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The Effect of the Problem-Based Learning Model on 21st Century Student Skills: A Meta-Analysis

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Abstract

This study aims to investigate the impact of Problem Based Learning (PBL) on the development of 4C skills (Critical Thinking, Creativity, Collaboration, Communication) among students. Through meta-analysis, data from 20 national and international journal articles published between 2018 and 2023 were analyzed. Findings indicate that the consistent use of PBL yields a highly significant effect, with an average effect size of 1.72. These results affirm the effectiveness of PBL in enhancing students' 4C skills, underscoring the importance of this instructional approach in the context of 21st-century education, which emphasizes critical thinking, creativity, collaboration, and communication skills. The practical implications of this study highlight the necessity of integrating PBL models in instructional design to facilitate the development of 21st-century skills among students. Further research could delve into specific aspects of PBL usage and its impacts on student learning outcomes and academic achievement.

A. Introduction

One aspect of national development is to enhance the education system to empower human potential and improve the quality of human resources [1]. In the 21st century era, education holds a crucial central role as it requires individuals equipped with skills to address challenges and find solutions to various issues faced [2]. The goal of National Education in the 21st century is to realize the nation's aspirations by creating quality individuals, globally competitive, with integrity, and capable of positively contributing to national development [3]. A happy and prosperous Indonesia, with a respected and equal position on the world stage, can be achieved through the formation of a society with quality human resources [4]. This is accomplished through individuals who are independent, have the will and ability to realize the nation's aspirations, in accordance with Ministerial Regulation No. 21 of 2016 [5]. Indonesian education must ensure that its quality aligns with the demands and challenges of 21st-century skills.

Students must master 21st-century skills, including critical thinking, creative thinking, collaboration, and communication, often referred to as the 4C skills [6]. Therefore, it is crucial to effectively integrate 21st-century skills into the learning process. It is important to recognize that the integration of 21st-century skills can be achieved through instructional materials development [7]. As a vital aspect of learning, instructional materials play a crucial role as learning resources that support the development of these skills [8]. Instructional materials consist of various types such as modules, e-books, flipbooks, handouts, brochures, and others [9]. These materials can be learned by students independently or taught through direct instruction. Integrating 21st-century skills into the learning models is also crucial. This aims to enable students to effectively and efficiently address problems, gain a deep understanding of the content, and develop the skills needed in real-life situations.

The use of instructional models can significantly impact the development of students' 4C skills in problem-solving [10]. In the context of the Free Curriculum, which aims to enhance 4C skills, several instructional models are recommended. These include project-based learning, discovery learning, inquiry learning, problem-solving, and problem-based learning [11]. Through the implementation of these models, students are expected to hone their critical thinking, creativity, collaboration, and communication skills to address real-life challenges [12], [13]. Numerous studies have shown that implementing the Problem-Based Learning (PBL) model has a positive impact on enhancing students' 4C abilities. According to [14], the Problem-Based Learning model is a learning approach designed to stimulate students' high-level thinking skills in the context of real-world problem-focused situations integrated into the learning process [15]. Meanwhile, according to [16], the Problem-Based Learning model plays a role as an approach where students engage in problem-solving through several stages of scientific methods. Through this approach, it is hoped that students can learn knowledge related to the problems they face and develop skills in problem-solving. The application of the Problem-Based Learning model also allows the assessment of students' abilities in problem-solving and communicating their knowledge discoveries by conducting experiments with their groups [17].

The study by [18] indicates that the Problem-Based Learning (PBL) model is capable of enhancing critical physics skills. Similar findings are supported by the research of [19], affirming that the Problem-Based Learning model significantly influences students' critical thinking skills. Furthermore, research by [20] explains that Problem-Based Learning also has a positive impact on students' creative skills in physics subjects. Given the importance of 4C skills and the significant influence of the PBL model on students, a meta-analysis was conducted to measure the effect size of the PBL model on 21st-century skills of students. The research problem formulation is how the use of the PBL model influences 21st-century skills considering educational levels, types of instructional materials, and learning outcomes. The objective of this study is to assess the extent of the influence of the PBL model on 21st-century skills, considering educational levels, types of instructional materials, and students' learning outcomes in relation to 4C skills.

B. Research Method

This research aims to analyze and compare the impact of the Problem-Based Learning (PBL) model on enhancing students' 4C skills [21]. The study employs a meta-analysis research design to synthesize findings from existing literature [22]. Meta-analysis research involves integrating similar research findings to produce insights aimed at understanding rapid research developments, as proposed by Glass [23]. Data collection involves analyzing documents from national and international journal articles through searches on Google Scholar. In the search for articles, the keywords "Problem Based Learning" and "4C" were used, with publication years ranging from 2018 to 2023. The search was limited to articles published in accredited journals. A total of 20 articles were found through this search process.

The research procedure is adapted to the meta-analysis steps proposed by David B. Wilson and George A. Kelley, as elucidated in the study by [24]. These steps include:

1. Defining the topic or issue to be investigated. In this research, the topic or issue under investigation is the impact of using Problem-Based Learning (PBL) instructional models on the development of students' 4C skills.
2. Determining the research years to be used as data sources. In this study, the period of research findings used as data sources consists of national and international journal articles published from 2018 to 2023.
3. Conducting a search for relevant research reports related to the problem or topic under investigation.
4. Reading the titles and abstracts of educational and research journals to assess their suitability with the research problem.
5. The research focus is emphasized on the identified issues, research methodology including the type of research, location and period of research, methods used, population and sample, sampling technique, data analysis technique, and the results obtained.
6. Each study is categorized based on its characteristics.
7. The results of each study are compared by adjusting their categories.

8. Conclusions are analyzed by evaluating the methods and data analysis used in each study, thus identifying the strengths and weaknesses of previous research.
9. Conclusions of the meta-analysis research are drawn based on the above steps.

In this research, the data analysis technique utilized is known as effect size analysis, also referred to as the analysis of the magnitude of the effect [25]. Subsequently, the obtained data is calculated using the effect size formula [26]. The effect size formula is as follows:

$$d = \frac{\bar{X}_t - X_c}{S_{pooted}} x\ 100\%$$

With:

D = Cohen's d effect size

$\bar{X}_t$ = mean treatment condition

The calculation results will yield values that are then interpreted using a table of effect size categories [27]. The effect size categories table is as follows:

Table 1. Criteria for Effect Size

Effect Size Magnitude	Description
0,00 – 0,20	Weak effect
0,21 – 0,50	Low effect
0,51 – 1,00	Moderate effect
> 1,00	High effect

C. Result and Discussion

A total of 20 articles have been analyzed with the moderator variables being educational level, subject matter, and 21st-century skills. After collection, each article was assigned a code, and then the effect size values were searched for. The effect size values of the impact of Problem-Based Learning (PBL) model on the 21st-century skills of students are documented in Table 2.

Table 2. Effect Size Results for Each Article

Code	Year	Effect Size	Category
A1	2018	3,57	High effect
A2	2021	4,00	High effect
A3	2022	0,97	Moderate effect
A4	2019	1,13	High effect
A5	2021	1,21	High effect
A6	2022	0,79	Moderate effect
A7	2019	2,95	High effect
A8	2020	1,53	High effect
A9	2018	1,30	High effect
A10	2020	2,00	High effect
A11	2021	1,05	Moderate effect
A12	2019	1,25	Moderate effect
A13	2021	0,80	Moderate effect
A14	2018	1,51	High effect
A15	2021	2,29	High effect
A16	2022	0,54	Moderate effect
A17	2020	2,80	High effect
A18	2021	1,46	High effect

A19	2020	2,53	High effect
A20	2019	0,67	Moderate effect
Mean		1,72	High effect

Based on the data provided in Table 2, there are 20 articles each with identification codes, publication years, effect size values, and categories indicating the impact of the Problem-Based Learning (PBL) model on the 21st-century skills of students. The effect size values depict the magnitude of PBL's influence on the 21st-century skills, while the categories indicate the level of influence. From the data, it can be concluded that the average effect size value from these 20 articles is 1.72, falling into the category of "Very High." This indicates that the PBL model has a highly significant impact on enhancing the 21st-century skills of students, based on the observed research collection. Some articles have higher effect size values than others, suggesting stronger PBL effects in those articles. On the other hand, there are also articles with lower effect size values, indicating a moderate or even low influence of PBL in those study contexts.

In analyzing the influence of the Problem Based Learning model on the 21st-century skills of students based on educational subjects, the average effect size values for each educational level can be seen in Table 3.

Table 3. The impact of the PBL model on 21st-century skills of students as assessed based on educational subjects

Code	Effect Size	Subject Matter	Mean	Skill
A1	3,57	Database	3,57	Critical
A2	4,00	Network System Programming	3,05	Critical
A3	0,97	Database Practicum	0,98	Communication
A4	1,13	Database Practicum	1,55	Communication
A5	1,21	Web Programming	1,20	Critical
A6	0,79	Basis Data	1,15	Critical
A7	2,95	Basic Programming	2,94	Creativity
A8	1,53	Basic Programming	1,52	Creativity
A9	1,30	Basic Programming	1,32	Creativity
A10	2,00	Database	1,06	Creativity
A11	1,05	Web Programming	1,13	Critical
A12	1,25	Computer Network Installation	0,54	Collaboration
A13	0,80	Database Practicum	2,67	Creativity
A14	1,51	Database Practicum	0,66	Creativity
A15	2,29	Database Practicum	1,13	Creativity
A16	0,54	Database Practicum	1,07	Creativity
A17	2,80	Computer Network Installation	1,00	Creativity
A18	1,46	Computer Network Installation	0,95	Critical
A19	2,53	Computer Network Installation	2,05	Critical
A20	0,67	Computer Network Installation	2,00	Critical

Based on Table 3, it can be observed that the average effect size for each subject indicates a highly significant impact of the PBL model, with the majority of subjects falling into the "Very High" category. The "Very High" category confirms a very strong and consistent effect, suggesting that the PBL model can be considered

an effective teaching method for developing 21st-century skills in students. However, the variation in the distribution of effect size values across subjects suggests that the influence of the PBL model may vary depending on the subject being taught, possibly due to differences in the complexity of the material or the applied teaching strategies.

The graph of the Effect Size and Mean tabulation data is as follows:

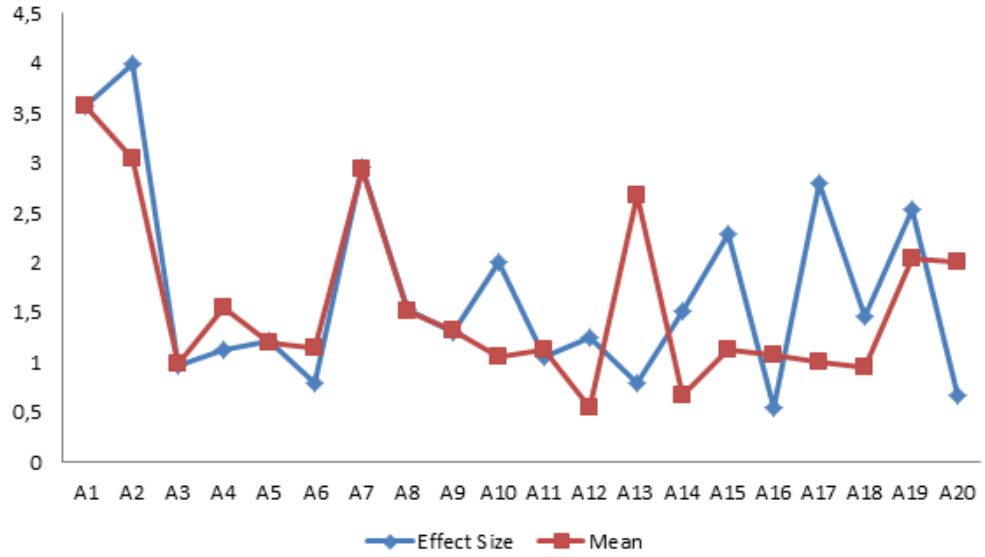

Figure 1. The tabulation of the meta-analysis data

D. Conclusion

The Problem-Based Learning (PBL) model of instruction demonstrates a highly significant effect with an average value of 1.72. Its utilization significantly enhances the 4C skills (Critical Thinking, Creativity, Collaboration, Communication) of students. With a consistently high average effect size, it indicates that the influence of the PBL model on 4C skills is consistently strong across various observed research contexts. This suggests that students engaged in PBL-oriented learning tend to exhibit better critical thinking, creativity, collaboration, and communication skills compared to those not involved in such learning. Therefore, these findings underscore the importance and effectiveness of PBL as a teaching method for promoting the development of critical 4C skills crucial in the context of 21st-century education

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