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The Effectiveness of Project-Based Learning on Science Process Skills in Chemistry Education: A Research Findings Perspective

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A B S T R A C T

This study aims to explore and analyze the effectiveness of Project- Based Learning (PjBL) in enhancing scientific process skills in chemistry education at the secondary education level. The research employs the Systematic Literature Review (SLR) method, analyzing 16 recent scholarly articles published within the last ten years. The findings indicate that implementing PjBL significantly improves students' scientific process skills, including critical thinking, problem-solving, and data analysis. Additionally, PjBL enhances students' motivation and engagement in the learning process. The reviewed studies suggest that integrating technology into PjBL, such as digital media and STEAM approaches, further strengthens its effectiveness in fostering a deeper understanding of scientific concepts. However, several challenges remain, including the need for teacher training in designing and managing project-based activities effectively, as well as limited learning resources. Therefore, this study recommends enhancing teacher training programs, providing more diverse teaching materials, and ensuring institutional support for the implementation of PjBL. Overall, the study confirms that PjBL is an innovative instructional strategy that optimally develops scientific process skills and can be widely applied in chemistry education.

1. Introduction

Project-Based Learning (PjBL) is an educational approach that emphasizes active student involvement in real-world projects that are relevant to daily life contexts. This approach is expected to address challenges faced in science education, where students often engage only in memorizing concepts without understanding the underlying scientific processes (Nuraini & Muliawan, 2020; Suryaningsih & Nisa, 2021). Research has shown that PjBL can enhance students' critical thinking and creativity skills, which are essential components of science mastery (Handayani et al., 2023; Hidayah & Pujiastuti, 2016).

One reason for the effectiveness of PjBL is its ability to integrate multiple disciplines, including technology, engineering, arts, and mathematics (STEAM), into science education (Fadhilah et al., 2021). Through this approach, students not only learn theoretical knowledge but also apply it in practical contexts. Studies indicate that students engaged in project-based learning show significant improvements in their science process skills, such as observation, measurement, and data analysis (Ernawati et al., 2021; Kusumaningrum & Djukri, 2016). This aligns with findings that experiential learning is more effective in building a deep understanding of concepts (Khabibah et al., 2017).

Furthermore, PjBL fosters collaboration among students, which is a crucial aspect of science learning. This collaboration allows students to share ideas, engage in discussions, and solve problems collectively, thereby enhancing their social and communication skills (T. N. Sari et al., 2023; Utama & Sukaswanto, 2020). Research suggests that students who work in groups within the context of PjBL tend to be more engaged and motivated in their learning process (Mahali et al., 2023). This indicates that PjBL not only enhances science process skills but also contributes to the development of students' character and social skills.

However, the implementation of PjBL is not without challenges. Teachers need a strong understanding of how to design and manage effective projects, as well as the ability to assess students' science process skills accurately (Desnita & Susanti, 2017; Pusparini et al., 2018). Research has shown that teacher training in PjBL application is crucial for the success of this approach (Purwanto, 2017). Additionally, support from schools and the provision of adequate resources are key factors for the successful implementation of PjBL (Lubis, 2021).

In the context of chemistry education, PjBL can be applied to a range of topics, from chemical reactions to environmental studies. By designing relevant projects, students can see the connection between theory and practice, thereby enhancing their understanding of chemical concepts (Astra & Wahidah, 2017; Pratiwi et al., 2020). Research indicates that students who learn through PjBL in chemistry tend to perform better than those taught through traditional methods (Handayani et al., 2023; Hidayah & Pujiastuti, 2016). This suggests that PjBL can be an effective alternative to improve the quality of chemistry education in schools. Overall, this paper will discuss various studies supporting the effectiveness of PjBL in enhancing science process skills in chemistry education. By analyzing existing research findings, it is hoped that this paper will provide deeper insights into how PjBL can be effectively implemented in science education and the challenges that may arise during its implementation (Maksum & Saragih, 2020).

Based on the above discussion, the objective of this research is to explore and analyze the effectiveness of Project-Based Learning (PjBL) in enhancing science process skills in chemistry education at the secondary school level. This study aims to provide empirical evidence regarding the impact of PjBL on students' ability to apply chemical concepts through project-based practical activities, as well as to evaluate how this approach can improve student motivation and engagement in the learning process. The novelty of this research lies in the

integrative approach that combines theory and practice in chemistry education, with an emphasis on developing science process skills, which are often overlooked in traditional teaching methods. Additionally, this research seeks to identify the challenges faced by teachers in implementing PjBL and provide empirically-based recommendations for improving the quality of chemistry education in schools. Thus, this study is expected to contribute significantly to the development of more effective and relevant teaching methods in science education.

2. Methodology

This research approach uses a qualitative method with a Systematic Literature Review (SLR) design. The stages of the research using this design are as follows:

a. **Identifying the Topic and Research Focus**: This involves determining the scope of the research, which focuses on the effectiveness of Project-Based Learning (PBL) in enhancing science process skills in chemistry education. The main research question is formulated: "How can the implementation of Project-Based Learning improve students' science process skills in chemistry education?"
b. **Literature Search**: This stage involves constructing a search strategy using predetermined keywords such as "Project-Based Learning," "science process skills," "chemistry education," and "effectiveness of PBL." The literature sources include academic databases such as Scopus, ScienceDirect, SpringerLink, Web of Science, and Google Scholar. The literature search is limited to publications from the past 10 years to ensure relevance to current trends. At this stage, 30 pieces of literature were retrieved based on the chosen keywords.
c. **Literature Selection**: This stage involves screening the literature based on titles and abstracts to ensure alignment with the research topic.
d. **Data Extraction and Analysis**: Information from the selected articles is coded using a thematic framework. This step aims to identify patterns, trends, research gaps, and the consistency of results across different studies.
e. **Data Synthesis**: The results of the research are classified according to major themes, such as the effectiveness of PBL, the enhancement of science process skills, and the challenges of implementation. At this stage, 16 articles were identified as most relevant and were analyzed further.

3. Results and Discussion

This study was conducted by analyzing 16 pieces of literature in the form of articles from previous research that discuss the impact of the PjBL learning model on students' science process skills. The selected articles are the most recent ones published within the last ten years to ensure that the data obtained reflects the

latest developments. The results of the analysis of these literatures are presented in the results and discussion section.

Result

The results of the analysis of several literatures in this study are divided into three categories: the identity of the articles, the impact of PjBL on students' science process skills, and the media used to support the learning process with the PjBL model. Table 1 presents the identities of the reviewed articles.

Tabel 1. Identity of the Reviewed Articles

No	Author(s) (Year)	Title of Article	Pedagogical Approach	Education-al Context	Approac h Used	Research Method
1	IB. Siwa, I W. Muderawan & I N. Tika (2013)	The Effect of Project-Based Learning in Chemistry on Students' Science Process Skills Reviewed from Students' Cognitive Styles	PjBL Approach	Senior High School (SMA)	Project-based Learning	Quantitati ve Research
2	Frida Anggriani, Nanik Wijayati, Eko Budi Susatyo & Kharomah (2019)	The Impact of Project-Based Learning in Chemistry on Concept Understanding and Science Process Skills of Senior High School Students	PjBL Approach	Senior High School (SMA)	PjBL Learning Model	Quantitati ve Research
3	Erlinda Eka Kurniawati, Sri Susilogati Sumarti, Nanik Wijayati & Nurbangun Nuswowati (2021)	The Impact of Project-Based Learning Oriented to Chemopreneur ship Assisted by E-LKP on Science Process Skills and Entrepreneurial Attitudes	PjBL Approach	Senior High School (SMA)	PjBL Learning Model Oriented to CEP Assisted by E-LKPD	Quantitati ve Research
4	Andrian Gandi Wijanarko, Kasmadi Imam Supardi & Putut Marwoto (2017)	Effectiveness of Guided Project-Based Learning Model to Improve Science	PjBL Approach	Primary School (SD)	Guided PjBL Learning Model	Quantitati ve Research

		Process Skills and Science Learning Outcomes				
5	Rania Surayya, Yunita Arian Sani Anwar & I Nyoman Loka (2024)	The Effect of Project-Based Learning Assisted by Lectora Inspire Media on Students' Science Process Skills	PjBL Approach	Senior High School (SMA)	Project-Based Learning with Lectora Inspire Media	Quantitative Research
6	Ni Wayan Prawita Aryani (2018)	The Effect of Project-Based Learning on Science Process Skills and Chemistry Concept Mastery of Senior High School Students	PjBL Approach	Senior High School (SMA)	Project-Based Learning	Quantitative Research
7	Suhanda & Sugeng Suryanto (2018)	The Application of Project-Based Learning in Improving Science Process Skills of Class X Students in SMA Negeri 2 Purworejo	PjBL Approach	Senior High School (SMA)	Project-Based Learning	Case Study
8	Nurwanti Fatnah, Dewiantika Azizah & Mutiara Dwi Cahyani (2021)	The Application of Project-Based Learning Model Through Fun Chemistry Activities to Improve Science Process Skills in Vocational Schools	PjBL Approach	Vocational School (SMK)	Project-Based Learning Model	Quantitative Research
9	Nida Hamidah, Muhammad Radian Nur Alamsyah & Serafica Btari Cristiani Kusumaningrum (2023)	The Effect of Project-Based Learning on Science Process Skills and Students' Motivation in Senior High School	PjBL Approach	Senior High School (SMA)	Project-Based Learning	Quantitative Research

10	Siti Suryaningsih & Fakhira Ainun Nisa (2021)	Contribution of STEAM Project-Based Learning in Measuring Science Process Skills and Creative Thinking of Students	PjBL Approach	Senior High School (SMA)	STEAM Integrated Project Learning	Quantitative Research
11	Nuril Maghfiroh, Herawati Susilo & Abdul Gofur (2016)	The Effect of Project-Based Learning on Science Process Skills of Class X Students in SMA Negeri Sidoarjo	PjBL Approach	Senior High School (SMA)	Project-Based Learning	Quantitative Research
12	Ratna Juwita (2022)	Best Practice in Building Science Process Skills Through Project-Based Learning Using STEAM Approach	PjBL Approach	Senior High School (SMA)	Project-Based Learning with STEAM	Quantitative Research
13	Putri Wismaningati, Murbangun Nuswowati, Triastuti Sulistyaningsih & Sunarko Eisdiantoro (2019)	Analysis of Science Process Skills of Students in Colloid Learning Using Project-Based Learning with SETS Approach	PjBL Approach	Senior High School (SMA)	Project-Based Learning with SETS Approach	Qualitative Descriptive Research
14	Cut Zaitun Umara, Cut Nurmaliah & Khairil (2016)	The Application of Project-Based Learning Model to Improve Science Process Skills of Students in Environmental Pollution Concept in Junior High School	PjBL Approach	Junior High School (SMP)	Project-Based Learning	Quantitative Research
15	Sih Kusumaningrum & D. Djukri (2016)	Development of Project-Based Learning	PjBL Approach	Senior High School (SMA)	Project-Based Learning Devices	Research and Development

16	Nuraini & Edy Waluyo (2021)	Devices to Improve Science Process Skills and Creativity Development of Instructional Design Model for Project-Based Learning Integrated with Science Process Skills to Improve Science Literacy	PjBL Approach	Junior High School (SMP)	Instructional Design Integrated with PjBL and Science Process Skills	Development Res

Table 2. The Impact of Implementing PjBL on Students' Science Process Skills

No	Category	Number of Studies	Percentage (%)	Description
1	Cognitive and science skills	4	25	This category includes the impact on the enhancement of students' cognitive abilities and the science process skills gained through the use of the PjBL model.
2	Science process skills and understanding	3	18.75	This category emphasizes the improvement of science process skills and deeper understanding of material, particularly in specific science concepts.
3	Science process skills and other aspects	3	18.75	This category describes the impact of PjBL that not only enhances science process skills but also additional aspects such as creativity and entrepreneurial attitudes.
4	Activity and motivation	2	12.5	This category focuses on the impact of PjBL in increasing students' active participation and motivating them to engage more in the learning process.
5	Literacy and creativity	2	12.5	This category includes the impact on improving science literacy skills, creativity, as well as critical and digital thinking abilities.
6	Use of technology and media	3	18.75	The use of the PjBL model can be integrated with specific technologies and media.

The implementation of PjBL in the learning process can also be supported by various teaching media that are tailored to the characteristics of the material being taught. Several types of media used in previous studies can be seen in Figure 1.

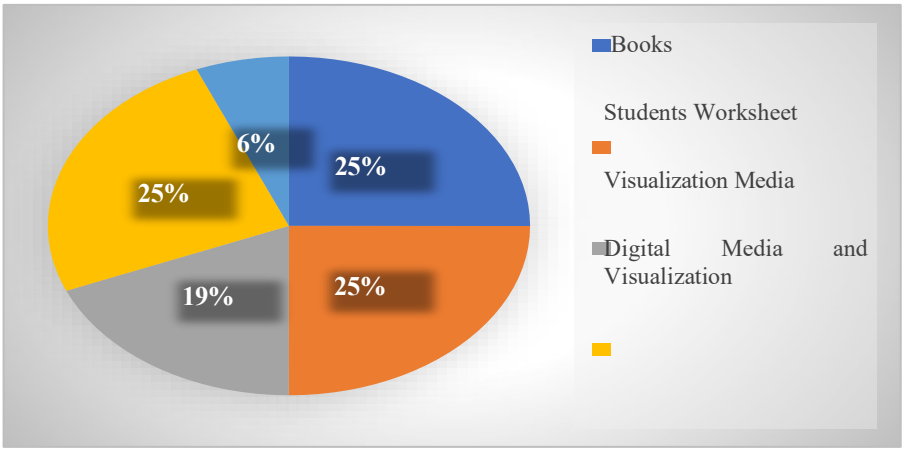

Figure 1. Types of PjBL-Based Teaching Media Found in the Literature Review

Dicussion

Table 1 illustrates the variation in studies examining the implementation of the Project-Based Learning (PjBL) model in enhancing students' science process skills across different educational levels. The majority of the research was conducted at the secondary school (high school) level, highlighting the relevance of this method in sharpening students' analytical and practical skills at this stage of education. Some studies also incorporate technology integration and creative approaches, such as the use of Lectora Inspire-based media, STEAM approaches, or a chemoentrepreneurship orientation, which enrich the students' learning experiences and enhance their motivation and conceptual understanding. Moreover, the research indicates that the PjBL approach is not only effective in improving science process skills but also in other aspects such as creativity, entrepreneurial attitudes, and science literacy.

Table 2 illustrates the impact of the implementation of Project-Based Learning (PjBL) on students' science process skills, categorized into six main aspects. In the category of "Cognitive and Science Skills," PjBL shows a significant improvement in students' cognitive abilities and science process skills, with a percentage of 25%. This emphasizes the effectiveness of PjBL in developing students' intellectual competencies, particularly through project-based learning activities that encourage independent and collaborative problem-solving. Previous studies have also shown that PjBL can enhance students' critical thinking and analytical skills, which are integral to science process skills (Ikra et al., 2022; Mahali et al., 2023; Sudirman et al., 2024).

The category "Science Process Skills and Understanding" contributes 18.75%, focusing on the enhancement of science process skills alongside a deeper understanding of the material. Project-based learning facilitates the exploration of complex scientific concepts, such as in chemistry lessons, thus helping students understand concepts more comprehensively. This impact is relevant for strengthening students' practical knowledge base. Several studies have shown that students involved in PjBL have a better understanding of science concepts and are

able to apply them in real-life situations (Berlian et al., 2023; R. Rahayu & Ismawati, 2022; W. P. Rahayu & Munadhiroh, 2020).

In the category of "Science Process Skills and Other Aspects," which also contributes 18.75%, PjBL not only focuses on science skills but also supports the development of creativity and entrepreneurial attitudes. This approach enriches learning with non-academic elements such as innovative thinking and adaptability, which are crucial in preparing students for challenges beyond the formal educational environment. Research shows that PjBL can enhance students' creativity and their ability to work in teams, skills that are important in the workforce (Fatmawati et al., 2022; Suryaningsih & Nisa, 2021).

The last two categories, "Activity and Motivation" and "Literacy and Creativity," each contribute 12.5%. PjBL has been shown to increase students' involvement in the learning process while motivating them to actively participate. Additionally, students' science literacy and creativity have also improved, particularly through the integration of relevant technology and media. With a project-based approach that involves the use of technology, students can develop critical and digital thinking skills, making PjBL a highly relevant pedagogical strategy for the digital era. Research indicates that the use of technology in PjBL can enhance students' motivation and engagement in learning (Astra & Wahidah, 2017; Cahyana & Nurjanah, 2021).

Based on the articles analyzed, several types of learning media have been used in the PjBL-based learning process. Data on these types of media can be seen in Figure 1. The Project-Based Learning (PjBL) model in chemistry education utilizes various types of learning media to improve the effectiveness of the learning process. Data show that media such as teaching materials (textbooks), student worksheets (LKS), visualization media, and digital media are the primary choices used to support the implementation of PjBL. Each of these media contributes specifically to helping students develop Science Process Skills (SPS), such as critical thinking, data analysis, and problem-solving. By using teaching materials and LKS, students can access theoretical information while simultaneously applying concepts through directed practical activities (Nurhamida & Andromeda, 2023; F. P. Sari et al., 2023). Research shows that well-designed LKS can increase student engagement in learning and strengthen concept understanding (Irfandi & Yuhelman, 2023; Utami et al., 2016).

Visualization and digital media provide an additional dimension to project-based learning. Visualization media, such as diagrams or animations, help students better understand abstract concepts, while digital media, such as applications and online platforms, allow for more interactive and collaborative learning. The use of digital media is also relevant to the needs of the digital age, where technology-based learning provides flexibility in exploring chemistry materials. These media work synergistically with the PjBL model to create an engaging and applicable learning experience (Akbar & Djakariah, 2024; Astari, 2018). Research shows that the integration of technology in learning can improve students' motivation and strengthen their critical thinking skills (Niswah et al., 2023).

Additionally, media such as literature and scientific journals, though rarely used, still play an important role in supporting the PjBL approach. These media provide students with access to deeper, research-based information, which can be used to improve their science literacy. With the variety of media used, the implementation of PjBL can be tailored to the specific needs of chemistry education, thereby promoting the more maximal and holistic development of students' Science Process Skills (Claudia et al., 2020; Dzikri et al., 2024). Research shows that the use of scientific literature in learning can enhance students' understanding of complex science concepts (Umar et al., 2023).

Therefore, the combination of appropriate media can strengthen the implementation of PjBL in science education. Previous research has shown that the use of varied media in learning can improve student learning outcomes and make the learning process more engaging (Harvina et al., 2022; Maulana & Khotimah, 2021). Thus, it is essential for educators to consider the selection of media that align with student characteristics and learning objectives to achieve optimal results in developing Science Process Skills.

4. Conclusion

Based on the results and discussion of this study, it can be concluded that the implementation of Project-Based Learning (PjBL) in chemistry education at the secondary school level has proven to be effective in enhancing students' science process skills. Analysis of various studies indicates that PjBL not only deepens students' understanding of scientific concepts but also strengthens critical thinking, creativity, and entrepreneurial attitudes. Furthermore, the integration of diverse teaching media, including digital learning materials, interactive visualizations, and technology-based approaches, enriches the learning experience and increases students' motivation in the learning process. Therefore, PjBL can be recommended as an innovative teaching method to optimally and practically develop students' science process skills in the context of chemistry education.

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