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The Effectiveness of Problem-based Learning on Students Creative Thinking: A Meta-Analysis Study

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PBL can significantly improve students' creative thinking than the conventional method. The subgroup analyses also revealed that the improvement of students' creative thinking in PBL was not affected by the experimental measurements, teaching methods, or the size of the sample but varied significantly across different education stages and subjects.

Keywords: Problem-based learning, Creative thinking, Creativity, Improvement, Thinking skill, Meta-analysis.

Introduction

With the approach of the twenty-first century and the challenges and pressures brought about by the fourth industrial revolution sweeping across the globe, there is an urgent demand for mankind to cope with all sorts of predicaments through various means. Education is indisputably one of the most crucial methods because it is the most effective approach to enhancing human capabilities. To surmount the challenges of science, technology, economy, culture, and life in the new century, education must cultivate human resources with the four crucial skills of communication skills, collaboration, critical thinking, and creative thinking, which are the basis of core competitiveness in the new century (Fatmawati et al., 2022). Out of these skills, creative thinking drives students to explore and discover new things, supports effective responses to challenges, and is integral to student growth and development (Gafour, 2020). Creative thinking triggers individuals to generate new and unique ideas and choose appropriate methods to solve problems successfully, and it is one of the essential skills for students to possess (Sudirjo et al., 2023). In addition, in a highly competitive and stressful environment, creative thinking can motivate students to collect materials systematically, methodically analyze information, and strategically practice new ideas, thus guiding them to find solutions to difficult problems, surpassing bottlenecks, and turning dangers into opportunities (Musaidah et al., 2022). That's the reason why creative thinking should be emphasized and valued.

As creative thinking is emphasised by human beings, the relevant theoretical system of creative thinking has also been gradually developed, commencing with the four stages of creative thinking proposed by Walles (1926), which mainly interpreted the progression of creative thinking, including: preparation; incubation; illumination; verication; The secondary is Wertheimer's (1945) structural theory, which uses Gestalt theory in psychology to explain creative thinking, indicating that creative thinking is realised through epiphanies, i.e. structural reorganisation and interpretation of meaning; Then followed Guilford's (1956) structure of intellect theory, which suggested that the core element of creative thinking is divergent thinking, i.e. fluency, flexibility and originality of thought; Drawing on Guilford's theory, Torrancee (1972) considered creative thinking to be at the centrepiece of creativity, and that creativity consists of four processes: perceiving a problem; formulating a hypothesis; verifying the hypothesis; and presenting the results, and developed the world-renowned Torrance Tests of Creative Thinking (TTCT), which tests an individual's fluency, flexibility, precision and uniqueness of thinking. Sternberg (1988) proposed a three-dimensional theory of creativity, namely, intelligence dimension, personality dimension, and modality dimension, claiming that the intelligence dimension is the vital dimension of creative thinking. These theories offered a significant foundation and direction for scholars to discuss and analyze creative thinking.

As one of the most prominent skills in the 21st century, creative thinking skills have been analyzed and interpreted by experts and scholars from a variety of perspectives, and a total of three insights have been developed, i.e., creative thinking is regarded as an ability, or a thinking process, or a mode of thinking. Firstly, Amrina et al. (2020) have considered that students use creative thinking to analyze problems creatively, which is an instrumental ability to explore issues, seek answers, and solve problems. Sudirjo et al. (2023) believe that creative thinking is an ability that is sensitive to problems and intimately related to problem-solving, mainly through identifying, analyzing, gathering information, drawing connections, and finally solving problems. Selviana et al. (2022) point out that creative thinking is a skill for solving problems, forming ideas, and producing new perspectives. It has also been recognized that creative thinking is an intellectual potential that can be fully developed in the learning process (Cahyono et al., 2021). From this perspective, creative thinking is indeed an invaluable ability that facilitates problem-solving and the production of new ideas. Another group of scholars resolved creative thinking from the perspective of the process that creative thinking is a systematic process of analysis, planning, commenting, and summarizing, which aims at obtaining correct decision-making solutions and solutions to problems (Nurcholifah et al., 2021). Anisaroh et al. (2018) are convinced that creative thinking is the process of securing new perspectives and ideas. Helaluddin et al. (2023) have concluded that creative thinking is a sophisticated mental process that involves a diverse range of activities, including making connections to previous experiences, comprehending new situations, arriving at new solutions, and yielding novel products. According to the points mentioned above, it is clear that creative thinking is also a systematic and intricate thinking or mental process. Other researchers claim that creative thinking is a mode or way of thinking that attempts to integrate various elements of the thinking process in a unique and novel way, which is processed and organized by the individual's brain to craft new ideas, perspectives, and things (Santi et al., 2019). In summary, creative thinking is extensively perceived as an ability, skill, or potential, as a thinking process, thinking procedure or mental process, and as a thinking mode or way of thinking, and the enriched meanings reflect the extensive use of creative thinking and the attention it has commanded.

Whether viewed as an ability, a thought process, or a mode of thinking, creative thinking is characterized by four essential features. According to Guilford (1975), creative thinking is characterized by four main features: fluency, flexibility, originality, and elaboration. Fluency, which indicates the smoothness of thinking, is measured by the quantity of ideas produced in a given period. The greater the number of ideas, the more fluid the thinking is. Flexibility, which refers to the variability of thinking, is gauged by the variety of ideas produced; a greater variety of ideas implies that the mind is able to jump between different kinds of ideas, associating as well as distinguishing between ideas. Originality, which refers to the novelty of the thinking, is assessed by the uniqueness of the ideas produced; the more different they are from those of others, and the more they have never appeared before, the higher the originality is. Elaboration refers to the meticulousness of thinking. The more detail you concentrate on, the better the elaboration.

In addition to this, It has been proven that creative thinking is divergent, i.e., it can output many different types of ideas (Adam & Mujib, 2020). Birgili (2015) has argued that creative thinking is open to varying perspectives and criticisms. It has been confirmed that creative thinking is characterized by sensitivity to problems and the ability to identify, analyze, synthesize, define, and solve problems (Sudirjo et al., 2023). In a nutshell, creative thinking is characterized by fluency, flexibility, originality, and elaboration, as well as divergence, openness, and sensitivity to problems. In the face of such a vast range of characteristics of creative thinking, only by understanding creative thinking in its essence can we grasp the goals to be achieved and the methods to be adopted in cultivating creative thinking.

Creative thinking is of the utmost strategic value as a vital problem-solving ability, a systematic process that provides accurate decisions, effective solutions, innovative perspectives, and a mode of thinking that solves fresh problems and creates novelties and is used extensively in practice to cope with global change (Hadzigeorgiou et al., 2012). Creative thinking should be prioritized as a development competency, especially in overcoming challenges (Gafour & Gafour, 2020). The cultivation of creative thinking has always been a topic of recollection. To improve students' creative thinking, scholars have used various ways and modes to explore enhancing and strengthening creative thinking. For example, from the perspective of problem-solving, it is believed that problem-based learning (Buana & Astawan, 2020; Anjarwati et al., 2018) and creative problem-solving (Septian et al., 2020; Yayuk & As' ari, 2020) are two approaches that can effectively improve students' creative thinking skills; in addition to this, researchers have used a variety of specific methods to improve students' creative thinking in the practice of education and teaching. For instance, Halim and Syahrun (2020) indicate that jigsaw cooperative learning promotes students' creative thinking skills. Forte-Celaya et al. (2021) analyzed the effect of active learning strategies on developing students' creative thinking. In addition, worksheet-based learning (Krisdiana et al., 2019), project-based learning (Yamin et al., 2020), journal article writing (Senel & Bagçeci, 2019), instructing with brainstorming (Hidayanti et al., 2018), these approaches also have been used to strengthen students' creative thinking skills.

Within all these methods and strategies, problem-based learning is multiplying and enhancing students' creative thinking. It is employed widely to develop creative thinking with a notable effect. There is a profound relationship between thinking and problem-solving, with the development of thinking contributing to the efficiency of problem-solving and the process of problem-solving facilitating the systematization and refinement of thinking. Kusumawardhany et al. (2022) directly indicated that problem-based learning is intricately associated with creative thinking because it confronts students with authentic problems, puts them into unconventional situations, and pushes them to apply the knowledge and skills they have acquired in order to solve these problems, thus outputting new perspectives and ideas and enabling them to develop their creative thinking (Ananda & Azizah, 2016). PBL provides ample opportunities for self-directed learning, utilizing real-world problems to stimulate students to explore and address issues on their own and for students to increase creative thinking as they tackle new situations and problems (Srikan et al., 2021). At the same time, problem-based learning is conducive to the development of creative thinking skills as it promotes active participation in meaningful problem-solving, careful problem identification, problem analysis, and problem-solving at a high level of cognitive activity (Hidayati et al., 2019). In addition to this, the problem-based learning model provides a discovery space for students, guiding them to utilize their potential to discover and solve problems driven by interest and motivation, thereby boosting creative thinking (Selvy et al., 2020). Thus, problem-based learning can provide authentic problems so that students can promote the development of creative thinking in the process of discovering, analyzing, and settling problems. In order to investigate the effect of problem-based learning on the development of creative thinking, the characteristics of problem-based learning will be analyzed in the following.

PBL originated from McMaster University School of Medicine in Canada and is a learning model designed by the School of Medicine in 1970, which mainly uses real clinical cases for students to diagnose so as to improve students' clinical problem-solving ability, which is based on the problem, and stimulates students to use their communication skills, information processing skills, and problem-solving skills to independently and autonomously learn and deal with the problem (Ernawati et al., 2022). With the extensive use of PBL in the field of education, scholars have developed different opinions on its definition, which mainly contains two kinds, the first of which considers PBL as a learning mode or learning method, and the second of which considers PBL as a teaching strategy or teaching method.

When PBL is used as a learning model, Amrina et al. (2020) identify it as an effective learning strategy based on real-life problems, with the aim of upgrading creative thinking and enhancing problem-solving skills, and a series of knowledge acquisition, conceptual understanding, and problem-solving, is an efficacious learning strategy. At the same time, Purba et al. (2017) believe that PBL is a learning method that develops high-level inquiry and thinking skills, which starts with authentic problems, focuses on knowledge construction, resolves problems through a complete step-by-step process, and enhances students' self-confidence and independence Susetyarini et al. (2022) are very confident that PBL is a discovery and problem-solving learning model that spurs students to use their existing knowledge and skills to locate answers to problems, thereby empowering their creative thinking and problem-solving skills. Some researchers are persuaded that PBL is an efficient learning method that employs authentic problems as the learning context, with the learning objectives of students' creative processing of information and practical problem solving, and with the eventual outcome of improving students' learning skills and performance (Ernawati et al., 2022). Therefore, PBL as a mode of learning is a miraculous method of learning that takes authentic, real, or life problems as a starting point and systematically addresses the problems faced through a series of knowledge, concepts, and skills, thus promoting problem-solving and creative thinking skills in students.

When PBL is considered an instructional strategy, some researchers point out that it is an instructional method with the primary purpose of problem-solving (Sulaiman, 2011). It is also a holistic approach to education that views the nature of learning as the active construction of new knowledge by the learner on the basis of what they already know; the main mission of PBL is to provide learners with opportunities to learn and understand theories of knowledge and develop cognitive abilities; it uses problems as triggers for students' self-directed learning, and group work and discussion as effective strategies for perfecting learning, and it is essentially about problem-solving to increase knowledge and understanding (Awang & Ramly, 2008). PBL is also recognized as a pedagogical approach that focuses on self-directed learning and teamwork, using problems as the entry point for knowledge acquisition and self-directed analysis and discussion and collaboration as the primary learning methods, with the firm belief that this series of procedures implicitly facilitates students' creative thinking and problem-solving skills (Srikan et al., 2021). PBL is also an innovative approach to education that is student-centered, places emphasis on stimulating students' intellectual curiosity through real-life problems, makes problem-solving the central task of teaching and learning, and makes critical thinking and creative thinking skills a crucial goal (Widiastuti et al., 2023). Therefore, PBL as a teaching strategy emphasizes student-centered methods, independent learning, teamwork, and problem-solving as the main purpose and the construction of student knowledge.

In summary, whether it is PBL as a learning model or PBL as a teaching method, realistic and authentic problems are its starting point, and students are its center. It takes knowledge construction and problem-solving as the ultimate goal and students' independent learning and teamwork as important learning strategies, which often enhance students' self-confidence and creative thinking skills.

Problem-solving is the starting point and central task of the PBL model. The process of problem-solving is crucial to the PBL model, and its procedures are mainly centered on problem-solving, which is generally regarded by researchers as consisting of five steps and is widely used in practice. Srikan et al. (2021) designed a 5-step process by applying the PBL model in a study to improve undergraduate students' creative thinking and digital media skills:(1) identifying the problem, (2) analyzing the problem, (3) researching the problem, (4) presenting the results, and (5) summarising and evaluating. Another researcher used the following five procedures in a study to analyze the impact of the use of the PBL model on high school students' creative thinking and problem-solving skills: (1) focusing on the problem and guiding students to become aware of the problem, (2) learning about the problem, so that students can learn about the characteristics of the problem, (3) independently researching and investigating the problem to find a solution to it, (4) solving the problem and presenting the results in a presentation, (5) analyzing and evaluating the problem-solving process (Sihaloho et al., 2017). Wijayanto et al. (2023) identify the five steps necessary for the PBL model as (1) explaining the problem and describing the basics of the problem, (2) assigning students and assigning them to groups as appropriate, (3) guiding the students to conduct independent and group investigations, (4) presenting the results of the investigations and research, (5) evaluating and summarizing the problem-solving procedures. Some researchers add several steps depending on the specific situation and requirements of the study. For example, one researcher used six steps: (1) outlining the subject of the course, (2) posing a problem, (3) defining the problem, (4) exploring the problem, (5) solving the problem, and (6) reflecting on the problem-solving process (Sulaiman, 2011). Other researchers used seven steps: (1) accessing or identifying the problem, (2) finding the focus of the problem, (3) authoritative analysis of the problem, (4) individual research, (5) teamwork, (6) problem-solving, and (7) evaluating the summary (Amrina et al., 2020). In essence, the analysis shows that no matter how many steps researchers use, there are five necessary procedures that they use whenever they apply the PBL model to improve students' creative thinking: First, identifying the problem, focusing on the problem, and posing or providing the problem; second, learning, analyzing or understanding the basic characteristics of the problem; third, investigating the problem, i.e., beginning a systematic investigation of the problem to find a solution; fourth, solving the problem and presenting the results or findings, and fifth, summarizing and evaluating and evaluating the process of solving the problem. These steps are essential procedures for systematic problem-solving, which guide students to carry out problem-solving learning activities in a structured manner and provide a refined operating procedure for increasing students' creative thinking skills.

In studies on the use of the PBL model to improve students' creative thinking, many researchers have affirmed and illustrated the ability of the PBL model to polish students' creative thinking skills. However, these studies are scattered and sporadic in their illustration of the effectiveness of the PBL model in fostering creative thinking. However, there has been no comprehensive, systematic analysis of the effects of the PBL model on improving creative thinking, and there are even fewer comprehensive reports on the exact level of impact of the PBL model on creative thinking. The absence of this synthesis report has prevented the researcher from gaining an in-depth and comprehensive understanding of the role of the PBL model in developing creative thinking. It has also resulted in limitations in the practical use of PBL. Therefore, a systematic literature review on the effect size of the PBL model in improving creative thinking is essential, as it will propel the researcher to a new level of awareness and use of the PBL model and provide new insights and opportunities for developing creative thinking.

This study focuses on collecting relevant studies on the application of PBL to enhancing students' creative thinking and undertaking a meta-analysis of the effect size of PBL to enhance creative thinking based on a comprehensive and systematic calculation and analysis of the effect size of PBL. In order to achieve these objectives, the main issues addressed in this study are as follows:

- Does PBL have a more significant effectiveness in improving students' creative thinking than conventional methods?
- Do The educational stage, measuring method, teaching method, sample size, and subject make a difference in the effect size of PBL on improving students' creative thinking?

The first question primarily compares the effectiveness of PBL with conventional teaching methods in enhancing students' creative thinking and examines whether PBL has a more significant effect. Since a quasi-experimental approach dominates the primary literature collected in this paper, the experiment was designed with an experimental and control group, in which the experimental group was taught employing PBL as a treatment. In contrast, the control group was taught employing a traditional teaching method; hence, the dependent variable is students' creative thinking, which is generally measured by various tests of creative thinking, and the independent variable is the teaching method, which is categorized as PBL versus conventional teaching methods; Every single study calculated the effect size by comparing the data from the experimental and control groups and then applying a formula, where the effect size represents the magnitude of the effect, with a higher effect size indicating that PBL improves students' creative thinking more than the traditional method. However, the sample, subjects, etc., constrain the effect size of a single article. It is impossible to fully and comprehensively demonstrate the effects of PBL, so it is essential to collect a considerable amount of literature, enter each effect size collected into the meta-analysis software, and then analyze them to derive a composite effect size across multiple studies and their level of significance. The overall effect size is the weighted mean of the individual effect sizes, which illustrates the effectiveness and significance of PBL as a whole; therefore, as long as the overall effect size in the meta-analysis is high and significant, it demonstrates that PBL is more effective than traditional methods in promoting students' creative thinking.

The second question focuses on analyzing the effect of moderating variables on PBL to boost students' creative thinking, as each study is affected by a handful of factors with varying high and low effect sizes, in order to analyze the sources of these differences and using PBL more efficiently, the educational stage, methods of measurement, teaching methods, sample size, and subject are considered as moderating variables to interpret the variability between different studies, and to analyze the causes of this variability, so as to explore more deeply the effective ways and strategies of using PBL to improve creative thinking.

Method

Research design

This article will use a meta-analytical approach to investigate the effectiveness of applying the PBL model to improve students' creative thinking skills. Meta-analysis is a scientific quantitative research method. Two essential pre-requisites are crucial to the application of the approach: firstly, providing the effect size, which is the object of analysis of the meta-analysis, the researcher must either extract or adopt the data from the primary literature to calculate the effect size; secondly, evaluating the risk of bias, which is required for the conclusions of the meta-analysis to be correct and reliable, i.e., to test the magnitude of the risk of the primary literature being published and to eliminate the risky literature (Borenstein, 2021).

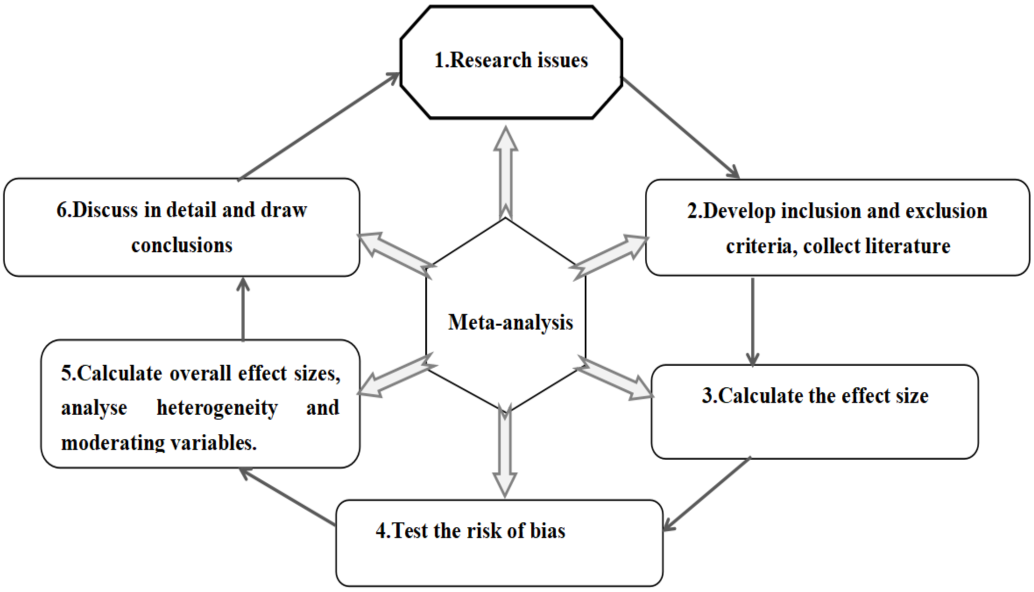

Figure 1: The Research Framework

To meet the above core prerequisites, this study designed a detailed and specific procedure for calculating effect sizes under a variety of studies such as t-tests, ANOVA, correlations, etc., utilizing four formulas; five risks of bias detection tests were also adopted to guarantee the accuracy of the research data. With this core prerequisite fulfilled, this study further designed a specific procedure for applying meta-analysis, firstly, to identify specific research issues and establish keywords to pinpoint the literature and secondly, to develop fine-grained inclusion and exclusion criteria to screen for literature that can provide effect size efficiently; Third, extract the mean, standard deviation, t-value, and correlation coefficient in the literature, and compute the effect size of each literature accurately by applying the formula; fourth, conduct the risk of bias test by using the CMA software, i.e., Funnel plot, Orwin's fail-safe N and other 5 tests based on the specific effect sizes; fifth, calculate the overall effect sizes, analyze the heterogeneity and moderating variables to determine the significance of the data; sixth, a detailed discussion and a succinct conclusion of the study(Asrizal et al ., 2023). According to this procedure, the research framework was designed for this study:

Develop inclusion and exclusion criteria and conduct data collection

This meta-analysis focuses on the effectiveness of utilizing the PBL model to develop students' creative thinking skills, with two research questions: Firstly, Does PBL have more significant effectiveness in improving students' creative thinking than conventional methods? Secondly, do The educational stage, measuring method, teaching method, sample size, and subject make a difference in the effect size of PBL in improving students' creative thinking? Concentrating on these two questions, the study will initially conduct a literature search. Using the keywords "problem-based learning, enhance or improve or develop, students, creative thinking skills or creativity," the study searched four databases, Web of Science, Scopus, Eric, and Google Scholar, and 76 relevant articles were found.

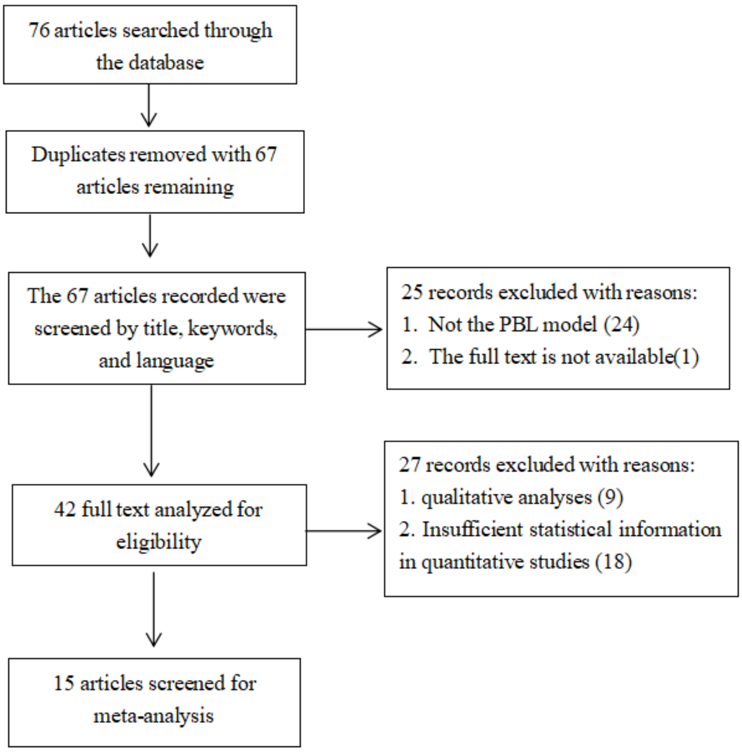

Figure 2: The Flow of Selecting Data Sources

This study uses the PICOS framework (Siagian et al., 2023) as the inclusion criteria for further screening of 76 articles, which can assist researchers in clarifying the inclusion criteria systematically and accurately. The specific screening criteria are as follows:： Population: students in primary schools and above; Intervention, the adoption of a problem-based learning model or a combination of such a model and other methods as a treatment; Comparison, a study that includes comparisons of experimental and control groups, or pre-tests and post-tests, or comparisons of the results of traditional methods with those of a problem-based learning model; Outcome, test scores with creative thinking in the results; Study design, the use of true experiments and quasi-experimental methods. On that basis, there are further criteria: 1. period: from 2013-2024; 2. articles written and published in English; 3. access to full text; 4. sufficient data for effect analysis, including mean, standard deviation, sample size, t-value, P-value, F-value, etc. Based on the inclusion criteria, the literature that reaches the criteria will be screened, and the specific sessions are as follows:

Analyzing the study sample

After screening the inclusion criteria, 15 articles were finally used as the data source for this study. In the meta-analysis, no explicit and specific rules and requirements regarding the amount of literature to be investigated. Based on the analysis of the literature employed by researchers over the years, most meta-analyses adopt between 10-60 articles of literature, which generally include both creative and critical thinking, while a single meta-analysis of creative thinking employs around 5 to 20 articles of literature (Asrizal et al ., 2023; Hikmah et al., 2023; Siagian et al ., 2023; Ramdani & Susilo, 2022). Thus, in a specific meta-analysis, the five separate works of literature on creative thinking are also amenable to meta-analysis, and the conclusions reached remain sound. This study is a meta-analysis specifically focusing on the application of PBL to enhance students ‘ creative thinking, and the number of literature is 15, which is within a reasonable range and appropriate for the application of meta-analysis. These 15 documents are rigorously screened from 76 articles, that is, the most representative of all the literature that fulfills the conditions of the meta-analysis, and among them, 9 documents in the last 5 years cover the latest data and views on the application of PBL to enhance students’ creative thinking. Therefore, the 15 original papers are sufficient to support the conclusions of this study.

The sample employed for meta-analysis in this paper is 15 articles, which were carefully selected to meet the inclusion and exclusion criteria of this paper fully. These 15 articles are across the period of 2013-2024, covering the last 10 years of major research data on the application of PBL to increase the creative thinking of students, and the research involves a wide range of subjects including biology, chemistry, economics, mathematics, physics, etc.; the number of students is large, up to 1009 students, including 531 male students accounting for 52.67%, 492 female students accounting for 47.33%, 25 students in primary school, 83 students in junior high school, 370 students in senior high school and 531 students in university.

Calculation of effect size

The effect size, as a measure of the strength of a phenomenon, is an important statistical concept regarding the effectiveness of a method; the larger the absolute value of the effect size, the more pronounced a phenomenon is, i.e., the more powerful the effect of a method. The effect size can be calculated as the standardized difference in mean between the experimental group and the control group, as the regression coefficient in a regression model, or as the degree of correlation between the two variables, which varies from study to study(Lakens, 2013). For example, some studies have employed Cohen's d, others Hedges' g, and others Eta Squared.

In practical research, the standard for measuring the strength and size of each effect size is inconsistent. In the meta-analysis, in order to compare the effect sizes of different studies, it is necessary to convert different types of effect sizes into the same effect size to analyze and compare them under a unified standard, and the unified effect size used in this study is Cohen's d. Therefore, this study needs to apply different formulas to calculate Cohen's d for each study, as follows:

$$d = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}} \qquad (1)$$

$$d = t\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \quad (2)$$

$$d = \frac{2r}{\sqrt{1 - r^2}} \quad (3)$$

$$d = \frac{2\sqrt{\eta^2}}{\sqrt{(1-\eta^2)}}, \quad \eta^2 = \frac{F \times df_{effect}}{F \times df_{effect} + df_{error}} \quad (4)$$

In quasi-experiments, some studies provide the mean and standard deviation of the experimental and control groups, i.e., Cohen's *d* can be used to calculate the effect size through the mean and standard deviation as in formula 1, $\bar{x}_1$ and $\bar{x}_2$ indicate the mean of the two groups, and SD_1^2, SD_2^2 indicate the variance of the two groups, respectively; this formula implies that the difference between the means of the two groups is divided by the pooled standard deviation of the two groups, i.e. the difference between the standardized means. In some quasi-experiments, applying the t-test to test the significance of the mean between the experimental and control groups, then the *d* effect size can be calculated using the t-value and the sample size of the two groups, i.e., formula 2. Some studies focus on the correlation between PBL and students' creative thinking and provide r-values. The d-effect size can be calculated by applying the r-value according to formula 3. At the same time, other quasi-experiments use analysis of variance (ANOVA) or multivariate analysis of variance (MANOVA) and provide F-values. The F-value and the degrees of freedom between groups (k-1), as well as the degrees of freedom within groups (n-k), are calculated to yield the effect size Eta Squared, thus converting Eta Squared to a *d* effect size as in formula 4 (Fritz, 2012). When the effect sizes of all the studies have been transformed into Cohen's *d* by calculation, each effect size can be analyzed using the CMA software.

Table 1. Categories of effect sizes

Effect Size	Category
$0 \leq ES \leq 0.2$	Low
$0.2 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	High

(Suryono et al., 2023; Hikmah et al., 2023)

The process of data analysis started with an overall analysis, i.e., bias analysis was performed first to test the publication bias of the 15 articles, and articles at risk of bias were screened out, which was done to ensure the impartiality of the data source; Subsequently, the size and level of the combined effect size of these studies were evaluated and the choice of whether to adopt a fixed or random model was made based on the magnitude of the overall heterogeneity, a step taken to ensure the accuracy of the data from the meta-analysis. Secondly, the moderating variables are analyzed according to the magnitude of heterogeneity. This is to find out the causes for the differences or connections between the data to dig out the deeper meanings behind the data, and, finally, the results of the whole study are fully interpreted, explained, and illustrated, mainly through a detailed and thick explanation, to draw a convincing conclusion.

Test the risk of bias

Publication bias in meta-analyses is an important factor affecting the quality of the analysis; therefore, it was crucial to test the 15 papers for publication bias before formal analyses were initiated. This study will use CMA Ver. 3 for publication bias testing, which contains five tests: First, Funnel plot, as the most commonly used approach to evaluate publication bias, mainly evaluates the magnitude of bias by analyzing the uniformity and symmetry of literature distribution in the funnel plot; Second, Orwin's fail-safe N, which determines publication bias by calculating the number of literature that need to override the current effect size, i.e., when the value of Orwin's fail-safe N is greater than 5k+10 (k is the number of original literature, which is 15), i.e., 85, it indicates that no publication bias has been observed (Siagian et al., 2023); Thirdly, Kendall's tau correction test ,and Egger's regression intercept test, these two tests determine the risk of bias by the significance of P-value, when $P>0.05$, all the studies do not have the publication bias; Finally, Duval and Tweedie's trim and fill, which focuses on publication bias by analysing the number of articles trimmed and filled, and the change in effect size after trimming (Aytaç & Kula, 2020).

Figure 3： Funnel Plot of Students' Creative Thinking

Table2. Analysis of Publication Bias

Publication bias analysis	Result
Orwin's fail-safe N	
Z-value	16.95
Z for alpha	1.96
P-value	0.00
N	15
Number of missing studies that would bring P-value to>alpha	1109
Kendall's tau correction test	
Tua	0.31
Z-value	1.63
P-value(2-tailed)	0.10
Egger's regression intercept test	
Intercept	3.05
t-value	1.53
P-value(2-tailed)	0.15
Duval and Tweedie's trim and fill	
Q-value	62.22
Studies trimmed	0

From the funnel plot, it can be seen that 15 articles are mainly distributed in the middle of the funnel, more evenly distributed on both sides of the funnel, and most of the articles fall within the confidence intervals, indicating no publication bias in these articles. Orwin's fail-safe N calculates a value of 1109, and 1109 is much greater than 85, which suggests that 1109 more articles with opposite conclusions would be needed to make the effect size of the original literature zero, so there is no publication bias in these studies. The p-value of Kendall's tau correction test is 0.11; the p-value of Egger's regression intercept test is 0.14, and the p-value of both tests is greater than 0.05, indicating no publication bias in these articles. The results of Duval and Tweedie's trim and fill indicate that the number of articles to be trimmed and filled is zero, which suggests that no original studies have been excluded or need to be filled in with new studies. In summary, the results of the above tests indicate that none of the 15 selected articles had publication bias, and further systematic analyses can be carried out.

Result

After publication bias analysis, 15 articles fully achieved the inclusion criteria. They were identified as data sources for analyzing the impact of problem-based learning on the development of creative thinking and, subsequently, the CMA Ver. Three software were used to analyze the effect size of the above literature at 95% confidence intervals: Standard error(SE), Variance(V), Lower limits (LL) and upper limits(UL), Z-Value, p-value, the effect size under the fixed and random effects models will be calculated as follows:

Table 3. Results of Effect Size Analyses for Primary Studies

Resource	*d*	SE	V	LL	UL	Z	*p*
Pamula et al., 2018	2.607	0.363	0.132	1.895	3.320	7.173	0.000
Helaluddin et al., 2023	2.552	0.345	0.119	1.876	3.228	7.399	0.000
Mariati et al., 2021	1.203	0.165	0.027	0.880	1.526	7.291	0.000
Siti et al., 2021	0.860	0.261	0.068	0.348	1.372	3.291	0.001
Dwi et al., 2023	0.759	0.204	0.042	0.360	1.159	3.723	0.000
Kani et al., 2018	1.387	0.351	0.123	0.699	2.076	3.949	0.000
Dwi et al., 2022	1.413	0.233	0.055	0.995	1.871	6.052	0.000
Indahet al., 2023	1.008	0.255	0.065	0.508	1.508	3.949	0.000
Farrah et al., 2020	0.515	0.232	0.054	0.060	0.970	2.220	0.026
Wartono et al., 2018	1.496	0.290	0.084	0.927	2.065	5.153	0.000
Te Sheng et al., 2022	1.042	0.361	0.130	0.334	1.750	2.885	0.004
Dianita et al., 2023	0.408	0.435	0.189	0.455	1.261	0.938	0.348
Esen et al., 2013	0.552	0.248	0.061	0.066	1.038	2.226	0.026
Roni et al., 2017	1.221	0.280	0.078	0.672	1.770	4.359	0.000
Jason et al.,2016	2.022	0.398	0.159	1.242	2.803	5.078	0.000
Fixed effect model	1.150	0.069	0.005	1.015	1.284	16.735	0.000
Random effect model	1.240	0.150	0.022	0.946	1.533	8.280	0.000

The overall effect size

As can be observed in Table 3, the composite effect size of the 15 articles is *d*=1.15 in the fixed model and *d*=1.24 in the random model, both of which have p-values less than 0.05, indicating that the problem-based learning method can significantly improve the level of student's creative thinking. Moreover, the combined effect size of PBL is high according to Cohen's *d* 's effect size criteria. Among them, the highest effect size *d*=2.607, *p*=0.000; the lowest effect size *d*=0.408, *p*=0.348; out of all the primary literature, only the effect size of the study of Dianita et al.(2023) was not significant, the results of the other 14 literature on the use of Problem-Based Learning to empower students' Creative Thinking were significantly effective. Subsequently, the Heterogeneity Test will be conducted, which is mainly used to test the heterogeneity of the effect sizes of the 15 articles. If the heterogeneity is significant, the meta-analysis will be performed using the random effects model, and vice versa using the fixed effects model (Suryono et al., 2023), and the results of the Heterogeneity Test are shown in Table 4.

The heterogeneity test

Table 4. Results for the Heterogeneity Test

Q-value	df(Q)	*P*	I^2
62.216	14	0.000	77.498

After the Heterogeneity Test, it can be seen that the Q-value is 62.216, $P<0.05$, the heterogeneity is significant; in addition, I^2 is used to measure the magnitude of heterogeneity of the effect size when it is less than 25 percent, it indicates that the heterogeneity is low, when between 25 percent and 75 percent, it indicates that the heterogeneity is medium, and when greater than 75 percent, it indicates that the heterogeneity is high (Aytaç & Kula, 2020). In this analysis, I^2 =77.498 is greater than 75%, which suggests that the heterogeneity of the effect sizes of the 15 articles is large, so this meta-analysis chose a random effects model with a mean effect size of 1.24. However, because of the large heterogeneity of all the articles, this paper is followed by a moderating variable analysis, i.e., subgroup analysis. In meta-analyses related to the development of the human mind, some researchers have used the subject learning and education stages as moderating variables (Hikmah et al., 2023). Some researchers incorporated sample size as a moderating variable、Other researchers have applied measurement and teaching methods as moderating variables (Abrami et al., 2008). Considering previous research, educational stage, measurement method, teaching method, sample size, and subject type will be used as moderating variables for the heterogeneity test of the meta-analysis to analyze the sources of heterogeneity. The following figure presents the heterogeneity test results for each moderating variable (subgroup).

Table 5: Heterogeneity Test results for each subgroup

Groups	Q-value	df(Q)	*P*
Education stage	13.096	3	0.004
Measuring method	1.891	3	0.595
Teaching method	1.867	1	0.172
Sample size	0.485	1	0.486
Subject	37.299	9	0.000

In the heterogeneity test, heterogeneity is not significant when the p-value is greater than 0.05; when the p-value is less than 0.05, heterogeneity is significant. From the results of the heterogeneity analyses of the moderator variables in the figure, it can be seen that the p-values for the measurement method (Q=1.891, *p*=0.595), teaching method (Q=1.867, *p*=0.172), and sample size (Q=0.485; *p*=0.486) are greater than 0.1, and the heterogeneity is not significant. This suggests that the adoption of different ways of testing creative thinking or creativity, the use of problem-based learning, or the combination of the PBL model with Computer Simulation, project-oriented approach scaffolding, brainstorming, and experiential learning methods to teach creative thinking or the size of the experimental sample had no significant effect on the heterogeneity of the effects of creative thinking skills. The p-value was less than 0.1 for the experimental subject (Q=37.299, *p*=0.000) and education stage (Q=13.096, *p*=0.004), indicating significant heterogeneity, thus requiring detailed analyses of these moderating variables.

The analysis of moderating variables

CTST： Questions to test creative thinking skills, set according to the essence of creative thinking; ET：essay test; MT：multiple tests，Observations, questionnaires, interviews, creative thinking indicators; TTCT：Torrance Test of Creative Thinking; PBL: Problem-based learning; PBL+：Problem-based learning integrated with other teaching methods.

Table 6. Results of Effect Size Analyses for Subgroups

Groups	Effect size and 95% confidence interval						Test of null (2-tail)	
	N	*d*	SE	V	LL	UL	Z	*P*
Education stage								
Elementary	1	0.359	0.421	0.177	0.430	1.220	0.938	0.348
Junior high school	1	0.510	0.230	0.053	0.060	0.961	2.220	0.026
Senior high school	6	1.509	0.209	0.044	1.100	1.918	7.233	0.000
University	7	1.179	0.225	0.050	0.738	1.619	5.248	0.000
Measuring tool								
CTST	3	1.607	0.475	0.226	0.675	2.539	3.380	0.001
ET	4	0.984	0.167	0.028	0.657	1.311	5.899	0.000
MT	4	1.273	0.400	0.160	0.490	2.057	3.186	0.001
TTCT	4	1.188	0.313	0.098	0.575	1.802	3.798	0.000
Teaching method								
PBL	9	1.414	0.252	0.064	0.920	1.908	5.611	0.000
PBL+	6	1.030	0.125	0.016	0.785	1.275	8.233	0.000
Sample size								
Less than 30	2	0.910	0.485	0.235	0.040	1.860	1.877	0.000
More than 30	12	1.265	0.160	0.026	0.952	1.579	7.918	0.000
Subject								
Biology	1	1.993	0.329	0.154	1.224	2.762	5.078	0.000
Chemical	2	1.069	0.324	0.105	0.433	1.705	3.296	0.001
Economic	1	2.519	0.341	0.116	1.852	3.187	7.399	0.000
Environment	2	1.764	0.786	0.618	0.223	3.305	2.244	0.025
Inter-discipline	1	1.022	0.354	0.126	0.328	1.717	2.885	0.004
Mathematics	2	0.660	0.172	0.029	0.324	0.997	3.847	0.000
Physics	2	1.339	0.199	0.040	0.948	1.730	6.714	0.000
Science	2	0.889	0.390	0.152	0.126	1.653	2.283	0.022
Statistics	1	0.546	0.245	0.060	0.065	1.027	2.226	0.026
Visual arts	1	1.336	0.346	0.120	0.688	2.044	3.949	0.000

Firstly, in terms of education stage, there are four education stages in this study: primary school, junior high school, senior high school and university, among which the effect size of senior high school is the largest（*d*=1,509， *p*=0.00）, next is university（*d*=1,179, *p=0.00*）, both are high effect sizes； The second is junior high school (*d*=0.510, *p*=0.026), elementary (*d*=0.395, *p*=0.348), both of them belong to the medium effect size, but much lower than that of senior higher school and university, in which the p-value of elementary is greater than 0.05, indicating that compared with other stages of education, the PBL model is not significant for the development of creative thinking in primary school students, but has a great effect on the development of creative thinking in high school and university students.

In terms of subject, this study contains ten types of courses, which are diverse, with the largest effect size being economic (*d*=2.519, *p*=0.000). The other courses with high effect sizes being biology (*d*=1.993, *p*=0.000), environmental education (*d*=1.764, *p*=0.025), visual arts (*d*=1.366, *p*=0.000), physics (*d*=1.339, *p*=0.000), chemical (*d*=1.069, *p*=0.001), Inter-discipline (*d*=1.022, *p*=0.000), science (*d*=0.889, *p*=0.022). This suggests that using PBL teaching methods in these courses can significantly improve students' creative thinking. Mathematics (*d*=0.660, *p*=0.000) and statistics (*d*=0.546, *p*=0.026) belong to the medium effect size; compared to the previous types of courses, the effect of PBL in mathematics as well as in statistics to improve the creative thinking of the students is not as prominent. However, the effect is still significant as the p-value is less than 0.05. In summary, the heterogeneity of this study is not related to the way the data from each study were tested, the method of teaching, or the sample size, but it is mainly influenced by the stage of education and the courses taught.

Discussion

Effectiveness of PBL compared to traditional methods in developing students' creative thinking

This study found a statistically significant effect of problem-based learning on students' creative thinking development through a comprehensive analysis of 15 articles using the random effects model (d=1.24, p<0.05). According to Cohen's (1988) criteria, the overall effect size is of a high category, which shows that problem-based learning is more excellent for developing creative thinking in students than the conventional methods the control group employs. This finding is in line with the findings of other researchers. Some studies confirm that PBL is an effective learning method that pushes students to learn through authentic problems that increase innovation and creativity in learning and can significantly enhance students' creative thinking than traditional methods, which directly instill knowledge instead of providing real problems (Simanjuntak et al., 2021; Amrina et al., 2020). Through a survey study of teachers, Widiastuti et al. (2023) noted that teachers recognized PBL as an effective teaching method to enhance creative thinking. The PBL model promotes students' active participation in authentic problem solving, playing the role of creative scientists throughout the process, actively discussing with the teacher, seriously participating in group work, enthusiastically exchanging ideas with fellow students, bravely expressing their ideas, and solving problems through joint efforts, so that the student's creative thinking ability can be rapidly improved (Wartono et al., 2018; Zulkarnaen et al., 2022; Anisaroh et al., 2018). The PBL model is a student-centered learning model that strengthens students' confidence in learning, improves student initiative, promotes active voice, and facilitates creative thinking; in contrast, in traditional teaching, students' learning is mainly arranged and designed by teachers, and their autonomy and motivation are inhibited, which is not conducive to the development of students' creative thinking(Hasanah et al., 2023; Purba, 2021; Anazifa, 2017). Eny et al. (2018) consider PBL a form of innovative learning that uses teamwork to systematically optimize students' creative thinking skills, pushing them to hone and empower their fluency, sensitivity, flexibility, elaboration, and originality of thinking in problem-solving. It can be concluded that problem-based learning is both an effective learning method and an efficient teaching method because it focuses on authentic problems, provides students with a wide space for discovery, allows students to assume the role of creators, resides at the center of the whole learning process, and actively participates in meaningful problem solving while employing systematic techniques for identifying, defining, analyzing, designing, implementing and evaluating the problem-solving process, and emphasizes teamwork, so it can enhance self-confidence and promote the development of creative thinking. The process of problem-solving and teamwork are valued, so it can improve self-confidence and promote the development of creative thinking.

The effect of educational stage, subjects on the effectiveness of PBL in improving students' creative thinking

Another finding of this study is that the stage of education and the subject significantly affect the improvement of creative thinking by PBL. An analysis of heterogeneity immediately followed the meta-analysis of the overall effect sizes of the 15 articles, and it was found that the heterogeneity of the effect sizes of these 15 articles was very significant (Q=62.216, p<0.1, I^2=77.4980) and came mainly from the stage of education and the type of subject.

Analyzed in terms of education stage, PBL is more suitable for use to improve the creative thinking of students at the high school and university levels, and this conclusion is based on the findings of other researchers. In a study on improving university students' classical 4C (communication skills, collaboration, critical thinking, and creative thinking) skills, Susetyarini et al. (2022) confirm that using PBL can improve university students' creative thinking skills. Srikan et al. (2021) employed PBL in a constructivist learning environment to improve the creative thinking of university students. They concluded that the method efficiently improved the creative thinking of Thai university students because of its explicit learning steps and well-designed learning environment, which were conducive to enhancing their creativity. The study of Hasanah et al. (2023) demonstrated that using PBL assisted by video animation can significantly improve the creative thinking of high school students because this method helps high school students form specific learning goals and motivates them to participate in their academic endeavors actively. The research of Eny et al. (2018) showed that PBL was able to significantly boost students’ creative thinking in a plastic waste disposal course for high school students.

For students in the lower grades, especially those in primary schools and below, the data from the Dianita et al. (2023) study on creative thinking in the primary school science curriculum screened for this study showed no significant effect of PBL. In a review study, Wijayanto et al. (2023) indicated that many studies have evidenced that PBL can be used to improve students’ creative thinking and suggested that PBL can also be utilized with children as young as 5 years of age but did not adequately demonstrate whether the effect was significant or not. However, in a meta-analysis of the application of other methods to improve creative thinking, there were different conclusions. Aytaç and Kula (2020) examine the adoption of a student-centered approach to improving students' creative thinking, and the study's conclusions show that preschool students are best suited to using a student-centered approach to increase creative thinking. A meta-analysis of the application of project-based learning to improve student’s critical and creative thinking found that the effect sizes of students’ creative thinking tended to decrease from primary to university level, with a high effect size of 2.808 at the primary level, which was the most effective (Hikmah et al., 2023). It is evident that PBL, as an effective method to improve creative thinking with explicit steps, specific objectives, and subtle design, significantly affects the creative thinking of students above the high school level. However, PBL is ineffective in improving primary school students' creative thinking skills. However, a student-centered or project-based learning approach is the desirable pathway that should be implemented and investigated.

In terms of subjects, the study covers 11 types of courses, including a variety of courses ranging from primary school to university. As a systematic, well-developed, and effective model of teaching and learning, PBL is highly valued and esteemed by experts, scholars, and front-line teachers. The application of PBL has spread to all stages of schooling, covering subjects such as math, physics, biology and chemistry, pedagogy, and statistics in higher education. The effectiveness of PBL on the development of creative thinking in different subjects is quite variable; it has the most significant effect on the development of creative thinking in economics, with high effect sizes for the development of creative thinking in biology, environmental education, visual arts, physics, science, chemistry, and interdisciplinary subjects. In a study on improving students’ higher-order thinking skills in microeconomics using PBL, Kurniawati (2019) noted that PBL improves students’ creative thinking skills. Susetyarini et al. (2022) indicated that PBL effectively improves creative thinking among university students through a study of learning in biology courses. The research of Satriawan et al. (2020) has revealed that the use of scenario-based PBL enhances students' creativity in physics; the increase in creative thinking in mathematics and statistics is of medium effect size. A comparative study by Ratnaningsih (2017) found that PBL was more powerful in improving students’ mathematical creativity than discovery learning, suggesting that PBL can be more effective in improving students' mathematical creativity. In summary, the possibility that PBL might be utilized for the improvement of creative thinking skills in such numerous disciplines suggests that PBL possesses a very wide range of disciplinary adaptability and enables the stimulation of students' creative interests and the enhancement of their creative thinking in the context of different disciplinary knowledge systems, which is ample proof of its powerful practicality and applicability.

The effect of measurement instrument, teaching method, and sample size on the effectiveness of PBL in improving students' creative thinking

It was also found that the adoption of different measurement tools, teaching methods, and sample sizes did not affect the effectiveness of PBL on creative thinking enhancement, and the reasons for this are explored in detail in this paper. Firstly, before the commencement of the test, the researchers need to verify the Clonbach Coefficients of the test instruments. When the coefficient value is greater than 0.79, it proves that these instruments have the credibility to be utilized for the test of creative thinking (Anjarwati et al., 2018; Creswell, 2017). A total of four measurement instruments (essay test, creative thinking indicators, Torrance test, and combination of multiple testing methods) were used in the 15 articles in this meta-analysis, and all four instruments passed the pre-use reliability test, so the students' creative thinking scores tested with them were highly reliable. In the 15 source papers, the effect size of creative thinking measured by the four tools is greater than 0.8, which is consistent with the overall effect size, so the measurement tools that passed the reliability test will not affect the experimental effect, i.e., no matter which measurement tool is used, the true effect size of using PBL can be tested with a scientific reliability test.

Secondly, regarding the effect of teaching methods on improving students' creative thinking, the findings of the heterogeneous analyses showed that the application of a single teaching method under PBL (d=1.414, p=0.000) or the combination of PBL with other methods (d=1.030, p=0.000) such as brainstorming, scaffolding, etc., yielded high effect sizes and the difference between the two was not significant. However, in the analysis of the reports of individual studies, it was found that the use of PBL in combination with computer simulation was more effective than PBL alone and conventional teaching methods in the study of Simanjuntak et al. (2021). The reason for this is that the combination of PBL and computer simulation is more advantageous because it promotes a greater focus on the problem-solving process, the development of creative thinking in the problem-solving process, and an understanding of the relationship between the theory and the observed phenomena. A combination of PBL and scaffolding was used in the research of Ernawati et al. (2023), and the conclusions of the study showed that this approach significantly improved students' creative thinking in biochemistry courses; he also agrees that PBL alone can improve students' creative thinking, but that scaffolding as an adjunct to PBL in biochemistry provides students with an interesting learning environment, timely feedback, and incentives to ask questions and express their opinions. Praminingsih et al. (2023) illustrated in their study that the use of PBL combined with brainstorming was more effective than traditional methods in improving students' creative thinking with respect to environmentally changing materials. Still, it was not obvious that this method was necessarily better than PBL alone. Chang et al. (2022) used project-oriented, problem-based learning to improve creative thinking in learning interactive disciplines among college students and reported significant results. Dianita et al. (2023) applied a combination of PBL and experiential learning to foster creative thinking in elementary school children's science courses, and the study results showed that this approach was very productive. The findings of these individual studies suggest that PBL, in combination with other teaching methods, can also significantly improve students' creative thinking. However, there is no particularly significant difference in the effectiveness of PBL alone versus a combination of PBL methods. However, combining PBL with other methods is also a highly recommended approach for the discipline or research design requirements.

The third aspect is the sample size; in this study, the sample size was divided into two groups with a cut-off of 30, and the results of the heterogeneous analyses showed that the size of the sample did not have a significant effect on the effect size. However, most studies used samples greater than or equal to 30. Siagian et al. (2023), meta-analysis on the application of the collaborative learning model to improve students' creative thinking, states that whether the sample is greater than or equal to 30 or less than 30, the effect of the PBL model on students' creative thinking is significant. There is no obvious difference, so the sample size does not affect the significance of the final effect size.

To sum up, the effectiveness of PBL is not affected by the measurement tools, single or mixed teaching methods, and the size of the sample, which shows that PBL is a systematic, mature, and refined method as long as the implementation procedures of PBL are strictly followed, following the purpose of PBL, i.e., taking the real problem as the starting point, focusing on the students, adopting the cooperation as the method, and aiming at the knowledge construction problem-solving. Meanwhile, teachers fully utilize their role as facilitators and different measurement tools will measure the real effectiveness of PBL, disparate methods will show the actual effect of PBL, and differing sample sizes will reflect the effectiveness of PBL.

Conclusion

Through a meta-analysis of the application of PBL to improve students' creative thinking skills, the main conclusion of this article is that PBL can significantly improve students' creative thinking. The intensive analyses and discussions found that PBL is more conducive to developing creative thinking in high school and university-level students, and comparatively speaking, PBL is not as effective for elementary-level students. PBL can be effective in various subjects and is particularly effective in enhancing students' creative thinking in economics courses and fostering creative thinking in biology, environmental education, visual arts, physics, science, chemistry, and interdisciplinary subjects. There were no significant differences in the use of various measurement tools, teaching methods, and samples in the study for PBL to enhance students' creative thinking, all of which were high-ranked effect sizes. However, combining PBL with other effective teaching methods is a new tendency to promote PBL to improve creative thinking, providing a new approach to promoting PBL.

Recommendation

In order to maximize the effect of PBL, teachers must adopt real-life, authentic problems in teaching, i.e., important problems that exist or are about to emerge in students' daily lives, rather than directly appropriating problems from books. Secondly, attention is paid to integrating students into the problem scenario so that they can identify the problem as a real problem they have to face rather than an assigned task so that students will realize the importance and relevance of problem-solving and will devote themselves to problem-solving so that they can accumulate knowledge of future life, gather experience in the form of judgment, and formulate ideas to deal with the problem through the problem solving so that they can learn to be dictatorial and develop creative thinking.

In applying PBL to improve students' creative thinking, it is important to put student-centeredness at the center of the process and implement it effectively. In order to achieve this, teachers should first be aware that students can learn independently and co-operatively, and they should take the initiative to provide students with sufficient learning space and cooperation opportunities so that they can take the initiative to identify and solve problems, construct knowledge, and exercise their thinking. Secondly, teachers should be clear about their role in this model. Student-centered learning does not mean that teachers should give up their authority and let students alone, but that they should play a more comprehensive and responsible role as guides, for example, by posing real and interesting questions, organizing structured groupings, providing guidance on difficult problems and conducting fair and impartial evaluations.

This study discovered that PBL has no obvious effect on improving students' creative thinking in primary school. The effect size belongs to the medium level, which is mainly attributed to the fact that there is less related research. It is impossible to conduct a comprehensive and in-depth study. It does not mean that PBL does not affect primary school students at all; as long as more scholars and primary school teachers adopt PBL, dig deeper to solve problems in teaching, and adjust the teaching strategies continuously, the effect of PBL on primary school students will be enhanced. At the same time, other teaching methods, such as student-centered or project-based approaches, should be applied to explore strategies to improve the creative thinking of primary school students to provide more effective approaches for the development of creative thinking at the primary school level.

The findings of the study also reveal that PBL is moderately effective in improving creative thinking at the middle school level and more effective at the high school and university level, and that it can be applied in small classrooms with fewer than 30 students and in large classrooms with more than 30 students or even more students with no change in effectiveness; Neither single nor blended approaches to teaching and various measurement methods affect the effectiveness of PBL, plus its broad subject adaptability to subjects such as economics, biology, chemistry, etc.; therefore, when selecting a method to increase the creative thinking of students in middle school and beyond, teachers can confidently choose PBL; in addition, apart from single PBL, trying to combine brainstorming, scaffolding, project-oriented learning, computer simulation and experiential learning with PBL can also increase students' creative thinking, and mixed or varied methods are more adaptable to different abilities and personalities, so the employment of mixed PBL can also improve students' creative thinking. Adopting mixed PBL is also an innovative way to open up new paths for in-depth study of the development of creative thinking.

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DO YOU REALLY WANT TO LEARN? THE MOTIVATING REASONS BEHIND INDIVIDUAL'S SWITCHING BEHAVIOUR ON NONFORMAL EDUCATION PLATFORM BASED ON PUSH-PULL-MOORING FRAMEWORK

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