Project Based Learning (PjBL) Model in Science Learning: A Bibliometric Analysis

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Abstract. The purpose of this research was described to gain comprehensive insight into Project Based Learning (PjBL) in science learning and find out the research topics that are being researched a lot at the moment. This research was carried out through bibliometric analysis using Scopus data sources, a total of 182 documents were obtained in the period 1994-2022. VOSviewer is used as a tool to image keywords, and the final research area in PjBL. The research results show that so far the number of publications regarding PjBL in science learning has fluctuated. The United States stands out as the leading country in terms of publication volume, with significant contributions from its authors and research institutions. An analysis of keywords indicates that, in the past two years, research on Project Based Learning has predominantly focused on topics such as physics, steam, integration, research methods, and junior high school education. This suggested bibliometric analysis offers valuable insights into the primary topics explored in the realm of Project Based Learning (PjBL) within the context of Science Learning.

1 Introduction

In the context of 21st-century global advancement, being competitive demands a diverse range of skills, particularly in the areas of science, technology, engineering, and mathematics [1]. Project-based learning (PjBL) is a recommended learning model because it is effective in engaging students meaningfully and gaining direct experience in science learning [2, 3]. The effectiveness of how teachers apply Project-Based Learning (PjBL) significantly affects both the students' comprehension of the material and the enhancement of their skills [4]. Some teachers consider the important goal of PjBL in science learning to be the development of students' knowledge and understanding of mathematics and science. The main characteristics of PjBL are the development of teamwork skills and the relationship between theory and practice so that the PjBL model is recommended because it can prepare students for their future work and life. Additionally, PjBL is considered suitable for proofreading and learning new content [5]. PjBL has a positive effect on learning outcomes...
can develop students' problem solving skills [7]. PjBL can motivate students from various backgrounds to persist in learning [8], improve mastery of concepts [9], critical thinking skills [10], students' communication skills after implementing PjBL [11] student literacy [12], [13], science process skills [14], and creative thinking skills [13–15–17].

Science learning must apply more innovative educational methodologies such as PjBL [18]. Implementing the PjBL model also helps science teachers to become more critical and reflective, and improves directed learning [19]. Teacher training using the PjBL method also shows an emotional increase which has an impact on their social life in the future [20].

In Indonesia, the approach to science education has not yet been fully aligned with the enhancement of skills relevant to the 21st century [17]. There are many challenges in implementing PjBL, such as students who are hesitant to seek help in learning, teachers who have difficulty assessing learning, uncertainty about the roles of teachers and students, and requiring longer allocations of learning time [2, 5, 21]. In addition, students stated that learning science in class was less enjoyable, they had difficulty in solving abstract science problems, and students were more interested in studying science that was related to problems in everyday life [22]. Regarding the role of teachers, it was found that many teachers did not understand PjBL-based science learning so that the learning steps implemented in class were not as appropriate as they should be [23]. A study revealed deficiencies in PjBL practices when using reflection and student-centred approaches, teachers experienced difficulties in relation to assessment. Teachers see PjBL as useful but need support in its implementation [4]. It was also found that in online learning during the pandemic, few people know how PjBL can be implemented effectively and fairly [24].

In this research, a bibliometric analysis study was carried out to provide knowledge about PjBL in Science Learning. The aim is to examine the number of journal publications per year, countries, and the most cited themes regarding PjBL. In this study, trends that emerge in research containing PjBL will be identified so that it becomes an attraction for further research. The study utilizes the following research questions: (1) What are the annual publications on the topic of PjBL in Science Learning?, (2) Which countries publish a lot of documents about PjBL?, (3) Which journals or proceedings publish a lot about PjBL?, and (4) What are the main publications and research interests based on keywords in Author keywords in co-occurrence analysis?

2 Methods

The research methodology was executed in various phases, starting with the identification stage. During this stage, data was gathered from the Scopus database using keywords such as "Project based learning," "PjBL," "Project-based learning," combined with "science education" or "science learning." This process yielded a total of 206 documents screening stage used Publication stage: final. The source type is Journal and Conference Proceedings and at the eligibility stage using all language criteria, 183 documents were obtained. Documents are entered into software, namely VOSviewer, to carry out bibliometric analysis regarding keywords in PjBL. After that, data analysis was carried out to determine the main themes discussed in the latest research developed on PjBL in science learning. The steps and criteria in the methodology phase applied in this study are outlined in Figure 1.
3 Results and Discussion

Retrieving data based on the Scopus database using the keywords "Project based learning" OR "PjBL" OR "Project-based learning" AND "science education" OR "science learning" resulted in the number of documents published in the period 1994-2022 as in Figure 2.

The research on PjBL that was obtained began with the first research in 1994-2022. Based on the number of published documents, it shows that research on PjBL is quite fluctuating, from 2014 to 2017 it increased, then decreased in 2018 and increased again in 2019. However, in 2020 it only experienced a slight decrease because research was still being carried out even though there was an outbreak. Covid-19, it can also be seen that in 2021 publications have increased even though the pandemic is still continuing. During the pandemic, one particular study was carried out to uncover a method of learning science from home, utilizing a contextual approach [25].
Based on the Scopus database, the most productive countries in the PjBL sector are obtained. This can be seen in Figure 3.

Figure 3 shows that the United States is the most productive country conducting research in the field of PjBL with 62 documents. For instance, the researcher Peek-brown from the CREATE for STEM Institute at Michigan State University in the United States conducted a study focusing on the perspectives of high school teachers as they transition to teaching curricular units aligned with NGSS (Next Generation Science Standards) through Project-Based Learning (PjBL) [26]. Miller E.C. a writer from Science Education, University of Wisconsin - Madison, United States who researches Motivating Teaching, Sustaining Change in Practice: Design Principles for Teacher Learning in PjBL Contexts [8]. Berland, a writer from the Department of Curriculum and Teacher Education, Stanford University, United States, researched Supporting Equity in Virtual Science Instruction Through PjBL: Opportunities and Challenges in the Era of COVID-19 [24].

The second most productive country is Indonesia with 30 documents. Here it can be seen that Indonesia is one of the countries that has researched a lot about PjBL in science learning. The terms include countries that have studied PjBL in the context of science education.

Below are also presented 10 sources from both journals and proceedings that publish a lot about PjBL, which can be seen in Figure 4.

![Graph showing productivity by country](image1)

**Fig. 3.** 10 Productive country in the field of Project Based Learning in Science Learning

![Graph showing journal/Proceedings productivity](image2)

**Fig. 4.** 10 Journal/Proceedings that publishes many PjBL articles in Science Learning
In Figure 4, it can be seen that of the 10 existing sources, most of them are dominated by journals. However, in places 3 and 4, the sources that publish the most PjBL articles come from proceedings such as the ACM International Conference Proceedings Series with 7 articles and Proceedings Frontiers In Education Conference Fie with 6 articles. Meanwhile, the journal source that publishes the most articles about Project Based Learning in science learning is the Journal of Physics Conference Series with 18 articles.

It turns out that a lot of research on PjBL has been published by the Journal of Physics Conference Series. Apart from being published by journals and proceedings related to education and technology, it turns out that proceedings related to astronauts also publish documents about PjBL, namely the Proceedings of the International Astronautical Congress IAC, for example, researched by Milord and Fredette regarding Sparking space curiosity: Ilead and DreamUp's hands-on activities to set educators and students on a path to space science and STEAM success [27], and others researched by Patel et. al, researching Space explorers™ academy: A unique expert led outreach program to engage youth in space! [28]. It was also found that the journal Frontiers In Psychology which comes from the field of psychology also received articles about PjBL, for example research conducted by Shernoff, Sinha, Bressler, and Schultz which researched Teacher perceptions of their curricular and pedagogical shifts: Outcomes of a project-based model of teacher professional development in the next generation science standards [29]. Additionally, this section employs a Co-occurrence type of analysis and an All keywords unit of analysis, with a minimum occurrence criterion of 4 for each keyword. Out of 979 keywords, 38 meet this threshold, highlighting keywords related to PjBL. The outcomes of this analysis are presented in Figure 5.

In Figure 5, the keywords associated with Project Based Learning are grouped into six distinct clusters. Unsurprisingly, the term "Project Based Learning" stands out as the most prominent, not just in cluster 1 but throughout the entire network. The key terms in cluster 1, which is indicated in red, primarily revolve around the implementation of Project Based Learning. This includes references to students, computing education, STEM education, and science learning. Apart from that, in this cluster the focus also includes training used to support Project Based Learning, such as learning systems and integration.

Project-based learning enables students to uncover extensive scientific information related to the subjects being studied. By selecting problems that are closely aligned with
everyday life contexts, it becomes easier for students to engage in learning [25]. Moreover, the findings from the meta-analysis indicate that the project-based learning approach outperforms conventional teaching methods in enhancing students' academic performance in science classes [30, 31]. Project-based science learning can provide meaningful narratives and activities for students to engage with [32]. Regarding STEM, PjBL is considered beneficial for improving STEM learning compared to conventional teaching approaches [33]. STEM represents an educational approach that combines science, technology, engineering, and mathematics to develop skills pertinent to the 21st century [34] and integration of interdisciplinary subjects that play a key role in future careers [10]. STEM has been proposed as a perspective for more integrated learning and is usually proposed in the form of interdisciplinary Project Based Learning activities, also to overcome gender bias in Science learning [35].

In science learning, the pedagogical competence of science teachers in PjBL can be improved through collaborative learning where students, teachers and other participants learn from each other. [4]. Science education is influenced by direction from a variety of sources including national, state, and local policies and teacher communities of practice [36]. Enhancing science education in schools can be realized through a well-integrated system that includes learning experiences for both teachers and students, professional development, and formative assessments of units, all aimed at aiding students in actively engaging in science [37]. In a study it was also found that STEM-based PjBL learning was used for students who experience visual impairments (VI) with assistive technology and multisensory experiences, supporting how students with VI are involved in STEM education [38]. In separate studies, it has been observed that PjBL is also implemented in computing education. This is in line with the perspective presented in Nolan and Temple Lang's "Computing in the Statistics Curricula" (2010), which advocates for a transformation in statistics education to broadly encompass computing. This shift emphasizes project-based learning to enable students to showcase both their technical abilities and creativity [39].

In cluster 2 the term that stands out is Computer Science Education. The main words in this cluster are related to the integration of PjBL with software technology, marked in green, items that appear such as software engineering, software design, computer aided instruction, and artificial intelligence. Studying the impact of creativity in computer science education (CSE) is a captivating area of research that offers ample opportunities for investigation. This is primarily because the concept of creativity is intricate, and the field of CSE research is relatively new in comparison to other educational domains that have delved deeper into this subject [40]. Improving computer science education, it is known that PjBL is able to identify improvements in the development of six of the seven skills assessed in computer science education [41]. Learning using the PjBL method also provides insight into student perceptions, and abilities related to computer science and related STEM (Science, Technology, and Engineering, and Mathematics) skills, which can help educators understand how to best prepare students for future success. As tech-savvy citizens, while helping move them toward greater interest and engagement in computer science [42]. It was also found in PjBL that teaching software engineering design to large, diverse groups poses many challenges, but the results encourage better software design skills [43]. The PjBL approach is also applied in software engineering and computer science, to illustrate, in the article titled "Collaboration Between Industry and Academia: Insights from Google Faculty in Residence Experiences," the discussion centers around Google Faculty in Residence (FIR), a program in which faculty members collaborate with seasoned Google developers. As part of the FIR program, participants receive training from Google developers on best practices in software engineering, as well as guidance on preparing students for the industry and strategies for enhancing recruitment and retention in computer science [44]. In the article An Interdisciplinary Program for Undergraduate Computer Science and Engineering Education
In the Field of Robotics, it is discussed that PjBL is applied to learning artificial intelligence [45]. In other research, namely the article Integrating AI and machine learning in software engineering courses for high school students, it is explained that PjBL is applied to high school students which includes artificial intelligence and machine learning subjects. [46].

In cluster 3 marked in blue, terms related to the education system appear more frequently, such as teaching, curriculum, education, problem based learning, and problem solving. The selected pedagogical approaches among secondary school science teachers include PjBL (43.50%), STEAM (16.70%), PBL (13.90%), Inquiry (12.00%), STEM (16.70%), and Personal Strategy (2.80%). PjBL is known for its capacity to foster creativity. The enhancement of student creativity is contingent upon a solid foundation in fundamental scientific principles. This implies that the acquisition of conceptual knowledge and the cultivation of creativity are integral educational objectives that should not be dissociated [47]. It was found that PjBL also develops critical thinking and problem solving skills [48]. In the current learning curriculum, there are many praxis-oriented programs such as projects. They prepare students to work on real-world projects. Project course settings should offer an environment similar to a real-world project, so students can gain experience [49]. Not only that, the role of teachers also significantly influences curriculum innovation design [50].

Cluster 4 is marked in yellow, showing the main words that appear including engineering education, computer science, computer programming, computer software, and motivation. In engineering education, it is known that female participants feel safe about PjBL in general, but still feel the pressure of male dominance in group interactions, due to gender bias from current social and cultural stereotypes [51]. It was also found that PjBL is widely applied in computer science, for example in the journal Computer Science bachelor students at Frankfurt University of Applied Sciences in their final year [52]. The use of computer simulations has been proven to help students visualize concepts so they are easy to understand [53]. Another research investigation revealed that elementary school educators, who possessed limited computer science expertise, incorporated it into project-based learning (PjBL) within the context of the standards-based elementary curriculum for Grades 3-5 [54]. The implementation of STEM project-based learning provides a significant increase in student motivation. There are significant differences before and after implementing STEM-based projects. According to this research, STEM project-based learning can be an alternative strategy to increase student motivation towards science learning [1]. Furthermore, during pre-service teacher training, attention is given to the motivation and engagement of participants in the course material, as well as students' evaluations of their training experience, with a specific focus on STEAM project-based learning activities [55].

In cluster 5 there is only one term, namely higher education, which is marked in purple. In an article titled "Advancing Culturally Tailored Scalable Personalization: Experiments with Data Science Students," it discusses the development of an extensive data science initiative designed to promote diversity within online data science education. This initiative was established to facilitate a range of fundamental skill-based higher education offerings. The program draws inspiration from project-based learning and culturally sensitive teaching practices, with a focus on evaluating the feasibility of implementing these methods in large and culturally diverse educational settings worldwide [56].

Finally, in cluster 6, there is also only one term, namely physics. Project-based learning uses projects to enable students to learn practical knowledge. In this research, PjBL was applied to physics students and the results showed that it was proven to increase their ability to apply their knowledge in the real world [57].
In Figure 6, it can be seen that in the last 2 years, research on project based learning has been mostly associated with physics, steam, integration, research methods, and junior high schools. So this can be a reference for other researchers for further research on PjBL. The utilization PjBL-centered STEM educational approach within physics learning materials has led to a substantial improvement in creative thinking abilities. There exists a notable disparity enhancement of students' creative thinking skills when comparing their levels before and after the implementation of STEM learning approach [17]. It is known that recently interest in STEAM-based education has increased, because it provides a variety of skills needed for economic development. A study shows that efforts have been made to implement the STEAM curriculum in the education system [58]. Especially important in the context of STEM and STEAM, where it is often stated that once they enter the job market, today's students will have jobs that do not currently exist [27]. In other research, it was found that there was a difference in concept mastery between the experimental class that used the PjBL model of science learning tools and the STEM approach and the class that did not use these tools. [59]. Incorporating STEAM-PjBL (Science, Technology, Engineering, Arts, and Mathematics - Project-based Learning) into science education fosters students' recognition of the practical application of scientific knowledge in everyday occurrences. It nurtures their inquisitiveness, problem-solving skills, and bolsters their willingness to pose inquiries and seek information from diverse sources. Furthermore, students derive significant and engaging learning experiences by engaging in the creation of STEAM projects [60].

4 Conclusion

From 1994 to 2022, there has been variability in the volume of publications pertaining to PjBL in science education. The United States stands out as the leading country in terms of the number of publications, featuring authors and research institutions actively contributing to this area. An analysis of keywords indicates that recent studies on PjBL in science education, particularly within the last two years, have predominantly focused on topics related to physics, STEAM (Science, Technology, Engineering, Arts, and Mathematics),
integration, research methodologies, and middle schools. This research offers valuable insights into the primary themes explored in the context of PjBL in science education.

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