



# Trends in PjBL to Improve Students' Scientific Creativity and Science Process Skills in Science Education (2010-2020): A Systematic Review

Lalu Syukran Muhsin<sup>1\*</sup>, Abdul Syukur<sup>1</sup>, Karnan<sup>1</sup>

<sup>1</sup> Master of Science Education, Post Graduate, University of Mataram, Mataram, Indonesia.

Received: December 04, 2024

Revised: February 13, 2026

Accepted: March 25, 2026

Published: March 31, 2026

Corresponding Author:

Lalu Syukran Muhsin

[lalusyukranm@gmail.com](mailto:lalusyukranm@gmail.com)

DOI: [10.56566/ijses.v3i1.272](https://doi.org/10.56566/ijses.v3i1.272)

Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



**Abstract:** The development of 21st-century skills requires science education to foster students' scientific creativity and science process skills through innovative learning models. One instructional approach that has gained increasing attention is Project-Based Learning (PjBL). This study provides a systematic review of the trend of using Project-Based Learning (PjBL) Model in enhancing students' scientific creativity and science process skills during the period 2010-2020, using bibliometric analysis through the Publish or Perish 8 and VOSviewer tools. The results show a significant increase in publications focusing on PjBL, especially in the themes of STEM integration, critical thinking, problem solving, and collaborative learning. PjBL has been shown to not only enhance students' scientific creativity and science process skills, but also increase the interactivity and relevance of learning through the application of technology. Thematic cluster analysis shows a close relationship between educational innovation and cross-disciplinary collaboration in preparing students to face global challenges. From a practical perspective, the application of digital tools in PjBL is highly recommended, especially in distance learning and hybrid classes. This study suggests further exploration of more innovative evaluation methods to measure the impact of PjBL, and emphasizes the importance of implementing this approach to address the challenges of 21st-century education.

**Keywords:** PjBL; Science process skills; Scientific creativity

## Introduction

Science learning in schools plays a very important role in developing students' competencies, especially in terms of scientific creativity and science process skills. As a field of study that prioritizes knowledge and application of theory in real contexts, science also plays a role in preparing students to face global challenges, such as climate change, technological advances, and public health issues. One approach that is increasingly receiving attention in the literature is the Project-Based Learning (PjBL) Model. PjBL is known as a learning model that places students as active subjects in the learning process by emphasizing the completion of

projects that are contextual and relevant to real life (Susilawati et al., 2025).

This learning model not only prioritizes the achievement of academic goals, but also improves students' skills in critical thinking, problem solving, and communication. Research by Thomas et al. (1999) shows that PjBL is able to encourage the development of students' cognitive and social skills simultaneously. PjBL allows students to work in teams, collaborate, and solve real problems that integrate theory and practice. In this context, this learning model is considered very effective in developing students' scientific creativity, namely the ability to find solutions and innovations in dealing with scientific problems (Susilawati et al., 2023). This scientific creativity, in turn, is key to the

### How to Cite:

Muhsin, L. S., Syukur, A., & Karnan, K. (2026). Trends in PjBL to Improve Students' Scientific Creativity and Science Process Skills in Science Education (2010-2020): A Systematic Review. *International Journal of Science Education and Science*, 3(1), 1-9. <https://doi.org/10.56566/ijses.v3i1.272>

advancement of science and technology (Doyan et al., 2023).

In addition, PjBL also plays an important role in improving science process skills. These skills include the ability to observe, classify, measure, and conduct experiments, all of which are essential for understanding natural phenomena and developing science-based solutions (Bell, 2010). In this approach, students are given the opportunity to plan and conduct experiments independently, which improves their practical skills in science.

Various studies conducted in the period 2010-2020 show a significant trend in the application of PjBL to improve both aspects. For example, research conducted by Blumenfeld et al. (2011) showed that PjBL improves critical thinking skills and the ability to overcome unexpected challenges. In a more specific study on science learning, PjBL has been shown to be effective in overcoming abstract and theoretical learning challenges, as well as helping students connect science knowledge to their daily lives.

The application of PjBL in the context of science education has a positive impact on the development of students' science process skills. A study by Barron et al. (2008) found that students involved in science-based projects tend to have a better understanding of scientific concepts because they can practice and apply the theories they have learned. Collaborative activities in PjBL also improve students' social and communication skills, which are important in the future world of work.

PjBL has also been shown to reduce the tendency of students to simply memorize material without understanding its application. This model provides an opportunity for students to connect the knowledge they gain to real-life contexts, which in turn increases their understanding of how science is applied in the outside world. Research by Hmelo-Silver (2004) shows that PjBL encourages students to think more deeply, design solutions, and communicate the results they achieve.

However, although many studies have shown the benefits of implementing PjBL, there are several challenges that must be faced by educators and students in its implementation. One of the main challenges is the time needed to plan and implement the project, as well as how to organize learning materials that are relevant and interesting to students. A study by Krajcik et al. (2023) showed that the success of implementing PjBL depends on the teacher's skills in designing and facilitating projects that can motivate students to be actively involved.

PjBL not only supports the development of students' cognitive and social skills, but can also strengthen their understanding of the importance of scientific research. In PjBL, students are invited to explore real-world problems, formulate hypotheses, and

design experiments to test these hypotheses. This process allows students to understand and apply the scientific method directly, which strengthens their competence in the field of science (Walan et al., 2021).

Furthermore, PjBL can play a role in increasing students' motivation to learn science. A study by Blumenfeld et al. (1991) showed that students involved in project-based learning tend to be more enthusiastic and have higher motivation to continue learning because they see the relevance of the learning material to their real life. This is very important, considering that students' interest in science tends to decline over time.

The positive impact of PjBL on students' science process skills and scientific creativity can also be seen in various specific fields, such as biology, physics, and chemistry. For example, in biology, students can conduct experiments on plant growth or animal behavior, while in physics, they can design experimental equipment to test basic physics theories. The application of PjBL allows students to not only memorize theories, but also understand and apply these concepts in their daily lives.

Through the PjBL approach, students are not only invited to solve problems, but also to produce innovations that can provide real solutions. This shows that PjBL is a very relevant and effective approach in the context of science learning, especially in developing students' scientific creativity and science process skills. With the increasing need for innovation in various fields, it is important for the education system to continue to integrate PjBL into their science curriculum, so that students can develop competencies that are relevant to the needs of the times.

Based on this background, this study aims to provide a systematic review of research trends on the application of PjBL in science learning and its impact on students' scientific creativity and science process skills. This review is expected to provide an overview of the PjBL approach and its effectiveness in improving the quality of science learning in various educational contexts.

## Method

This research method is descriptive analytical, which aims to understand and describe research trends on project-based learning models to improve problem-solving skills in science learning. The data used in this study were obtained from information sources indexed by Google Scholar using analysis tools such as Publish or Perish and Dimension.ai. To conduct a search on Google Scholar, keywords related to research trends on project-based learning models to improve problem-solving skills in science learning. In this study, an analysis was carried out on 1,000 documents that had

been indexed by Google Scholar from 2015 to 2024. The Google Scholar database was chosen as a place to search for documents because Google Scholar applies consistent standards in selecting documents to be included in its index, and Google Scholar displays more documents than other top databases, especially research in the field of education (Hallinger et al., 2019, 2020; Zawacki-Richter et al., 2019). To filter the data that has been collected through Publish or Perish, the researcher uses Preferred Reporting Items for.

### *Research Design*

This study aims to provide a systematic review of the trend of implementing Project-Based Learning (PBL) Model in improving students' scientific creativity and science process skills during the period 2010-2020. This review uses a qualitative research approach with a systematic analysis of various studies that have been published in international journals, conferences, and research reports related to PBL in science learning. Researchers will identify and categorize research results based on their main findings related to the impact of PBL on the two variables studied, namely students' scientific creativity and science process skills. Data collection was carried out using a literature study method that includes relevant articles from databases such as Google Scholar, JSTOR, ERIC, and Springer, focusing on research conducted between 2010 and 2020.

The data analysis process in this study will be carried out systematically using qualitative meta-analysis techniques. Researchers will assess the methodological quality of the studies reviewed, and extract key findings that show the relationship between the implementation of PjBL and the improvement of students' scientific creativity and science process skills. In addition, this study will compare various PjBL models used in science learning at various levels of education (e.g., elementary, middle, and high schools), and evaluate the context and challenges faced by educators in implementing these models. Researchers will also consider variations in results based on factors such as geographic location, type of science subjects, and the role of technology in project-based learning (Barron et al., 2008; Thomas et al., 1999).

The results of this systematic review are expected to provide a clearer picture of the trend of PjBL implementation in science learning, as well as its impact on the development of students' scientific creativity and science process skills. This study also aims to identify existing research gaps and provide recommendations for educators, researchers, and policy makers in optimizing the implementation of PjBL in science classes. Thus, the results of this study are expected to be the basis for the development of better education policies and provide insights for more effective science

teaching in the future (Bell, 2010; Blumenfeld et al., 2011).

### *Data Collection*

In this study, data collection was carried out through a systematic literature study method by identifying, evaluating, and summarizing relevant articles from various sources that can be accessed through international academic databases. The data collection process began with a search for articles from databases such as Google Scholar, JSTOR, ERIC, and Springer covering the research period between 2010 and 2020. The selected articles were studies that discussed the application of the Project-Based Learning Model (PjBL) in the context of science learning, with a primary focus on its impact on students' scientific creativity and science process skills. Inclusion criteria included studies using quantitative, qualitative, or mixed research designs, which focused on evaluating the effectiveness of PjBL in science education. After the collection of articles was carried out, the researcher would filter them based on predetermined methodological quality criteria, such as the relevance of the topic, the clarity of the research objectives, the validity of the instruments used, and the suitability of the data obtained with the focus of the research. In addition, the articles used must also have sufficient empirical evidence to support the analysis of the relationship between PjBL and increased scientific creativity and science process skills. Researchers will ensure that the studies included in this review cover a variety of educational contexts, such as formal (primary, middle, high school) and informal education, as well as a variety of science disciplines, including biology, physics, and chemistry (Hmelo-Silver, 2004).

In the data analysis process, researchers will use thematic coding techniques to identify key themes that emerge in the collected research. Each screened article will be evaluated in depth to assess the results found, including the impact of PjBL on students' scientific creativity and science process skills. This process involves coding data based on indicators such as improving critical thinking skills, the ability to apply scientific theory in real contexts, and collaboration and communication skills in science-based projects (Blumenfeld et al., 2011). This study is expected to produce a more comprehensive picture of the implementation of PjBL and its impact on the quality of science learning at various levels of education.

### *Data Analysis*

The data collected in this study were analyzed using two main bibliometric tools: Publish or Perish 8 and VOSviewer. These tools were chosen because of their ability to perform citation analysis and network

mapping that can provide in-depth insights into research trends, relationships between authors, and emerging topic developments in the relevant literature. Publish or Perish 8 is a software that uses data from Google Scholar to calculate various citation metrics such as the number of citations, H-index, and G-index, which allow researchers to evaluate the productivity and academic impact of a particular author or article. With this tool, researchers can identify the most frequently cited works, which can be an indication of the importance of the article in the development of a particular field of study (Harzing, 2013).

On the other hand, VOSviewer is a software tool used to create bibliometric network visualizations, such as citation maps and keyword co-occurrence maps. VOSviewer combines network analysis with graphical representations that allow researchers to understand the relationships between authors, articles, journals, and keywords in the research field being studied. The network map generated by VOSviewer provides a clear picture of interrelated research clusters, making it easier for researchers to see the development and relationships between topics in the chosen research field. The use of these two tools allows researchers to map the structure of knowledge in the literature related to the application of the Project-Based Learning (PBL) Model in science learning.

Through analysis using Publish or Perish 8, researchers can identify key authors who have made significant contributions to the topic, as well as leading journals that frequently publish related articles. This will help in understanding the trends and developments in the application of PjBL in science education, as well as exploring the influence of these studies on learning practices in the field. In addition, citation analysis also provides information on how broadly and deeply this topic has been studied in various countries and educational contexts. With this data, researchers can explore the relationship between topics that appear in the literature and the development of PjBL theory and practice (Confraria et al., 2017).

Meanwhile, using VOSviewer to analyze keywords in the selected studies will allow researchers to identify the concepts most frequently discussed in the literature related to PjBL and science. The resulting keyword map can show the relationship between broader concepts, such as "scientific creativity", "science process skills", "project-based learning", and "educational evaluation". In addition, the resulting network map also allows researchers to find out if there are areas that are still under-explored or the emergence of new trends that are starting to get more attention in PjBL research, providing insights for further research development (van Eck et al., 2014).

### *Visualization Techniques*

To complement the bibliometric analysis, visualization techniques were employed to illustrate the findings. VOSviewer provided several types of visualizations, including Overlay, density, and network visualizations are commonly used in bibliometric analysis to provide complementary insights into research trends and structures. Overlay visualizations illustrate the temporal evolution of keywords and concepts within the literature by using color schemes to indicate the periods in which specific terms were most frequently cited, thereby helping to identify emerging and declining research trends (van Eck et al., 2014). Density visualizations, on the other hand, emphasize the concentration of research activity by highlighting topics with a high frequency of occurrence, enabling researchers to identify dominant and intensively studied themes within a field (van Eck et al., 2014). Meanwhile, network visualizations present the relationships among authors, institutions, and keywords, making it possible to identify collaboration patterns, research clusters, and the overall structure of scholarly networks (Harzing, 2013). These visualizations serve not only to summarize the data but also to provide a clearer understanding of how different research areas within PjBL in science education are interrelated and evolving.

### *Ethical Considerations*

This study strictly adheres to ethical guidelines in the use of bibliometric data. The bibliographic data used in this study were publicly available through academic databases and were analyzed without any modification. As this research does not involve human participants or sensitive data, ethical approval was not required. All references to authors and publications in the study were appropriately cited to maintain academic integrity.

### *Limitations*

While bibliometric analysis provides valuable insights, it is not without its limitations. One of the main limitations of this study is the reliance on citation counts and keyword analysis, which may not fully capture the quality or depth of the research in the field. Bibliometric tools are also limited by the quality of the underlying databases, and some research might not be indexed in the sources used, particularly non-English language publications or conference proceedings that are not widely disseminated (Harzing, 2013). Additionally, the focus on keywords may miss broader themes that are important but do not appear frequently in the literature.

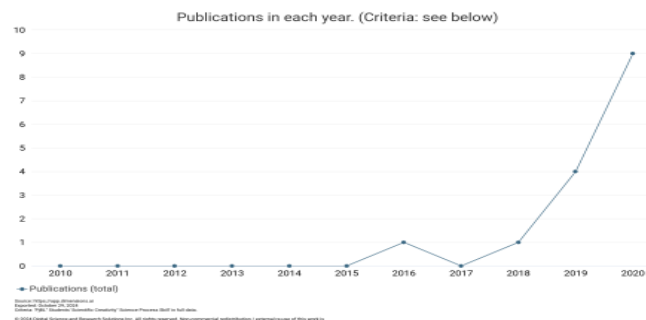
## **Result and Discussion**

This section presents the findings of the bibliometric analysis and discusses the implications of

these results in the context of Project-Based Learning (PjBL) in science education, particularly in enhancing students' critical thinking skills. The analysis identifies key trends in the literature, provides an overview of the most frequently cited authors and journals, and highlights the thematic clusters that define the field of PjBL as it concerns critical thinking and science education. Additionally, the section explores the temporal evolution of research topics and the relationships between these topics, drawing on the findings from the Publish or Perish 8 and VOSviewer tools.

*Trends in Research Publications*

Period 2010 to 2014 Early Stagnation Phase During this period, the number of publications per year appears very low or even non-existent. Period 2015 Early Interest Phase, there is an increase in the number of publications indicating that interest in this topic is starting to increase. Furthermore, the Fluctuation phase in 2016 to 2017 where the number of publications decreased and then increased again. Then in the Stable Growth phase from 2018 to 2019, in these years, the graph shows stable growth even though the number of publications is not yet significant. This indicates consistency in interest and increased knowledge on this topic. Researchers may start to find new, more effective approaches or there are educational policies that encourage this PjBL approach. Then the Significant Spike in 2020 as the Peak Attention phase, shows a significant spike in the number of publications, reaching its highest peak in a decade. This indicates that in 2020, this topic has become a major concern for many researchers. This surge is likely to occur because previous research has shown strong evidence of the effectiveness of PjBL in improving students' science process skills and scientific creativity. On the other hand, the development of educational technology may also encourage increased implementation of PjBL in various schools, making this topic increasingly interesting to study.



**Figure 1.** Annual publication trends on PjBL and students' scientific creativity and process skills (2010-2020)

This trend shows an increasing interest in the application of project-based learning models in science

learning to develop students' scientific creativity and science process skills. The spike that occurred in 2020 could be an indication that this topic is increasingly relevant and starting to be taken into account in education policies. It could also indicate an increase in the availability of technological infrastructure and the development of methods that facilitate the wider and more effective application of PjBL.

With this review, researchers can see opportunities to continue further research on aspects that may not have been touched upon, such as methods for evaluating scientific creativity and deeper science process skills in the context of project-based learning. In addition, educational policies that encourage the implementation of PjBL also need to be explored to see the extent to which policy support can influence the effectiveness of the implementation of this learning model.

*Primary Sources of Publications*

The following table shows the ranking of journals that publish the most articles related to PjBL in science education. The Journal of Science Education Research Journal is ranked first with the highest number of publications, which is 17 articles (table1). This shows that this journal has a significant contribution to PjBL research in the field of science education. In second and third place, there are the Journal of Physics Conference Series and the International Journal of Instruction, each with 3 publications. These two international journals also have high relevance in PjBL studies, focusing on project-based approaches to improve critical thinking skills in science.

**Table 1.** Top 10 Journals Publishing Articles on PjBL in Science Education

Rank	Journal Name	Publications
1	Journal of Science Education Research	17
2	Journal of physics conference	3
3	International Journal of Instruction	3
4	Indonesian Science Education Journal	2
5	JBPI (Journal of Indonesian Biology Education)	2
6	Studies in Learning and Teaching	2
7	Research and Development in Education	2
8	Learning and individual differences	1
9	Creativity Research Journal	1
10	International Journal of Science Education	1

In addition, several other journals such as Jurnal Pendidikan IPA Indonesia, Studies in Learning and Teaching, and Research and Development in Education recorded 2 publications each. Meanwhile, journals such as Learning and Individual Differences, Creativity Research Journal, and International Journal of Science Education each had 1 publication. Although the number

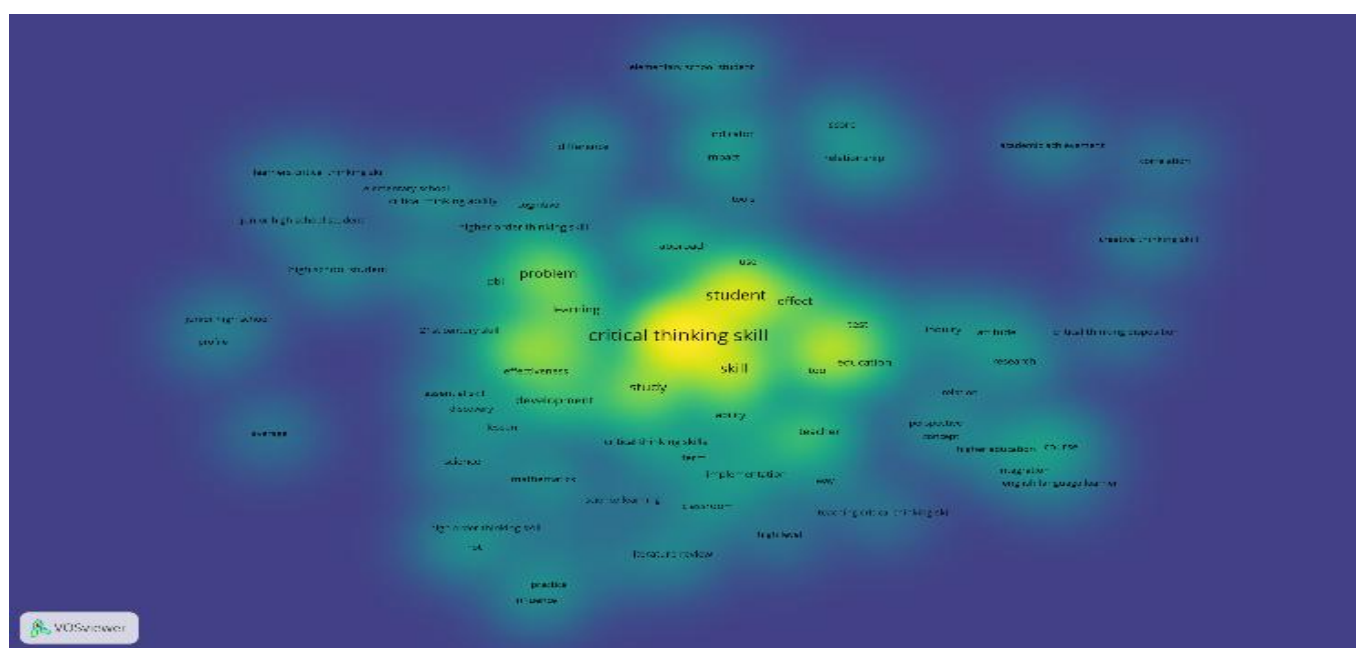
of publications is smaller, these journals are still important because they provide different perspectives on the application of PjBL in science education. Overall, these data illustrate a fairly diverse distribution of publications, both from local and international journals, related to the application of PjBL in the context of science education.

#### *Thematic Clusters and Key Research Topics*

Based on the VOSviewer analysis shown in Figure 2, several main thematic clusters were identified in the literature on the application of PjBL in science education. These clusters illustrate interrelated research areas and reflect important developments in the field. Among the themes that emerged, there was a cluster focusing on critical thinking and problem-solving, indicating that PjBL is often linked with efforts to improve students'

analytical thinking skills and skills in facing complex challenges.

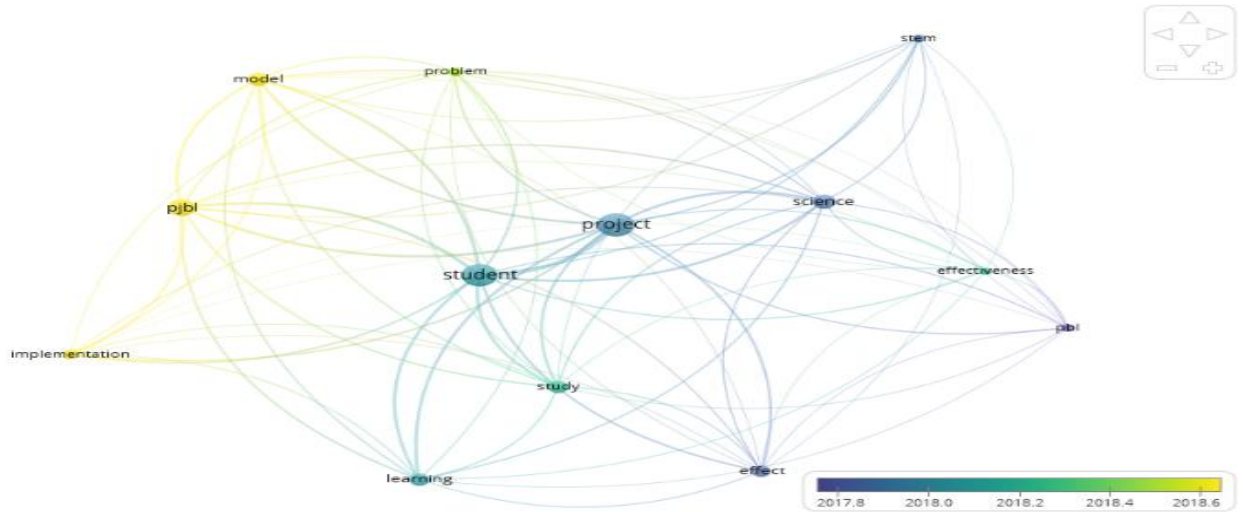
In addition, there is another cluster that includes STEM integration, which shows a strong focus on combining science, technology, engineering, and mathematics in project-based learning. This cluster also includes the theme of collaborative learning, which illustrates the importance of student interaction in PjBL projects to develop social and communication skills. Each of these clusters forms an interconnected network, reflecting how various 21st-century competencies, such as creativity, teamwork, and technical skills, are strengthened through the application of PjBL in science education. This visualization highlights the multifaceted role of PjBL in shaping learning that is more holistic and relevant to students' future needs.



**Figure 2.** Visualization of thematic clusters in PjBL and students' scientific creativity and process skills

Based on the image showing the visualization overlay of the temporal evolution of research topics related to the Project-Based Learning (PjBL) Model in improving scientific creativity and science process skills (2010-2020), there is a significant increase in research focus on several key themes. In the early period (2010-2014), the main topics that were widely discussed were the development of science process skills and the application of PjBL in improving students' basic skills, such as observation and classification. During this period, themes such as "collaborative learning" and "critical thinking" began to emerge but had not yet dominated the literature. The lighter colors on keywords such as "problem-solving" and "scientific creativity" indicate that research began to develop to integrate more complex aspects in science learning.

Entering the 2015-2020 period, these topics began to receive greater attention, with the emergence of new clusters focusing on STEM integration and technology applications in PjBL. Research in this period showed the dominance of themes such as "STEM integration", "critical thinking", and "problem-solving", which increasingly reflect the need to prepare students with 21st century skills. In addition, these topics became more frequently cited, with lighter colors indicating an increased focus on developing critical thinking and problem-solving skills through a project-based approach. This indicates that PjBL is not only considered as a method to improve science process skills, but also as a tool to strengthen more complex and relevant skills to the demands of the times.



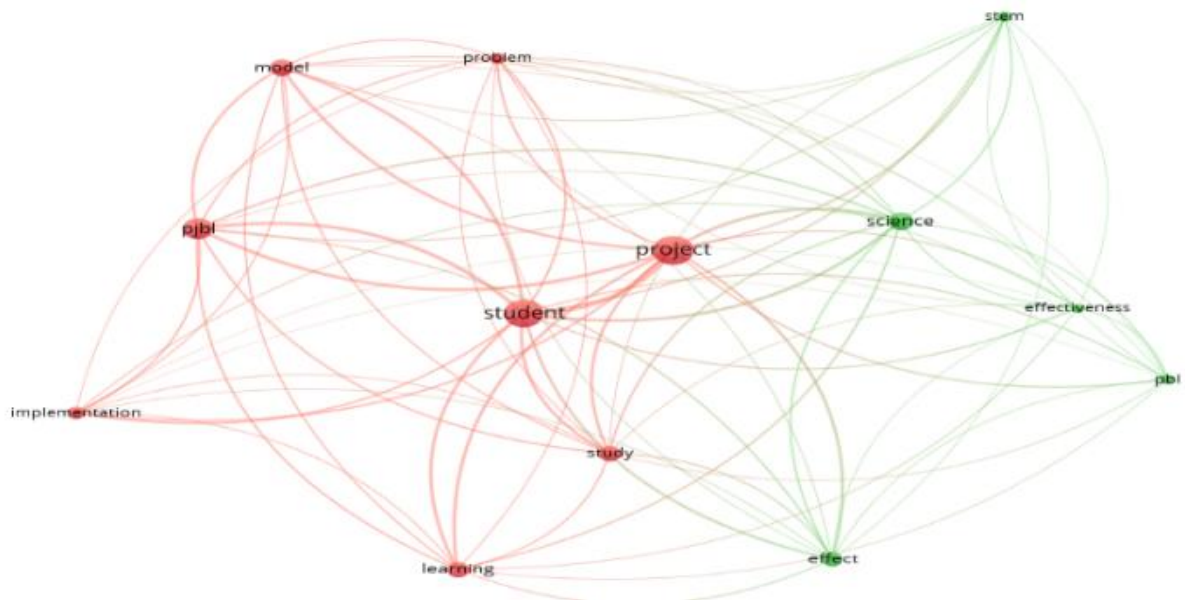
**Figure 3.** Overlay visualization showing temporal evolution of keywords

*Citation and Author Network Analysis*

Based on the citation analysis and author networks shown in the figure, there are strong connections between several key authors in PjBL research in science education. Highly cited authors, such as Bell (2010) and Thomas (2000), stand out in shaping the theoretical foundations for implementing PjBL to improve students’ scientific skills. This interconnected author network suggests close collaboration among researchers in developing an understanding of how PjBL can be effectively implemented in science learning contexts. Most of the authors in this network come from different institutions and countries, demonstrating global engagement in the topic, and they cite each other in their

work, creating a dynamic and growing research ecosystem.

In addition, the network visualization also shows how the works of prominent authors often appear in newer literature, with several younger authors building on theories and concepts developed by key authors. The citation map also reflects the strong influence of works on critical thinkin, problem-solving, and STEM integration, which have become a major focus of PjBL research in recent years. This author network indicates the consistency and growth in PjBL research, as well as the significant contributions made by the authors in forming a deep theoretical foundation for the use of PjBL to improve students’ science process skills.



**Figure 4.** Network visualization of citation and author collaboration in PjBL research

*Implications for Research and Practice*

The findings from this bibliometric analysis have significant implications for both research and practice.

From a research perspective, the increasing integration of scientific creativity and science process skills in PjBL opens up promising avenues for future studies,

particularly in exploring the effectiveness of technology-enhanced PjBL in developing critical thinking in various educational settings. Future research could also examine the impact of cross-disciplinary collaboration in PjBL, as it is clear that cross-disciplinary research is essential to the development of this field. change the paragraph with keywords from a practical perspective, educators are encouraged to consider the integration of digital tools in PjBL, especially in the context of distance learning and hybrid classrooms. These findings suggest that technology-enhanced PjBL not only supports critical thinking but also helps students engage with scientific content in a more interactive and applicable way, making learning more relevant and meaningful.

## Conclusion

This study demonstrates that Project-Based Learning (PjBL) plays a substantial role in enhancing students' scientific creativity and science process skills in science education. The bibliometric analysis reveals a consistent growth in research interest, particularly in relation to critical thinking, problem solving, STEM integration, and collaborative learning. The findings indicate that PjBL supports experiential and inquiry-oriented learning, enabling students to engage in authentic scientific practices that foster higher-order thinking skills. Additionally, the increasing use of digital technologies within PjBL reflects its adaptability to contemporary educational demands. Overall, PjBL emerges as a promising instructional model for developing essential 21st-century skills, suggesting its continued relevance and potential for broader implementation in science education.

## Acknowledgments

Thank you to all parties who have helped in this research so that this article can be published.

## Author Contributions

All authors contributed to writing this article.

## Funding

No external funding.

## Conflicts of Interest

No conflict interest.

## References

- Barron, B., & Darling-Hammond, L. (2008). *Teaching for Meaningful Learning: A Review of Research on Inquiry-Based and Cooperative Learning*. Stanford University.
- Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House:*

- A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39-43.  
<https://doi.org/10.1080/00098650903505415>
- Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (2011). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, 26(3-4), 369-398.  
<https://doi.org/10.1080/00461520.1991.9653139>
- Confraria, H., Mira Godinho, M., & Wang, L. (2017). Determinants of citation impact: A comparative analysis of the Global South versus the Global North. *Research Policy*, 46(1), 265-279.  
<https://doi.org/10.1016/j.respol.2016.11.004>
- Doyan, A., Susilawati, Harjono, A., Muliyadi, L., Hamidi, Fuadi, H., & Handayana, I. G. N. Y. (2023). The effectiveness of modern optical learning devices during the Covid-19 pandemic to improve creativity and generic science skills of students. *The 1st International Conference on Science Education and Sciences*, 020005.  
<https://doi.org/10.1063/5.0122553>
- Hallinger, P., & Chatpinyakoo, C. (2019). A Bibliometric Review of Research on Higher Education for Sustainable Development, 1998-2018. *Sustainability*, 11(8), 2401.  
<https://doi.org/10.3390/su11082401>
- Hallinger, P., & Nguyen, V.-T. (2020). Mapping the Landscape and Structure of Research on Education for Sustainable Development: A Bibliometric Review. *Sustainability*, 12(5), 1947.  
<https://doi.org/10.3390/su12051947>
- Harzing, A. W. (2013). *Publish or Perish, Version 8.1.0*. Retrieved from <http://www.harzing.com/pop.htm>
- Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235-266.  
<https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Krajcik, J., Schneider, B., Miller, E. A., Chen, I.-C., Bradford, L., Baker, Q., Bartz, K., Miller, C., Li, T., Codere, S., & Peek-Brown, D. (2023). Assessing the Effect of Project-Based Learning on Science Learning in Elementary Schools. *American Educational Research Journal*, 60(1), 70-102.  
<https://doi.org/10.3102/00028312221129247>
- Susilawati, Doyan, A., Rokhmat, J., & Muliyadi, L. (2023). Analysis Validation of Modern Physics Learning Media Based on Smartphone Integrated Project Based Learning to Improve Students' Creativity and Scientific Literacy. *Jurnal Penelitian Pendidikan IPA*, 9(10), 7888-7892.  
<https://doi.org/10.29303/jppipa.v9i10.5404>
- Susilawati, Doyan, A., Rokhmat, J., Muliyadi, L., Rizaldi,

- D. R., Fatimah, Z., Ikhsan, M., & Ardianti, N. R. (2025). Integration of Smartphone-Based Learning Media and Project-Based Learning to Enhance Creativity and Scientific Literacy in Physics. *International Journal of Information and Education Technology*, 15(7), 1449–1459. <https://doi.org/10.18178/ijiet.2025.15.7.2346>
- Thomas, J. W., Mergendoller, J. R., & Michaelson, A. (1999). *Project-based learning: A handbook for middle and high school teachers*. Buck Institute for Education.
- van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. In *Measuring Scholarly Impact* (Vol. 60, Issue 5, pp. 285–320). Springer International Publishing. [https://doi.org/10.1007/978-3-319-10377-8\\_13](https://doi.org/10.1007/978-3-319-10377-8_13)
- Walan, S., & Gericke, N. (2021). Factors from informal learning contributing to the children's interest in STEM - experiences from the out-of-school activity called Children's University. *Research in Science & Technological Education*, 39(2), 185–205. <https://doi.org/10.1080/02635143.2019.1667321>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education - where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 39. <https://doi.org/10.1186/s41239-019-0171-0>