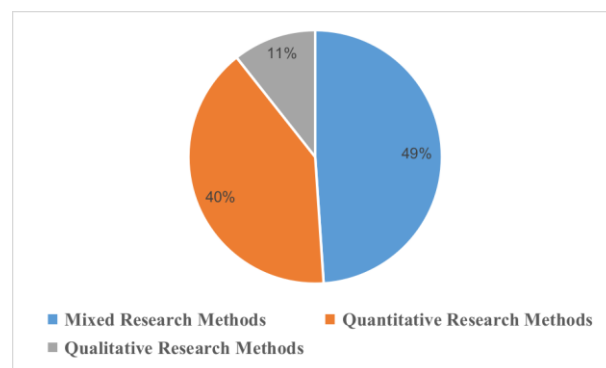


3.3. Research methodology and total sample size

In the 47 empirical studies examined, mixed research methods emerged as the predominant approach, with 23 of them (49%) utilizing this method. Following closely, 19 studies (40%) employed quantitative research methods, while qualitative research methods were employed in five studies (11%). Mixed methods research on PBL generally used questionnaire tests and interviews. Literature that only used quantitative research tended to conduct experiments and questionnaire tests. The qualitative research on PBL tended to employ interviews and textual analysis (See Figure 5). The mixed research method was a research procedure that combined qualitative and quantitative methods. It involves leveraging data and results obtained from qualitative and quantitative methods to elucidate the research questions and hypotheses. This research method compensated for the shortcomings of quantitative research

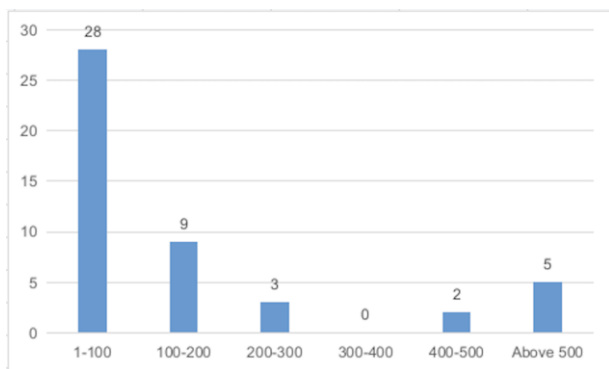
methods, which often fall short in providing a profound insight into individual experience and attitude. Similarly, it overcomes the constraints of purely qualitative research, which typically involves smaller sample sizes and can be susceptible to individual subjective biases (Creswell and Clark, 2011). Therefore, the use of mixed research methods in this study could ensure that the findings were objective and comprehensive.

Figure 5. Distribution map of research methods



Regarding the number of samples, most (28 out of 47) literature recruited 1-100 samples. This was followed by nine literature which had around 100-200 samples and five literature with more than 500 samples. Only 3 studies utilized sample sizes ranging from 200 to 300 individuals, and two studies conducted their research with sample sizes of 400 to 500 samples (See Figure 6). This indicates that managing a total sample size within the range of 1-100 was more manageable, whereas sample sizes exceeding 300 became too challenging to ensure if sample attrition occurred due to various study-related factors. For example, He (2022) studied 4,238 high school students and 119 high school teachers in the study of PBL in high school chemistry and found that the effectiveness of the experiment might be affected by the uncontrollable factors of large samples leading to sample size loss. This could be attributed to larger total sample sizes leading to sample groups missing out on pre-test or end-of-year tests, necessitating the exclusion of these invalid samples.

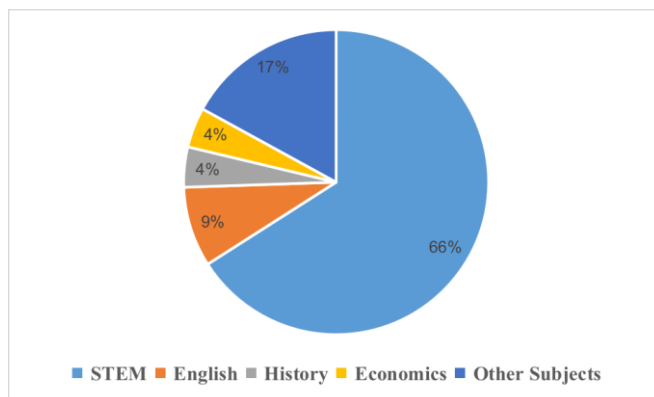
Figure 6. Distribution map of the total number of samples



3.4. Research discipline

This study revealed that 31 studies centered around STEM (Science, Technology, Engineering, Mathematics), making it the most prominent subject area within the reviewed articles. This was followed by a total of 8 literature studying other disciplines (Medicine, Moral education, Music and Biology, Geography, Labor, Food Safety, etc.). Four studies focused on English subjects. The number of articles focused on the subjects of History and Economics was the same (See Figure 7). In 2017, the Compulsory Primary School Science Curriculum Standards (2022) promulgated in China clarified for the first time the definition of the Chinese version of STEM, which was that "STEM was a project-based learning, problem-solving oriented curriculum organization". Therefore, it was evident that PBL could be used as a pedagogical approach to carry out STEM education and to improve students' proficiency throughout STEM projects. Furthermore, PBL was an approach that required students to apply interdisciplinary knowledge to solve real-world issues, thereby establishing authentic learning situations (Anila Asghar, 2012). Therefore, the application of the PBL approach in interdisciplinary STEM has garnered significant attention from numerous scholars in the field.

Figure 7. Research discipline distribution map



4. Effectiveness: Is PBL effective in high school education

An analysis of 47 literature sources demonstrates a clear consensus: PBL has predominantly yielded positive results in high school education. Out of the reviewed articles, 46 supported its effectiveness, with only one suggesting otherwise. These studies commonly recognized that the PBL environment, collaborative learning strategies, and problem-solving components played important roles in positively influencing both students and teachers in terms of knowledge, competence, and thinking.

4.1. The impact of the environment of project-based learning

Three studies clearly illustrated that the relaxing and stress-free environment of PBL could increase high school students' engagement in PBL activities, such as collaborative group communication and solving driving problems. For example, Somjai and Soontornwipast (2020) explored the effect of PBL on the topic of English vocabulary learning effectiveness. And found that the atmosphere of the teaching and learning environment of PBL was relaxed and stress-free. Students in such an environment would be active and willing to participate in classroom activities and learn new vocabulary effectively. Similarly, Saleh (2020) used a mixed research method including quasi-experiments, questionnaires, and semi-structured interviews to test the 70 high school students' understanding of physics concepts and creative thinking skills in PBL activities. This study found that

students in the experimental group were more open and freer in communicating with each other. In the PBL environment, students perceived a lack of academic pressure when tackling physics problems, allowing them to foster more innovative ideas and gain a deeper understanding of pertinent physics concepts. Additionally, Gao (2020) tested 30 high school students' learning behaviors in a geography class which also employed PBL mode. The findings indicated that in geography PBL activities, teachers created authentic PBL scenarios related to the students' real-world experiences. This approach effectively stimulated students' interest in learning and encouraged active engagement in project tasks. This showed that the relaxed learning environment created by PBL could effectively improve the enthusiasm of high school students in participating in activities and interests in learning, and thus improve the quality of classroom teaching. Therefore, establishing a conducive and relaxed learning environment was a key element in improving the effectiveness of PBL in high schools.

4.2. The impact of the cooperative learning approach

12 out of 47 literature also illustrated that the PBL stimulates the use of a cooperative learning approach which promotes the students' communication skills, teamwork skills, and learning interests of high school students and teachers. For example, Yamada (2021) tested the perceptions of 19 teachers and 73 students on collaborative group learning in PBL-based English activities by using questionnaire and text content analysis methods. The findings showed that the teachers preferred collaborative communication in PBL practice which provided them with the opportunity to learn about their students. In a study conducted by Tyurina (2022), a combination of experimental and observational methods was employed to assess the influence of PBL on students' leadership skills. The findings demonstrated a noteworthy improvement in the leadership skills of the experimental group that utilized PBL, in stark contrast to the control group that did not. Thus, collaborative interactions in PBL were a key factor in the

development of students' leadership skills. Virtue and Hinnant-Crawford (2019) found that high school students not only self-examine and learn through collaborative peer-to-peer situations in PBL as a way of improving self-reflection and independent learning, but they also improved their competence in interpersonal skills through collaborative group learning. Sulaiman and Uden (2023) conducted similar experiments on PBL in high schools involving 88 students from Malaysia and 66 students from South Korea. Their research, utilizing quasi-experiments and questionnaires, verified that students' interest in learning was significantly increased in the STEM group PBL. Additionally, Tian (2023), Shi (2020), Wu (2019), and Giaffredoa (2022) also demonstrated the impact of the cooperative learning approach on high school students by using mixed research methods. In their literature, collaborative learning in the PBL model promoted the development of students' collaborative communication skills and problem-solving skills. Chmelárová (2021), Makkonen (2021), and Gao (2020) similarly demonstrated that collaborative learning in a STEM PBL model promoted students' communication and problem-solving skills. Their research, based on either quantitative or qualitative methods, consistently indicated that the use of a collaborative group learning approach in PBL could increase students' interest in learning and make them actively engaged in the project activities. Overall, these findings suggested that the approach of cooperative group communication in PBL effectively exercises students' communication skills and cooperative problem-solving abilities. It also promoted positive interactions between teachers and students, as well as among fellow students.

4.3. Impact of driving questions

Out of the 46 studies proved that the application of PBL was effective in terms of its impact on high school education. Eight papers supported the idea that the formulation of driving questions positively influenced the motivation and interest of high school students in their learning process. These driving questions should be

challenging, engaging, and authentic questions, and driving questions should include the basic knowledge and skills that students learn (Hu,2021). For example, previous studies had also concluded that one of the factors affecting the success of PBL implementation was the provision of challenging and engaging problems. Students would actively participate in the activities when presented with problems that pique their curiosity and interest (Bhuyan, 2020). Dobson (2021) used questionnaires and action research methods to conduct a PBL experiment in high school. The experiment aimed to enhance students' character ability and yielded a significant increase in students' participation when teachers asked questions that were relevant to the students. Similarly, Makkonen (2021) investigated the effect of PBL on the learning outcomes of gifted and talented students in physics classes in a Finnish high school by using interview and questionnaire tests. The results illustrated that almost all students felt the driving questions stimulated their interest in learning in the project activities. Putra (2021), Tian (2023), Schneider (2022), Sulaiman and Uden (2023) also used experimental methods and questionnaires to conclude that the process of solving driving problems can lead to the improvement of students' problem-solving skills. In sum, the findings of this study were in line with previous studies (Gu and Ye,2023). The conclusions demonstrated that posing engaging and challenging driving problems enabled students to apply their knowledge and skills effectively in problem-solving.

Yet only 1 out of 47 documents articulated that PBL was ineffective in high school education. (Chimbi & Jita, 2021) from Zimbabwe tested the implementation of an eight weeks PBL model in history subject by using observational and interview research methods. Their findings proved that PBL in history subjects conducted by four teachers was ineffective in high schools because of the numerous PBL tasks, the long cycle, the absence of adequate preparation, the lack of publicity in schools, and the focus on examination results. These factors led to the failure of project-based learning in this high school.

5. Influencing factors: What factors influence the effectiveness of PBL application in high school education

According to the third research question. What factors influenced the effectiveness of project-based learning applied in high school education? By analyzing these 47 empirical research studies, it could be concluded that the effectiveness of PBL application in high school education was influenced by students' factors, teachers' pre-course preparation, and the role of guidance and driving questions.

5.1. The students' factors

Students' factors included intellectual ability and personality. Four papers illustrated that student factors could affect the effectiveness of PBL application in high school education. For example, Chmelárová (2021) explored the learning situation of high school students majoring in economics during PBL. The results of the study showed that more than half of the high school students had a high frequency of procrastination in completing the project tasks. Because of their procrastinating personality liked to work on the project at the last minute at the end of the activity. As a result, the PBL tasks could not be completed on time. Sun (2022) used a mixed research method of questionnaires and interviews to explore what learning challenges 48 high school freshmen majoring in information engineering encountered when completing PBL activities. The results showed that the challenges students encountered in completing the PBL were that they were unfamiliar with the use of the learning tools and hands-on processes. Therefore, it was difficult for students to learn PBL for programming. Another study by Wu (2019) used an experimental method to explore the learning performance of five high school students in two months geography and labor PBL courses. The results showed that the students' oral expression, problem-solving, hands-on, and creative skills enabled them to develop PBL geography curriculums that met their school's characteristics. Makkonen (2021) used a mixed research method in physics teaching to explore the learning outcomes of gifted students in high school PBL. The study

proved that these gifted students possessed sufficient competencies to fulfill the challenges of the project, such as the ability to understand conceptual knowledge and use information technology, and the ability to calculate. The students were interested in and able to complete the project tasks. The above findings suggested that the effectiveness of PBL in high school was affected by students' knowledge and ability as well as personality factors. Thus, the design of PBL should be in line with the existing knowledge level and personality characteristics of high school students. Projects should be carefully designed to both challenge students' learning abilities as well as ensure that students do not have negative feelings of withdrawal and intimidation towards problem-solving.

5.2. The teachers' factors

Although PBL emphasized the concept of student-centered teaching and learning, the role of the teachers was also important and could influence the effectiveness of PBL implementation in high school education. This study found that teachers' factors affecting the effectiveness of PBL implementation in high schools included teachers' pre-course preparation, mentoring, and motivational roles. Two literature mentioned that teacher pre-course preparation could be effective in fostering student engagement and learning within the context of PBL. Chimbi (2021) also found that teachers majoring in medicine needed to take time to prepare project plans in advance to ensure that the content meets students' demands, thus ensuring the effectiveness of PBL. Additionally, Lotter (2020) stated that the lack of adequate preparation and planning by teachers was a key contributor to the failure of PBL. Therefore, teachers were crucial in PBL in high schools, and their preparation, guiding, and motivating roles could influence the successful implementation of learning.

8 out of 10 literature had mentioned that teachers' guidance and encouragement also play an important role in PBL in high schools. Shaharuddin (2022) experimented on STEM PBL in a Malaysian high school with 70 students. After nine months of experimentation, they found that

teacher encouragement was a determinant of the effectiveness of PBL implementation. In the process of students completing the project tasks. The teachers' guidance and encouragement could help students better solve the problems, produce the project products, and improve the effectiveness of PBL implementation in high school. Similarly, Bhuyan (2020) conducted a four weeks IT PBL learning experiment covering 30 ethnically diverse high school students. they also highlighted teachers play a key role in the success of the project. This is to say, that teachers shared their relevant work experience with students during this project activity. Under the guidance of the teacher, students increased their interests and knowledge and the project activity achieved positive. Morrison(2021), Somjai (2020), de la Torre-Neches(2020), Maulana(2019), and Yamada (2021) conducted studies on the learning activities and performance of high school students and teachers in a PBL model. These results showed that high school teachers' guidance and encouragement promoted the development of teacher-student relationships in the activities. Thus, teachers' encouragement could stimulate students' participation in the activities and their interest in learning, and effective guidance could help students acquire knowledge and skills quickly.

However, Chmelárová (2021) conducted an experiment on the effectiveness of PBL for students in economics through a questionnaire survey. His results showed that if high school teachers over-intervened and directed the learning of high school students, it could affect the successful implementation of PBL and negatively hindrance to students' completion of PBL tasks. In summary, these research results proved that the effectiveness of PBL in high school was also affected by teachers' factors. Appropriate guidance and adequate preparation from teachers could make project-based activities effective, and improve the effectiveness and quality of teaching. However excessive intervention could hinder students' learning and affect the implementation of PBL.

5.3. Impact of the medium of instruction

Six studies illustrated that the application of PBL in combination with other instructional media could increase the effectiveness of its application in high school education. For example, Gao (2020) used a smart classroom teaching model that integrated big data, cloud computing, mobile Internet, and other educational information technology in a geography PBL experiment. The findings confirmed that students could easily and effectively produce geography project products when using these information technology tools. Teachers could observe students' performance in the classroom at any time with the help of these multimedia tools, which enhanced communication with students. This also showed that the use of information technology improves the effectiveness of PBL in high schools. Basilotta (2020) combined the use of mobile phones and tablets in high school project activities. The research showed that high school students improved their communication skills and learned to use these new media tools to support their learning. They also expressed that they like to use these media tools in PBL. Sánchez-Cambronero (2021), Somjai (2020), and Hossein-Mohand (2021) all similarly used experimental and questionnaire methods to study how students' learning behaviors and performances were when teachers taught with multimedia tools in PBL in high schools. These studies proved that the use of multimedia tools for teaching and learning in project-based classrooms could increase students' interest in learning and subject competence, and the effectiveness of PBL in high school education. In sum, the application of instructional media could effectively improve the effectiveness of project-based teaching in high school, teachers could teach more efficiently by using instructional media, and students could increase their motivation and development of their learning level through using instructional media.

6. Research limitations and future direction

This study had several limitations. Firstly, this study only focused on high school education and did not study the teaching of other grades. These findings of the study only

served as a reference for the application of PBL in high school education, and it could not provide suggestions for the education of other grades. Therefore, future research could focus on grades, such as primary schools, junior high schools, and universities. Secondly, the time of the study and the type of language of the journals. This study only analyzed the Chinese and English core journal literature of PBL in high schools between 1 January, 2019 and 1 August, 2023. The sample literature was small, and the study could not analyze literature before 2019 and published in other languages. Thus, the timeframe and the type of language of the literature could be expanded. For example, expanding the time of the literature retrieval to 10 years or even longer. The languages could include Spanish and Hindi, to ensure access to and analysis of more authoritative or high-quality literature. Thirdly, this study only used CNKI and WOS as the search databases for obtaining Chinese journals and English journals, and did not analyze the core journal literature in other databases. More databases could be used to search for literature on related research. For example, Scopus, Wiley, and ProQuest could be used as data sources for research literature to obtain more comprehensive and influential literature on PBL.

7. Research implication

This study had several contributions to both theory and practice. In terms of theory, the study could provide directions for future scholars who want to conduct PBL activities in high schools as well as theoretical studies. For example, my analysis concluded that in the past five years, the literature studies on PBL in high school focused more on STEM and English subjects. While none of the literature on PBL studies was about high school in Chinese and politics. Therefore, future PBL research could conduct in-depth studies on high school in Chinese or political subjects. In terms of practice, this study could guide school teachers and instructional administrators on teaching practice. For example, this study analyzed that the effectiveness of PBL in high school was affected by the knowledge level and personality of students, teachers' motivation and preparation,

the importance of the school, and publicity. Therefore, teachers should fully prepare the lessons before carrying out project-based teaching activities. The content of the teaching should be in line with the knowledge level of the high school students and improve their interest in learning. The schools should pay attention to the all-round development of the high school students as well as the school's characteristics of the school to fully integrate the PBL activities into the teachers' teaching.

8. Research conclusions

This study conducted a systematic literature analysis of 47 empirical journal articles on the application of PBL in high school education from 1 January 2019 to 1 August 2023. To ascertain the current status of research regarding the utilization of PBL in high school education, the reasons for the successful implementation, and the factors influencing its effectiveness in the implementation of PBL in high schools. First, this study analyzed the current research status of PBL in high school education. Based on the dimensions of how many relevant literature articles were published, what were the sources of journals, what were the research methods and total number of samples, and what were the research discipline. After the analysis, it was concluded that from 2019 to 2023, the core journal on the application of PBL in high school education reached a peak in 2020, with an annual publication volume of 14 articles. The literature was published in 34 different journals, with the highest number of articles published in the *International Journal of Instruction and Teaching Geography*. Regarding countries, China, the United States, Indonesia, and Spain published a majority of articles on PBL. The largest number of literature was concentrated in China, with a total of 10 documents. By analyzing these 47 articles, it was found that the total sample size in the literature was the largest in the range of 1-100 examples. The disciplines studied in the 47 documents were most concentrated in STEM (Science, Technology, Engineering, and Mathematics), with a total of 31 documents

This research reviewed 47 studies and found that 46 of

them provided evidence supporting the effectiveness of PBL in high school education, while only one article illustrated that the application of PBL was ineffective. The PBL environment, cooperative learning approach, and driving questions were the reasons that PBL could be successfully implemented in teaching and learning in high school education. The effectiveness of the PBL application was affected by the students' knowledge and abilities, and procrastination in completing tasks. As well as the teachers' insufficient preparation before class, numerous tasks, the long period, the lack of publicity in schools, and the over-emphasis on examination results. In addition, the role of teachers' guidance and motivation, and the combination of PBL and instructional media would also affect the implementation effect of PBL in high schools. In conclusion, this study offers a comprehensive reference for exploring the current application status and future directions of PBL in high school education.

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