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Impact of Blended Problem-Based Learning on Students' 21st Century Skills on Science Learning: A Meta-Analysis

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Abstract

Various similar primary studies report varying impacts of applying blended problem-based learning (Blended PBL) in improving students' 21st-century skills. This study aims to group similar studies on the effect of blended PBL on students' 21st-century skills in science learning through meta-analysis. In addition, studies were analyzed on variations in models, education levels, subjects, and 4C skills. There are 44 articles worth analyzing. The data was analyzed using Excel and JASP applications by presenting results in size effect values, forest plots, and published bias tests. The results of the analysis show that science learning with blended PBL improves 21st-century skills that are better at science learning than other learning (g=0.617, 95% Cl 0.296–0.937, $p < 0.001$, $I^2 = 96.861\%$). Analysis of moderator variables showed that in the variation model, level of education, subjects, and 4C skills, there was a significant effect. These findings confirm that blended PBL is efficiently used to train students' 21st-century skills in science learning.

Introduction

In 21st-century learning, there are basic skills that every student must master to compete globally. The form of 21st-century skills is in the form of 4C skills (Silber-Varod, Eshet-Alkalai, & Geri, 2019). These skills include critical thinking, creativity, communication, and collaboration (Wrahatnolo, 2018). Creativity skills encourage students to think deeply in solving problems (Khoiri, Komariah, Utami, Paramarta, & Sunarsi, 2021; Nurkhin & Pramusinto, 2020). This capability allows students to discover innovative solutions (Siburian, Corebima, & Saptasari, 2019). In addition, communication skills are key in conveying the results obtained, both in writing and verbally, clearly and effectively (Blackmore, Kasfiki, & Purva, 2018). In all learning activities, student-centered learning is emphasized, so collaboration skills are crucial in the learning process (Scager, Boonstra, Peeters, Vulperhorst, & Wiegant, 2016).

The significant development of ICT encourages the formation of students' 21st-century skills. Communication and collaboration in 21st-century learning can be done anywhere and anytime, thanks to the presence of technology (Dakhi, Jama, & Irfan, 2020; Khahro & Javed, 2022; Kolm et al., 2022). With online learning, students and teachers can collaborate and communicate through the online platform provided (Panigrahi, Srivastava, & Sharma, 2018; Saragih, Cristanto, Effendi, & Zamzami, 2020). Online learning allows students to easily access learning materials, assignments, and reference materials and study independently according to their time and needs (Liu, Lomovtseva, & Korobeynikova, 2020). In addition, the presence of technology also supports the application of Blended Learning in schools (Rasheed, Kamsin, & Abdullah, 2020). Blended Learning combines online and face-to-face learning (Hofmann, 2018; Picciano, Dziuban, Graham, & Moskal, 2021). Blended learning allows students to optimize learning time and space according to existing ICT needs and availability (Bouilheres, Le, McDonald, Nkhoma, & Jandug-Montera, 2020). ICT media allows various activities such as conferences, tutorials, and discussions through online platforms (Singh & Thurman, 2019; Tucker, Wycoff, & Green, 2016).

Technological advances should be the primary support in the learning process. However, ironically, problems related to students' ability to master 21st-century skills are still widely encountered. Previous researchers' analysis results reported that students' critical thinking skills in physics learning were included in the low category (Asysyifa, Wilujeng, & Kuswanto, 2019; Neswary & Prahani, 2022; Wulandari, Hariyono, Suprapto, Hidaayatullaah, & Prahani, 2021). In fact, from elementary school to college education levels, students' high-level thinking skills related to learning science about environmental materials are relatively low (Ichsan et al., 2019). In implementing direct learning in schools, teachers also seem to have difficulty improving students' critical thinking skills in biology learning (Bustami, Syafruddin, & Afriani, 2018; Saputri, Rinanto, & Prasetyanti, 2019). Further efforts must be made to overcome these obstacles and create a learning environment that encourages students to develop 21st-century skills.

One solution offered by previous researchers in supporting the improvement of 21st-century skills is the implementation of problem-based learning (PBL) and blended science learning. In physics, blended learning allows for systematically compiling learning materials in an e-learning system for teachers (Krasnova & Shurygin, 2020). Blended learning supports the improvement of students' physics learning outcomes (Alsalhi, Eltahir, Dawi, Abdelkader, & Zyoud, 2021). Science learning can support improving students' process skills and learning outcomes in secondary school (Harahap, Nasution, & Manurung, 2019). Blended learning strategies have improved academic performance, motivation, attitude, and student satisfaction and provided convenient and flexible learning. Implementing blended learning strategies has also proven cost-effective (Khalil, Abdel Meguid, & Elkhider, 2018). Blended learning can encourage students' science motivation in learning (Rafiola, Setyosari, Radjah, & Ramli, 2020; Khairani, Suyanti, & Saragi, 2020). This learning has a good effect on the formation of attitudes and performance from science learning outcomes (Alsalhi, Eltahir, & Al-Qatawneh, 2019). Blended PBL learning encourages the improvement of skills in the study of biology and physics (Lukitasari, Purnamasari, Utami, & Sukri, 2019; R Sujanem & Suwindra, 2023; Marnita, Taufiq, Iskandar, & Rahmi, 2020). Through this learning, students learn about concept knowledge and hone problem-solving skills useful in everyday life (Ali, 2019). Science learning can encourage students to be more communicative and collaborative in elementary school through problem-based learning (Khairani et al., 2020). Blended learning makes students more creative and can increase collaboration skills in biology learning (Nurwidodo, Ibrohim, Sueb, Abrori, & Darojat, 2023; Sugiharto, Corebima, & Susilo, 2019). Train students' communication skills in higher education in blended learning (Suana, Distrik, Herlina, Maharta, & Putri, 2019). However, research results also report the negative effects of blended learning and problem-based learning (PBL). Some students may have difficulty managing time and self-managing online learning. The results of the learning evaluation report on blended PBL make it difficult for students to understand the material as a whole (Koppikar, Amashi, Vijayalakshmi, Kandakatla, & Baligar, 2022). In addition, challenges in supervising and controlling the learning process can also be an obstacle in implementing blended learning (Hrastinski, 2019).

Various study results report the impact of applying blended learning models and problem-based learning on increasing 4C performance. However, to date, these reports have not provided a comprehensive answer. Therefore, the problems described in these similar studies can be formulated in the following research questions (RQ):

RQ 1: What is the impact of blended PBL on 21st-century skills compared to other learning?

RQ 2: What is the effect of moderators in blended PBL on the variation model, level of education, subjects, and 4C skills?

Method

This study used meta-analysis methods to investigate the impact of influences from similar studies. Meta-analysis is a process of statistical analysis that combines the results of similar individual studies to synthesize findings from previous studies. To carry out the meta-analysis, this study followed the guidelines of Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) (Moher, Liberati, Tetzlaff, Altman, & Group, 2010). In addition, a systematic review analysis is carried out to identify and analyze relevant studies to answer research questions. The stages of the meta-analysis include a) study collection, b) coding, c) effect size calculation, and d) moderate effect tracing of study characteristics (Glass, McGaw, & Smith, 1981).

Search Article and Inclusion Criteria

The databases used in the analyzed studies were sourced from Eric, Dimensions, Google Scholar, Science Direct, and Springer databases. The search for similar studies used keywords with Blended-PBL, PBL, Blended, Science, and 21st-century skills. The words AND and OR filter the studies sought and are limited to titles and abstracts. All studies obtained are synchronized to the Reference Manager (Mendeley) as a reference source. Researchers applied the PRISMA Guidelines to conduct this study's inclusion and exclusion process. Some of the inclusion criteria used include:

1. The studies range from 2013 to 2023
2. Studies are written in English.
3. Studies are not at the level of early childhood/kindergarten education
4. Studies come from ISSN-indexed journals, international and conference
5. Published studies related to blended PBL in learning physics, chemistry, biology, and science.
6. Studies do not include medical and health fields.
7. The study presents complete information on the number of samples, mean values, and standard

deviations from the control and experimental classes and t values.

Figure 1 shows inclusion and exclusion in this study. The total number of studies found is 18017 articles in the ERIC database, 206 articles in Science Direct, 126 articles, and 76 articles. In Springer, there are 9 articles, and in Google Scholar, 17600 articles.

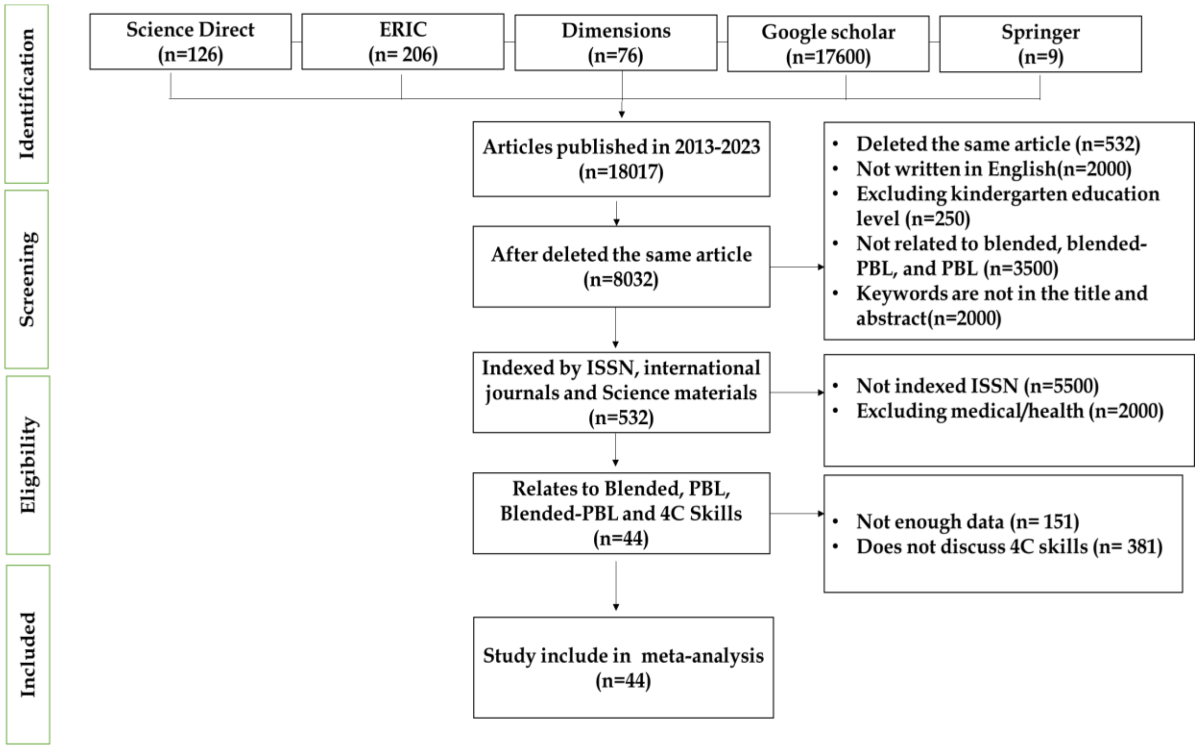

Figure 1. PRISMA Flow Diagram

Data Analysis

A meta-analysis combines quantitative data from various studies to analyze the effect of blended PBL by calculating effect size. Data is analyzed and processed using Excel and JASP applications. Excel applications are used to process data and estimate effect sizes. In contrast, JASP applications are used in meta-analyses to describe forest plots, identify heterogeneity, examine funnel plots, and detect potential publication bias. To calculate the effect size, the mean value (x), standard deviation (SD), and sample size (n) of the control and experimental groups (Hedges, 1982). The equation used in calculating the size effect is presented in Equation 1 and Equation 2.

$$g = \frac{\bar{X}_E - \bar{X}_C}{SD_{whitin}}\left(1 - \frac{3}{4df-1}\right) \quad (1)$$

$$SD_{whitin} = \sqrt{\frac{(n_E-1)S_E^2 + (n_C-1)S_C^2}{n_E+n_c-2}} \quad (2)$$

If the study does not find the average value and effect of the measure, it can be calculated using the t-test value (Rosenthal, 1986; Thalheimer & Cook, 2002). Use the following equation to convert the t-test value to an effect measure.

$$g = \frac{t}{\sqrt{n}}\left(1 - \frac{3}{4df-1}\right) \quad (3)$$

g is the effect measure calculated based on the data obtained, while SD is the standard deviation. In estimating the size of this effect, researchers reported using g Hedge, which is known to perform better than Cohen's d in overcoming statistical bias (Borenstein, Hedges, Higgins, & Rothstein, 2021). The classification of effect size values includes g = 0.2 (small effect), g = 0.5 (medium effect), g = 0.8 (large effect), g = 1.20 (huge effect), and g = 2.0 (very huge effect) (Sawilowsky, 2009).

Results

Description of Characteristics of a Meta-Analysis Study

Forty-four studies are considered worthy of analysis from data findings amounting to 18017. The article is done coding with ease of analysis. In addition, article grouping is based on author, education level, models, 4C Skills, subject, and effect size (g). There are 3 models spread over PBL, blended PBL, and blended. Education levels are spread across primary schools, secondary schools, and universities. There are 4C skills: critical thinking, creativity, collaboration, communication, and educational fields spread across physics, chemistry, biology, and science. The studies used in the meta-analysis are presented in Table 1.

Table 1. Characteristics of a Meta-Analysis Study

Articles	Education Level	Models	4C skills	Subjects	g
(Webster et al., 2022)	University	PBL	Collaboration	Biology	0.1
(Siew & Mapeala, 2016)	Primary Schools	PBL	Critical thinking	Science	1.08
(Anazifa & Djukri, 2017)	Secondary Schools	PBL	Critical thinking	Biology	0.02
(Ismoyo, 2017)	Secondary Schools	PBL	Critical thinking	Physics	0.68
(Suwono & Dewi, 2019)	Secondary Schools	Blended PBL	Critical thinking	Biology	1.39
(Sulaiman, 2013)	University	PBL	Creativity	Physics	-1.85
(Yoon, Woo, Treagust, & Chandrasegaran, 2014)	University	PBL	Creativity	Chemistry	1.23
(Batlolona, Diantoro, & Latifah, 2019)	Secondary Schools	PBL	Creativity	Physics	1.9
(Zhou, Huang, & Tian, 2013)	Secondary Schools	PBL	Critical thinking	Chemistry	0.19
(Ayyildiz & Tarhan, 2018)	Secondary Schools	PBL	Critical thinking	Chemistry	1.32

Articles	Education Level	Models	4C skills	Subjects	g
(Temel, 2014)	University	PBL	Critical thinking	Science	0.7
(Balim, Inel-Ekici, & Özcan, 2016)	Secondary Schools	PBL	Critical thinking	Science	0.6
(Sriarunrasmee, Techataweewan, & Mebusaya, 2015)	University	Blended	Communication	Science	0.41
(Ramdani, Purwoko, & Yustiqvar, 2021)	University	Blended	Creativity	Science	0.05
(Hussain & Anwar, 2017)	Secondary Schools	PBL	Critical thinking	Chemistry	2.73
(Rudibyani, 2019)	Secondary Schools	PBL	Creativity	Chemistry	1.66
(Lisniandila, Santyasa, & Suswandi, 2019)	Secondary Schools	PBL	Critical thinking	Physics	0.81
(Parno, Asim, Suwasono, & Ali, 2019)	Secondary Schools	PBL	Critical thinking	Physics	0.3
(Nurdin & Setiawan, 2016)	Secondary Schools	PBL	Critical thinking	Physics	0.53
(Sari, Suyanti, & Yus, 2022)	Primary Schools	PBL	Creativity	Science	0.27
(Twiningsih, 2019)	Primary Schools	PBL	Creativity	Science	0.51
(Sinaga, 2021)	Secondary Schools	PBL	Critical thinking	Physics	-0.3
(Saldo & Walag, 2021)	Secondary Schools	PBL	Creativity	Physics	0.41
(Zain, 2018)	Secondary Schools	Blended	Critical thinking	Physics	0.92
(Sholikh, Sulisworo, & Maruto, 2019)	Secondary Schools	Blended	Critical thinking	Physics	0.6
(Denny, Utami, Rohanah, & Muliyati, 2020)	Secondary Schools	Blended	Critical thinking	Physics	2.14
(Setiadi, 2021)	Secondary Schools	Blended	Critical thinking	Science	1.64
(Kesuma, Sesunan, & Wahyudi, 2022)	Secondary Schools	Blended	Critical thinking	Physics	0.98
(Zulhamdi, Rahmatan, Artika, Pada, & Huda, 2022)	Secondary Schools	Blended	Critical thinking	Biology	1.72

Articles	Education Level	Models	4C skills	Subjects	g
(Ahyar, 2023)	University	PBL	Communication	Science	2.67
(Jatmiko et al., 2018)	Secondary Schools	PBL	Critical thinking	Physics	0.45
(Boleng & Maasawet, 2019)	Secondary Schools	PBL	Critical thinking	Biology	0.27
(Marnita et al., 2020)	University	Blended PBL	Collaboration	Physics	0.87
(Rai Sujanem, Poedjiastuti, & Jatmiko, 2018)	Secondary Schools	PBL	Critical thinking	Physics	-4.55
(Mustofa & Hidayah, 2020)	Secondary Schools	PBL	Critical thinking	Biology	-0.87
(Sihaloho, Sahyar, & Ginting, 2017)	Secondary Schools	PBL	Creativity	Physics	0.57
(Angraeni, 2021)	University	PBL	Critical thinking	Physics	0.08
(Bektiarso & Dewi, 2021)	Secondary Schools	PBL	Creativity	Physics	1.23
(Rajeswari, 2015)	Secondary Schools	PBL	Critical thinking	Chemistry	0.45
(Priyadi & Suyanto, 2019)	Secondary Schools	PBL	Critical thinking	Biology	1.1
(Suana, Ningsih, Maharta, & Putri, 2020)	Secondary Schools	Blended	Critical thinking	Physics	0.88
(Najib & Jatmiko, 2022)	Secondary Schools	Blended	Critical thinking	Physics	0.07
(Syukri, Herliana, Amalia, & Wahyuni, 2022)	Secondary Schools	Blended	Creativity	Physics	0.55
(Serevina & Meyputri, 2021)	University	Blended	Creativity	Physics	0.8

Effect Size Test Results of Blended PBL on Student Science 21st Skills

RQ 1: What is the impact of blended PBL on 21st-century skills compared to other learning?

In performing meta-analyses, randomized effects were used to consider variations between studies included in the analysis. Using random effects in meta-analyses allows combining data from different studies by accounting for variation and heterogeneity and overcoming statistical biases (Borenstein et al., 2021). The heterogeneity test results using a randomized effect approach from 44 studies investigating the effect of blended PBL on 21st-century skills in science learning were presented as forest plots. Information about the data code, point estimation, effect size (g), and 95% confidence interval (Cl) is shown in Figure 2 as a forest plot.

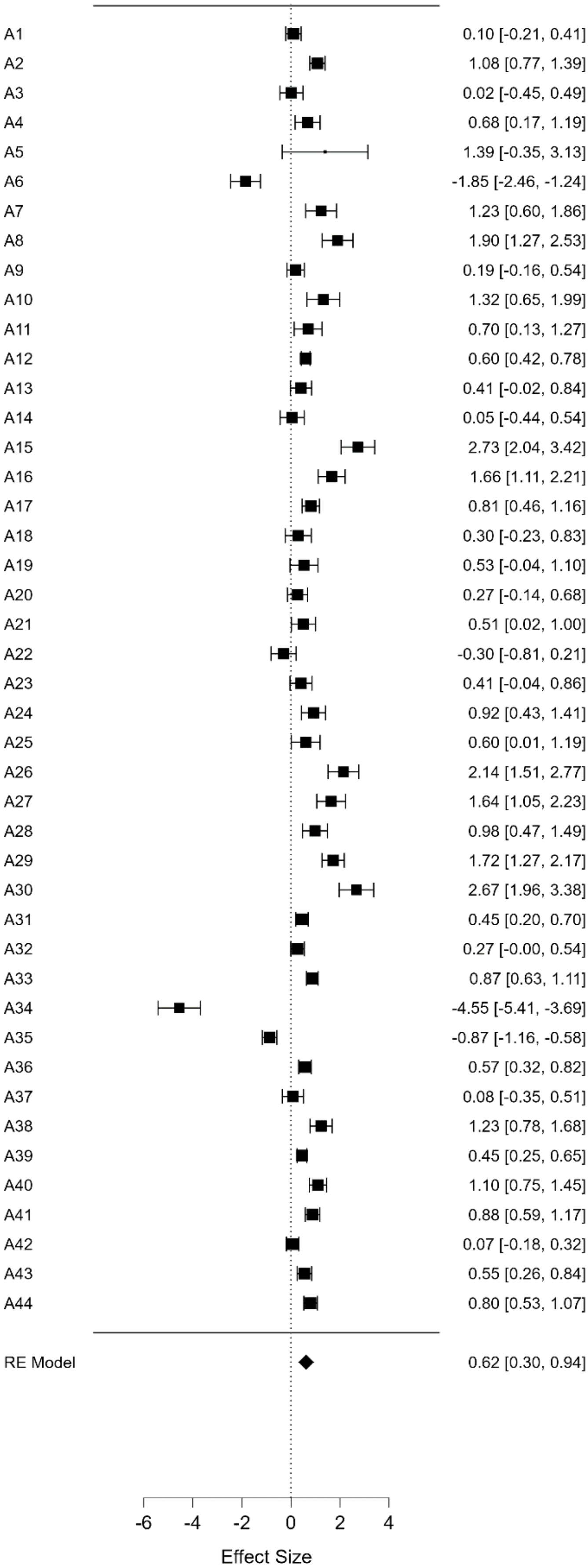

Figure 2. Forest Plot for Effect Size

The distribution of effect size values at a 95% confidence level shows significant variation. Some studies show the distribution is on the right side of zero, while others are between the left side. Research on the right side of zero provides information about a significant increase. The interval range of effect size distribution at a 95% confidence level is between 0.3 to 0.94. The average effect size value is 0.62, which falls into the medium category. The heterogeneity test was used to evaluate the impact of blended PBL on 4C skills. In heterogeneity tests, data are presented through Q, p, and I values. The value I is used to describe the true degree of heterogeneity of the data distribution (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). The results in Table 2 indicate differences in learning improvement using Blended-PBL compared to other learning in the randomized effect model (g = 0.617, 95% Cl 0.296–0.937, $p < 0.001$, $I^2 = 96.861\%$).

Table 2. Results Meta-Analysis

Variable	Overall	95% Confidence (Cl)	
		Lower	Upper
Number of Samples (K)	44		
Heterogeneity test (Q)	575.978		
P-Value	<0.001*		
Standard score (z)	3.774	0.296	0.937
Effect Size (g)	0.617		
Heterogeneity test (I^2 %)	96.861	95.504	98.219

* P-Value < 0.05, Significant effect

Results of the Blended PBL Model Effect on Moderator Variables

RQ 2: What is the effect of moderators in Blended-Problem Based Learning on variation model, level of education, field of education, and 4C skills?

The results of the heterogeneity test allow the analysis of the moderator effect of the studies conducted. Test the hypothesis on the moderator effect to obtain a significant effect if the p-value <0.05. Analysis of the blended PBL moderator effect involving variables of model variation, level of education, field of education, year of publication, and 4C skills can be found in Table 3.

Table 3. Moderator Analysis

Moderator	k	Effect size	Category	Qb	P-Value
Model Variation				27.48	0.000*
Problem-Based Learning	30	0.494	Small effect		
Blended Learning	12	0.873	Large effect		
Blended PBL	2	0.879	Large effect		
Level of education				8.092	0.02*
Primary Schools	4	0.859	Large effect		
Secondary Schools	30	0.622	Medium effect		
University	10	0.499	Small effect		

Moderator	k	Effect size	Category	Qb	P-Value
Subjects				29.363	0.000*
Physics	22	0.384	Small effect		
Chemistry	6	1.228	Huge effect		
Biology	7	0.461	Small effect		
Science	9	0.853	Large effect		
4C skills				33.135	0.003*
Critical Thinking	28	0.567	Medium effect		
Creative	12	0.610	Medium effect		
Collaboration	2	0.492	Small effect		
Communication	2	1.522	Huge effect		

* P-Value < 0.05, Significant effect

Publication Bias

Publication bias associated with statistically insignificant effects was an important issue in the meta-analysis (Borenstein et al., 2021). This bias can arise from various factors that affect the process of publishing research results (Egger, Smith, Schneider, & Minder, 1997). Several methods commonly used in meta-analysis are used to identify and overcome publication bias, including funnel plot, file drawer analysis, and egger regression. Funnel plots are used to observe the symmetry of the distribution of published study results, while drawer analysis files attempt to estimate the number of studies that may not be published due to insignificant or not in line with expectations. Egger regression, on the other hand, is a statistical method used to test for publication bias based on the relationship between the study's sample size and the reported effect. By applying these methods, researchers can identify and reduce potential publication bias, resulting in more accurate and reliable meta-analysis results. The results of the publication bias test are shown in Figure 3 and Table 4.

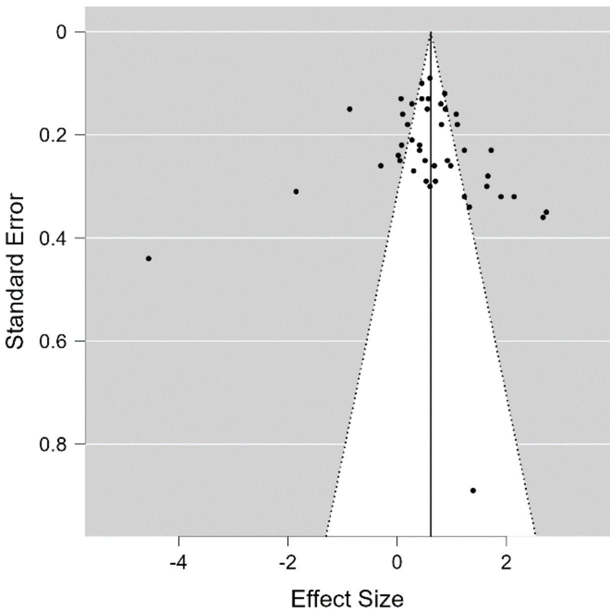

Figure 3. Funnel plot

Table 4. Publish Bias Test

Variable	Egger's test	File Drawer Analysis	Funnel plot asymmetry
z	0.368		
p	0.0713		0.054
Fail-Safe N		5838.00	
Target Significance		< .001	
Kendall's τ		0.050	0.204

*p>0.05 No publish bias

Figure 3 shows the symmetrical shape of the funnel plot. The results of the funnel plot are supported by a p>0.05 value indicates that the effect size distribution tends to be symmetrical. The p values in the egger test and funnel plot asymmetry, namely p=0.0713 and p=0.054, which exceed the set limit, indicate a symmetrical distribution of effect sizes. Furthermore, fail-safe number value analysis was used to evaluate publication bias using the 5K+10 method (Rosenthal, 1986). In this meta-analysis, the fail-safe value of N was 5838.00 at a 95% confidence level based on the Rosenthal procedure. Since the value of 5K+10 is much lower than the value of fail-safe N, it can be concluded that there is no publication bias. Thus, based on the results obtained, no bias was found in all tests performed.

Discussion

The study results showed a positive effect of blended PBL on 4C skills in science learning, with the average value of the effect size being 0.617. The magnitude of the finding value obtained informs the effect of a size greater than g = 0.5, which means that the application of blended PBL is in the medium category. The findings of studies that have been carried out are in line with previous researchers. The results of previous research reported the value of the effect size of 11 studies on science learning achievement by applying problem-based learning obtained a value of 0.871 in the large category (Funa & Prudente, 2021). In addition, mapping studies from the application of blended learning in supporting the mastery of critical thinking skills significantly improve students' critical thinking skills (Ayu, Saputro, & Mulyani, 2020). The application of blended learning in K12 reported a size effect value of 0.74 in the health sector's medium category in science learning (S. Li & Wang, 2022). However, other findings report different impact results. The application of learning before it is implemented in schools has little positive effect (C. Li, He, Yuan, Chen, & Sun, 2019).

Blended PBL learning combines face-to-face and online blended learning and problem-based learning elements. Problem-based learning helps students develop problem-solving and independent learning (Hung, 2015). Meanwhile, blended learning encourages accelerating the knowledge transfer process in effective learning to improve students' abilities at the K12 level (Turk, Ertl, Wong, Wadowski, & Löffler-Stastka, 2019). Increasing student abilities is influenced by interaction in learning, internet networks, and the presence of students and teachers (Nortvig, Petersen, & Balle, 2018). Students are more actively engaged, and learning attendance is increased in blended learning (Gleadow, Macfarlan, & Honeydew, 2015; Ustun & Tracey, 2020).

Variations of models from studies have been analyzed in blended, PBL, and Blended PBL learning reviews. The results of this study showed significant effects based on variations in the model. The PBL model is widely implemented to train students' critical thinking and creative skills (Jatmiko et al., 2018; Rahmadita, Mubarok, & Prahani, 2021; Siew, Chong, & Lee, 2015). The combination of blended Learning and PBL can support online and online learning to encourage mastery of critical thinking skills (Lukitasari et al., 2019; R Sujanem & Suwindra, 2023). In blended learning, online platforms influence the learning process, so this learning model encourages students to communicate actively and collaborate with fellow students (Ustun & Tracey, 2020).

In science learning, there are variations in the effect of different sizes. In chemistry, there is the largest size effect compared to other fields. The application of blended PBL in learning shows a significant influence between physics, chemistry, biology, and science fields. The blended learning model supports learning activities, especially in the experimental process (Harahap et al., 2019). Science learning is perfect for explaining real-world problems.

The application of the blended PBL model at the education level is spread at the primary school (SD), secondary school, and university levels, which have different effects. Learning at every level shows a significant influence. Previous studies re-explain the definition of various applications of blended PBL from 8 studies in higher education on blended PBL (Thorndahl & Stentoft, 2020). Blended learning supports good teaching and learning in primary, secondary, and tertiary schools (Kumar et al., 2021). At the middle school education level, it positively influences student motivation and learning outcomes in problem-solving (De Witte & Rogge, 2016). Blended learning is positively influenced, especially at the university level, so its use is dominant in the university environment (Castro, 2019; Ma’arop & Embi, 2016).

Analysis of moderator variables regarding 21st-century ability skills shows a separation in critical thinking, creativity, collaboration, and communication. This learning significantly affects the development of 21st-century skills in students. One important aspect of developing critical thinking skills is learning that focuses on critical and creative thinking processes (Styers, Van Zandt, & Hayden, 2018). Active learning encourages the formation of students' science critical thinking (Styers et al., 2018). Students are taught to analyze information, evaluate arguments, and make decisions based on careful consideration. In addition, in the context of 21st-century learning, communication has a crucial role. Advances in technology and online platforms allow students to communicate anytime and anywhere (Dakhi et al., 2020). Through this communication, students can develop effective communication skills, such as conveying ideas clearly, listening with empathy, and collaborating well in teams. Blended learning as a whole supports the learning process in schools. By utilizing technology and a combination of face-to-face and online learning, students can gain a diverse and well-rounded learning experience (Nerantzi, 2020). This method allows students and teachers to access learning resources, interact, and engage in learning activities (Dakhi et al., 2020). Thus, blended learning can increase the effectiveness and efficiency of learning in schools.

Conclusion

A meta-analysis of 44 articles showed that science learning using blended PBL improved 21st-century skills better than other learning (g = 0.617, 95% Cl 0.296–0.937, p < 0.001, I^2 = 96.861%). The effect size is included in the medium category. The results of the publication bias test using the egger test method, file drawer analysis, and funnel plot asymmetry showed that no publication bias was detected. Analysis of moderator variables in the form of model variations, education level, field of education, and 4C skills have significant effects, indicating that these factors play an important role in research. Taken together, the findings of this meta-analysis confirm that blended PBL is an efficient learning model for improving 21st-century skills.

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