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Meta Analysis: The Effect of Project-based Learning on Students' Learning Outcomes in Chemistry Learning

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Abstract
One of instructional model which can be implemented in Merdeka Curriculum is Project-based Learning (PjBL). In this model, students design a project based on their contextual understanding, thus having an impact on learning outcomes especially in knowledges aspect. Using meta-analysis with PRISMA method, researchers have traced various research articles and proceedings from 2020 to 2024 by using Publish or Perish with the keywords "project-based learning", "learning outcomes", "chemistry", "pjbl", "hasil belajar", "kimia". There are 200 articles found, after going through several stages there are seven articles that are the subject of this research. By calculating the effect size value of each study, the average effect size result was 1.1825 which was included in the high category. For summary that, the Project-based Learning model has an affect on student learning outcomes in chemistry learning, especially on the topics of acids and bases, colloids, chemical equilibrium, chemical bonds, solutions and thermochemistry.

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INTRODUCTION

The Republic of Indonesia's Ministry of Education, Culture, Research, and Technology created the Merdeka Curriculum in an attempt to address the country's current learning issue. Low student learning outcomes and disparities in the quality of learning between groups and areas are the hallmarks of this crisis (Anggraena et al., 2021). To raise the standard of learning and education in Indonesia, numerous learning models that were included in the 2013 Curriculum were again improved. The learning model is a framework that outlines the steps involved in setting up educational opportunities to meet pre-established learning goals (Sutanto, 2017).

John Dewey's learning theory serves as the foundation for the Project-based Learning (PjBL) approach. PjBL emphasizes collaboration, understanding, social skills, problem solving, and cooperation (Wahbeh et al., 2021). PjBL is a learning model that applies students' knowledge and trains thinking skills. There are six stages in carrying out learning with the PjBL model, including preparing questions or project assignments, designing project plans, preparing schedules, paying attention to project progress, reviewing results and evaluating activities (Sutanto, 2017). This learning approach has the advantage of requiring students to actively apply preexisting theories and concepts, which makes it easier for them to understand chemical materials, which often require contextual understanding (Sugiarti et al., 2023).

The application of the knowledge possessed makes learners optimize understanding and improve learning outcomes. Learner learning outcomes can be a reference to the success of the learning process carried out. This is in line with the opinion of Sayani and Sutiani (2020), that learning outcomes are the results obtained by students from a learning process in terms of knowledge, understanding and attitudes (Sayani & Sutiani, 2020). Learning outcomes are information or data collected by teachers about student learning achievements in various aspects, especially knowledge aspects. This data collection is carried out to monitor interest and motivation to learn, process and improve learning outcomes. The findings of the TIMSS (Trends in International Mathematics and Science Study) and PISA (Program for International Student Assessment) studies demonstrate that Indonesian students' learning outcomes are still comparatively low (Ulumudin et al., 2019). In 2018 Indonesia ranked 71st out of 79 countries that took this test. Next, Indonesia ranked 67th out of 81 countries participating in PISA. The lower average PISA score was followed by a higher ranking the year before, this does not suggest that kids are learning much. For science, the average in 2018 was 396 and decreased in 2022 to 386. From this data, it can be seen that the increase in PISA rankings does not indicate good learning outcomes (Lubis, 2023).

Low learning outcomes are not only caused by the technical assessment carried out, but also the difficulty of the learning material (Ulumudin et al., 2019). Chemistry material is material that requires understanding of concepts. Abstract concepts make it difficult for students to understand the material which results in misconceptions and low learning outcomes (Deleña & Marasigan, 2023; Islami et al., 2018; Novesti, 2022). Various studies have been conducted to develop teaching tools or assessment instruments with the PjBL model to optimize student learning outcomes (Savitri, 2022; Syafe'i & Effendi, 2020). Selvianita's research (2023) showed that students' learning outcomes increased from an average of 42.86 to 77.43 after applying this learning model (Selvianita & Hardeli, 2023). Not only that, Sugiarti's research (2023) also showed an average increase from 70.42 to 77.82 (Sugiarti et al., 2023).

Various studies have been conducted to see the effect of the Project-based Learning model on learning outcomes. Meta-analysis research by Dayanti (2023) states that PjBL affects science learning outcomes with an average effect size of 2.895 (Dayanti et al., 2023). This is also in line with Nurhasnah (2022) which obtained an effect size of 1.67 (Nurhasnah et al., 2022). Not only that, research by Izzah (2021) also saw the effect of PjBL on learning outcomes in high schools and vocational schools with an average effect size of 1.29 and 1.32 (Izzah et al., 2021). Widarbowo's research (2023) showed the effect of PjBL on students' biology learning outcomes with an effect size of 1.050 (Widarbowo et al., 2023). The other research is the research of Wagino (2022) who conducted a meta-analysis of the effect of PjBL on learning outcomes in several fields, such as biology, mathematics, physics, environment, geography and so on (Wagino et al., 2022). Supartiningsih (2017) has conducted a meta-analysis of the effect of learning models on student chemistry learning outcomes that discuss several learning models (Supartiningsih, 2017). In addition, Fadhilah's research discusses the effect of PjBL on learning outcomes but in general and Zhang's research on the impact of PjBL on learning (Fadhilah et al., 2023; Zhang & Ma, 2023).

This study presents a meta-analysis that examines the impact of Project-based Learning (PjBL) models on student learning outcomes in chemistry subjects, which is an important step in filling the gap in the current literature. Although a number of previous studies, such as those by Selvianita (2023) and Sugiarti (2023), have reported significant improvements in learning outcomes using the PjBL model, there has been no comprehensive review that systematically combines and analyzes these results in the specific context of chemistry. This study introduces a meta-analysis methodology that distills data from various studies to provide a clearer picture of the effectiveness of PjBL in improving understanding of chemistry concepts, addressing the problem of material difficulties that often lead to misconceptions (Deleña & Marasigan, 2023). By presenting average effect sizes and identifying key variables that influence learning outcomes, this study offers the impact of PjBL on students' learning outcome in chemistry learning by filling the gaps in previous research.

METHOD

This study is a meta-analysis of the effect of implementing learning with the Project-based Learning model on participants' learning outcomes using the PRISMA (Preferred Reporting Item for Systematic reviews and Meta-Analyses) method. The PRISMA methode is a guideline designed to improve transparaency and accuracy in reporting systematic reviews and meta-analysis. In this study, the PRISMA method was used to ensure that the entire analysis process was conducted in a systematic and accountable manner. By using PRISMA, this study not only provides a comprehensive synthesis of the effectiveness of PjBL in improving chemistry learning outcomes, but also improves the reliability of the meta-analysis results by complying with internationally recognized reporting standards. The findings from this meta-analysis are expected to make a significant contribution to the development of more effective teaching methods and provide evidence-based guidance for improving chemistry learning outcomes in various educational contexts. The stages in this study are identification, screening, eligibility and included (Haddaway et al., 2018). The stages of research can be seen in Figure 1.

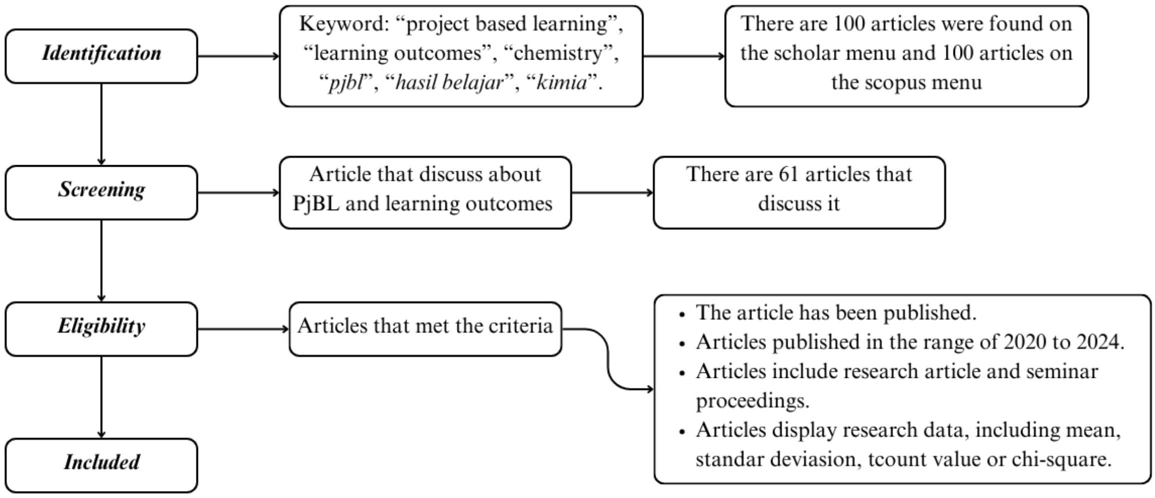

Figure 1. Research procedure

The initial step taken at the identification stage is to collect and analyze research data from previous studies related to the effect of PjBL on chemistry learning outcomes. The data obtained is based on national and international journal articles and seminar proceedings in 2020-2024. Articles were searched using Publish or Perish on the scholar and scopus menus with the keywords "project based learning", "learning outcomes", "chemistry", "pjbl", "*hasil belajar*", and "*kimia*". There are 100 articles were found on the scholar menu and 100 articles on the scopus menu.

The next stage is screening, the articles obtained previously are limited to articles that discuss the effect of the pjbl model on student learning outcomes in chemistry learning. From this step, 61 articles were obtained that discussed the effect of Project-based Learning on students' learning outcomes. Next is the eligibility stage by selecting articles that match the criteria: (1) The article has been published; (2) Articles published in the range of 2020 to 2024; (3) National articles include research articles and seminar proceedings; (4) Articles display research data, including mean, standard deviation, t_{count} value and chi-square value.

The next stage included determining the effect size of each article. In this case there are seven articles that have appropriate data. The data contained in the research results were analyzed for their effect size values using the formula that can be seen in Table 1 and classified according to the categories in Table 2 (Becker & Park, 2011).

Table 1. Formula to determine effect size

Statistic	Formula
t_{count}	$ES = t.\sqrt{\frac{1}{nE} + \frac{1}{nC}}$ $ES = t\sqrt{\frac{2}{N}}$
$\overline{X}$ dan SD	$ES = \frac{X_E - X_C}{SD_C}$
Chi-square	$ES = \frac{2r}{\sqrt{1-r^2}}\ ;\ r = \sqrt{\frac{x^2}{n}}$

Table 2. Effect size category

Statistic	Formula
0 ≤ ES ≤ 0,2	Low
0,2 ≤ ES ≤ 0,8	Medium
ES ≥ 0,8	High

RESULTS AND DISCUSSION

From the stage of determining articles that match the criteria and have been narrowed down, seven articles were obtained which include research articles and seminar proceedings. The identity of the seven articles can be seen in Table 3.

Table 3. Articles' identity

Code	Author	Year	Topic	Reference
A1	Vivi Selvianita; Hardeli	2023	Acid and base	(Vivi Selvianita & Hardeli, 2023)
A2	Sugiarti; Taty Suliastri; Syarifah Fatimah	2023	Colloids	(Sugiarti et al., 2023)
A3	Cindi Katarina Br Perangin Angin; Tita Juwitaningsih	2023	Chemical Equilibrum	(Perangin Angin & Juwitaningsih, 2023)
A4	Fintan Wulandari; Soenandar M. T Tengker; Marlina Karundeng	2024	Chemical Bonding	(Wulandari et al., 2024)
A5	Lily Budinurani	2020	Solutions	(Budinurani, 2020)
A6	Misye G. Sumampow; Sofia S. Krisen; Joice D. S. Caroles	2023	Colloids	(Sumampow et al., 2023)
A7	Shella Julia Rani Hulu; Muruniaty Simorangkir	2022	Thermochemistry	(Hulu & Simorangkir, 2022)

The data obtained from the seven articles were processed using the equation in Table 1 and categorized according to Table 2. The effect size of each article presented in Table 4.

Table 4. Articles' identity

Article Code	Effect Size	Category
A1	0,4757	Medium
A2	0,6514	Medium
A3	0,5231	Medium
A4	3,7307	High
A5	1,0354	High
A6	0,9939	High
A7	0,8672	High
Mean	**1,1825**	**High**

Articles with codes A1, A3, A4, A5 and A6 use equations with t_{count} value data which can be seen in Table 1. Meanwhile, article A2 uses the average data of the control class and experimental class, as well as the standard deviation value. Next, the article with code A7 is equipped with chi-square data to determine the effect size.

Researchers in articles with code A1 carried out experiments with a one-gorup pre-test post-test design and learning with LKPD. Data collection was carried out by giving multiple choice questions to students. From the research conducted, an effect size value of 0.4757 was obtained, which means that there is an effect of PjBL that is carried out on the learning outcomes of students on acid-base material with a moderate category (Selvianita & Hardeli, 2023).

The next research was conducted by Sugiarti (2023) on colloidal material with a quasi-experiment method applied with STEAM. Data was collected by conducting a post-test on the sample. From the effect size value obtained, it can be seen that the PjBL model has an influence on student learning outcomes in colloidal material with a moderate category. Colloidal material contains principles and concepts that are closely related to everyday life and require contextual understanding. Through the application of knowledge that has been owned will optimize the understanding of the concept of students (Azzara & Iswendi, 2024; Sugiarti et al., 2023).

The article with code A3 explains the research conducted with a quasi-experimental design of non-equivalent control group design through digital flipbook media assistance. With a multiple choice question test instrument given to students, it can be seen that there is an effect of PjBL that is carried out. from the effect size value, it is obtained in the medium category for the effect of PjBL on learning outcomes on chemical equilibrium material (Perangin Angin & Juwitaningsih, 2023).

Other articles have effect size values that fall into the high category, namely articles with codes A4, A5, A6 and A7. In article A4, the research conducted applied PjBL assisted worksheets and given multiple choice instruments (Wulandari et al., 2024). Article A5 describes research conducted by means of lesson study (Budinurani, 2020). Research in article A6 obtained data through pre-test and post-test on colloidal system material (Sumampow et al., 2023). While article A7 research uses learning modules and is tested with multiple choice instruments (Hulu & Simorangkir, 2022).

Looking at the data on the effect size value of each article and its category, it can be said that each article is included in the medium to high category. After summing up, the average effect size value of all articles is 1.1825, which means that overall the article is in the high category. Based on this data, it can be interpreted that the Project-based Learning model has an effect in improving student learning outcomes in chemistry learning, especially in acid and base materials, colloids, chemical equilibrium, chemical bonds, solutions and thermochemistry. The Project-based Learning model can be used with the aim of developing students' creativity and increasing their understanding. This is because the PjBL model generally links concepts and understanding through phenomena that exist in everyday life (Nasir et al., 2019). With the PjBL model, students can improve learning outcomes and build process skills that should be owned by students (Juwita, 2022; Selvianita & Hardeli, 2023).

The similarities in the results of this study indicate that PjBL is effective in improving students' overall understanding and can be used to develop students' creativity and process skills. However, there are differences in the effectiveness of PjBL across different chemistry topics. For example, some articles reported stronger effects on chemical bonds and solutions than others. This difference is due to variations in the way PjBL is applied, differences in the complexity of the material being taught, or the students' level of prior understanding (Budinurani, 2020; Wulandari et al., 2024). From these differences, the application of the PjBL model may require specific adjustments for each chemistry topic in order to maximize learning outcomes. For example, specific strategies or approaches tailored to the characteristics of specific chemistry materials may increase the effectiveness of PjBL. Further research is needed to explore the factors that influence this difference in effectiveness and to develop more detailed guidelines for applying PjBL in various chemistry contexts.

In learning that applies the Project-based Learning model, students will find problem solving and learn concepts. Meanwhile, the teacher as an educator will be a facilitator during the learning process. Learners and their groups will study various real problems. From the various projects carried out, it is expected that students will learn from what they see and observe through their environment. With these skills will improve good learning outcomes.

CONCLUSION

Student learning outcomes in chemistry can be enhanced by implementing the project-based learning paradigm. Numerous studies on the impact of PjBL on student learning outcomes attest to this. On the other hand, meta-analyses assessing the impact of PjBL on chemistry learning outcomes are yet lacking. This makes it impossible for this research to use the effect size value to determine how PjBL affects chemistry learning. Based on the research completed, the selected articles' average effect size value is 1.1825, falling into the high category. Accordingly, PjBL can be used to improve student learning outcomes in chemistry, particularly in the areas of solutions, acids and bases, colloids, chemical equilibrium, chemical bonding, and thermochemistry.

RECOMMENDATIONS

This research still shows the effect of PJBL on several topics in chemistry learning. Future research is expected to find the effect of PjBL in learning chemistry for other topics that have not been discussed in this article. There were differences in the effect size results for each topic due to variations in the way PjBL was applied, differences in the complexity of the material taught, or the students' initial level of understanding. Therefore, further research is also needed to explore the factors that influence these differences in effectiveness and to develop more detailed guidelines for implementing PjBL in various chemistry contexts.

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