Project Based Learning in Physics Teaching: Bibliometric Analysis and Research Trends in Last Ten Years

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Abstract. Rapid technological advancements and innovations in the 21st century have prompted numerous experts to seek and analyse recent century-appropriate learning models. The learning potential of constructivism is an alternative for preparing students for the future. Project-based learning (PjBL) models are one of the most popular constructivism models. This study's objective was to present a classification and bibliometric analysis of PjBL in the teaching and learning process of physics. Article categories, abstracts, and keywords were utilised to retrieve research data from the Scopus database and there were 604 documents related to PjBL research on physics. The bibliometric analysis revealed the growth of publications in terms of number, type, and language, as well as the top ten publications based on countries, institutions, and researchers from Indonesia and the rest of the world. In relation to research trends on PjBL in physics, global researchers produce 16 clusters, while Indonesian researchers produce 5 clusters. Additionally, new perspectives for expanding the use of PjBL in physical education were discussed. Implementation of PjBL in physics, particularly in physics education, has been dominated by STEM approaches that can enhance students' critical thinking, problem-solving, creative thinking, and creativity.

Keywords: Project based learning, bibliometric, 21st century skills, physics research trends

1 Introduction

With the introduction of rapidly evolving educational technology, the 21st century presents numerous opportunities and challenges that are very different from those of the past [1]–[4]. The rapid development of innovation and technology motivates the field of education to analyse and seek out appropriate classroom learning methods [5] so that students can adapt to life in the 21st century [6]. In the 21st century, learning becomes more accessible, simpler, and cheaper [7]. Through student-centered classrooms and personalised learning approaches, 21st century education represents a progressive academic landscape in which the learner is better prepared for life than for work [8].

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In the 21st century, schools will incorporate project-based curricula that engage students in addressing real-world problems and issues of significance to humanity [9]. Teachers cannot impart knowledge directly to students. Students must, however, actively construct their own knowledge [10]. The students of today are the first generation to have grown up with digital technologies. They spend their entire lives surrounded by and using digital devices, including computers, video games, digital music players, cell phones, and video cameras [11].

Constructivism is a theory that asserts learning is an individual activity in which learners attempt to comprehend all perceived information and construct meaning from it [12], [13]. Constructivism is a learning philosophy, so it is crucial to have an achievement test that implements numerous constructivist practises [14], which PjBL does [15]. Innovative and student-centered, project-based learning encourages students to conduct investigations, collaborate in research, and create projects; they are also proficient in the use of technology and capable of solving problems [16]–[18]. This learning requires active student participation and highlights the significance of student activities [19]–[21]. This model enables learners to become independent [22].

In the 21st century, technology can become an enabler for students to experiment with notes that must be accompanied in order for students to use technology effectively in a safe and productive manner [23]. Project-based learning can have a positive effect on classroom learning and can improve students' problem-solving skills [24]. Successful implementation of PjBL in the classroom depends on teachers' ability to shape, motivate, and guide students [23].

Through a series of PjBL activities based on the 4C's of critical thinking and problem solving, creativity and innovation, collaboration, and communication, students are expected to master soft skills [25]–[28]. Examples of 21st century skills include developing personal and social skills, sharing information, values, and knowledge, and participating in society [29]. Combining PjBL with STEM can improve learning efficiency and significance [30], [31].

STEM education encourages students to engage in active learning and aims to equip them with the essential skills required in the workplace [32], [33]. The integration of PjBL with STEM can enhance the cognitive, affective, and psychomotor skills of students [34]–[36]. According to research, STEM education influences the 4C abilities of students, namely their ability to think logistically, be creative and innovative, solve problems, and work in teams [37]–[39].

The paper conducted a bibliometric analysis of a trend in research on project-based learning in physics based on the explanation provided. Bibliometrics is the study of publishing patterns in the distribution of information using mathematical and statistical techniques [40], [41]. Bibliometrics is the study of techniques for retrieving and statistically analysing the information contained in published scientific articles [42]. The objective of this study was to examine project-based learning in physics using bibliometric mapping with the Scopus database and the VOSviewer application.

2 Method

This study employs a bibliometric analysis with Scopus database data sources. The researcher began by entering the phrase "project-based learning in physics" on the title, keywords, and abstract before selecting the years 2012 to 2021. The complete steps were illustrated on Figure 1. From 2012 to 2021, 604 documents were related to project-based learning in physics. The data were saved as (.csv) and (.ris) files. The data was then processed in Microsoft Excel and VOSviewer, which can be utilised to describe data in table, graph, and map formats.

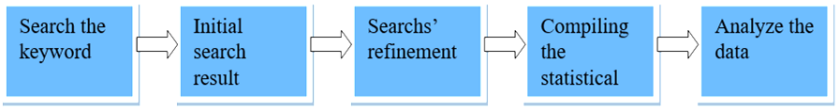

Fig. 1. Steps on conducting with bibliometric analysis

The relationship between PjBL and 4C as it relates to collaboration and communication was not discussed further in this study. This study is limited to analysing the extracted titles, keywords, and abstracts from the Scopus database. Therefore, it is impossible to estimate the relationship's strength with precision. In addition, the extent to which PjBL is applied to physics in Indonesia and the rest of the world is unknown.

3 Results and discussion

3.1 Publication Output, Document Source, and Language Source

The Scopus database contains 604 documents related to PjBL research on physics. Figure 2 depicts the publications devoted to PjBL research in physics over the past decade. In the last ten years, from 2012 to 2021, the number of physics-related PjBL documents has fluctuated, with the greatest increase occurring in 2019 with an increase of 61 documents.

Figure 3 shows the number of documents based on their sources reveals that conference proceedings articles predominate with 364 documents, followed by journals (203), book series (25), and books (12).

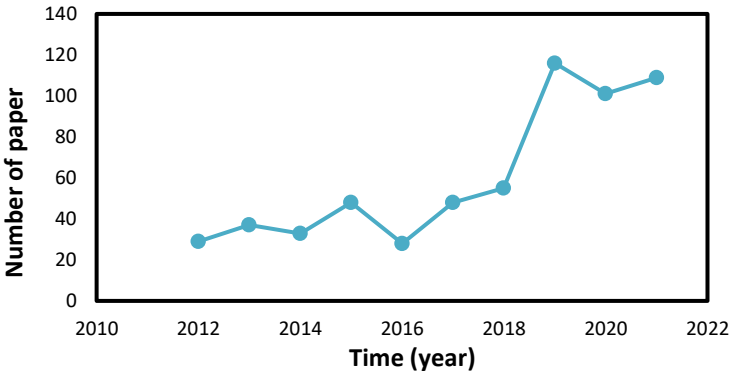

Fig. 2. Documents' distribution in PjBL topic

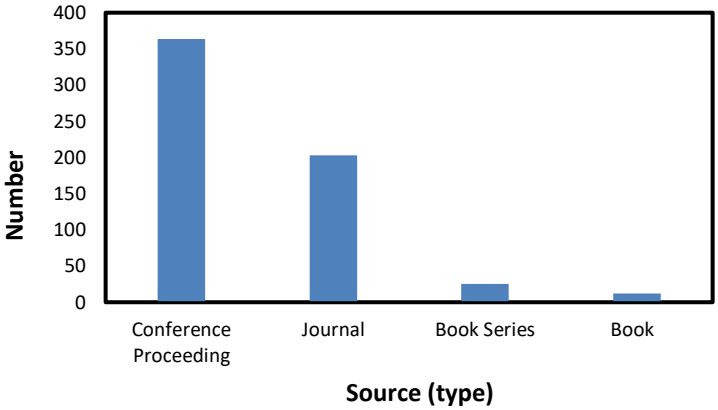

Fig. 3. Documents' type number of PjBL topic

In addition, the majority of the 604 documents used English as the language of the articles. Another document employs Portuguese, Russian, Spanish, and Turkish, and a document with an unspecified language was discovered, as indicate in Figure 4.

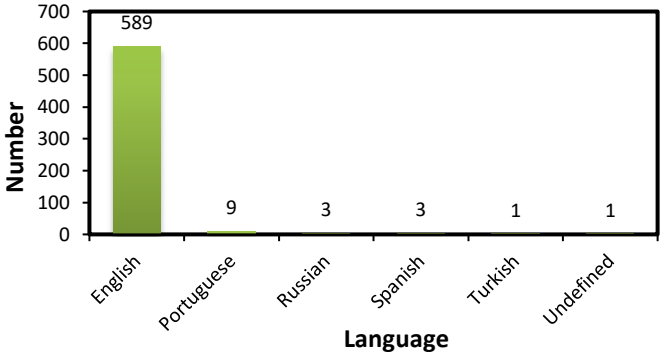

Fig. 4. Documents' language number of PjBL topic

3.2 Publication Distributions of Countries and Institutes

With 189 cross-border documents between 2012 and 2021, it is evident that the United States dominates the market based on Figure 5's distribution of the top ten countries. Indonesia ranks second with 81 total documents. Italy, Spain, Brazil, Russia, and Germany all contributed nearly the same amount of documents: 25, 24, 23, and 21 respectively.

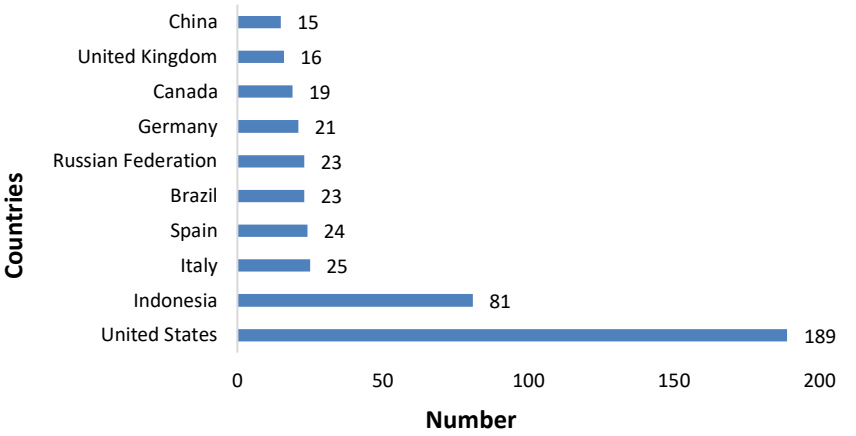

Fig. 5. Documents' countries distribution number of PjBL topic

Table 1 displays the number of physics-related PjBL documents published by institutions between 2012 and 2021. Indonesian Education University, Surabaya State University, Padang State University, Semarang State University, and Malang State University are among the top ten universities in the world. First place was awarded to Indonesian Education University, which contributed 12 documents, followed by Texas A&M University, which contributed 9 documents.

Table 1. Countries and its publication number of PjBL documents

Institution	Number of Documents
Universitas Pendidikan Indonesia	12
Texas A&M University	9
Universitas Negeri Surabaya	9
Universitas Negeri Padang	9
Universitetet I Oslo	8
Universitas Negeri Semarang	8
Michigan State University	7
Universitas Negeri Malang	7
Harvard University	6
Universidade Federal de Santa Catarina	6

3.3 Publication Patterns: Source Titles

The publication pattern of the journals and proceedings that contributed the most to PjBL physics research is displayed in Table 2. The Journal of Physics Conference Series is a prestigious conference with 89 documents containing articles on PjBL in physics.

Table 2. Source titles and its publication number of PjBL documents

Source Titles	Number of Documents
Journal of Physics Conference Series	89
ASEE Annual Conference and Exposition Conference Proceedings	56
Aip Conference Proceedings	19
Proceedings Frontiers in Education Conference Fie	13
Physics Education	11
Proceedings of SPIE The International Society for Optical Engineering	11
European Journal of Physics	10
Ceur Workshop Proceedings	8
Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	8
Physics Education Research Conference Proceedings	8

3.4 Top Authors in Researching PjBL in Physics

In terms of the ten most prolific researchers on project-based learning in physics, the top ten are listed in Table 3. Yohandri topped the list with nine Indonesian-origin documents. Five of the top ten authors originate from Indonesia.

Table 3. Authors and its publication number of PjBL documents

Author	Number of Documents
Yohandri	9
Dwikoranto	5
Hopf, M.	5
Pizzolato, N.	5
Caballero, M.D.	4
Setiani, R.	4
Astra, I. M.	3
Budi, A.S.	3
Bychkov, I.	3
Christianson, R.	3

3.5 Visualization of Research Trends on Project Based Learning in Physics on VOSviewer

Figure 6 displays that, according to the search results, STEM keywords appear most frequently in the highlighted yellow research articles. Also highlighted in yellow were

the terms project-based learning and machine learning. The term is prevalent in the title, abstract, and keywords. Computer-based learning and data analysis, on the other hand, are uncommon terms. After being analysed with network visualisation by VOSviewer, sixteen clusters representing the relationship between topics were obtained.

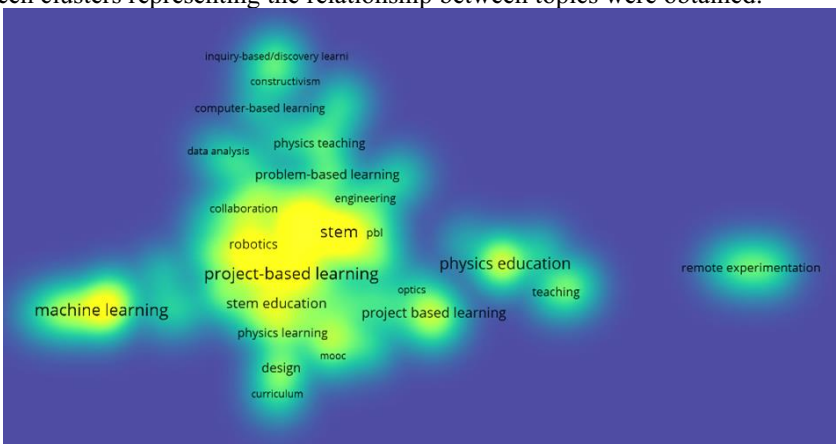

Fig. 6. Density visualization with VOSviewer of research on PjBL in physics during 2012-2021

Several parameters of the relationship between variables associated with project-based learning in physics, such as physics education, STEM, and machine learning, were identified based on the VOSviewer mapping (Figure 7). It is possible to identify research trends by analysing the mapping of a more specific relationship. Project-based learning is associated with physics education, STEM, STEM education, physics education, the internet of things, and even Arduino, as shown in Figure 8. Using the project-based learning approach and the open-source Arduino platform can increase students' motivation to pursue STEM education (Figure 9) [43]. Using the Arduino Uno microcontroller also encourages students to learn fundamental physics concepts and their everyday applications [44]. Implementing Arduino as a learning context enables its application in physics project-based learning.

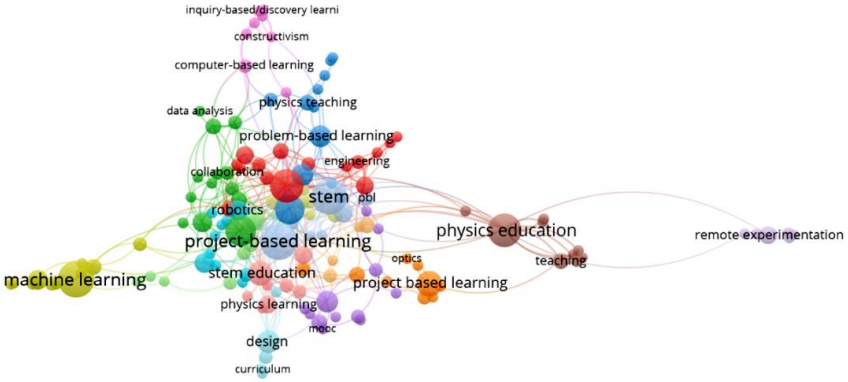

Fig. 7. Network visualization with VOSviewer of research on PjBL in physics during 2012-2021

Figure 10 depicts the relationship between project-based learning and STEM education within the context of physics education. As depicted in the image below, STEM is related to physics education, e-learning, design, primary education, secondary education, and creativity, which is not overly dominant. STEM-based PjBL instruction can improve students' critical and creative thinking, as well as their problem-solving skills [45]–[47].

The 21st century 4C learning concept includes creativity [48]. Figure 11 indicates that project-based learning is associated with student creativity. Models of project-based learning can encourage students' creativity [49]–[51].

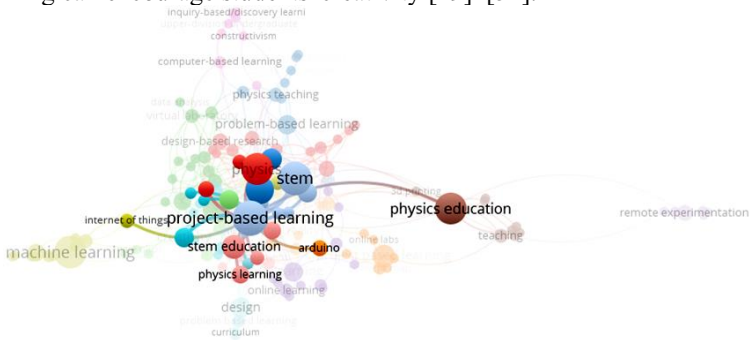

Fig. 8. PjBL related with other domains

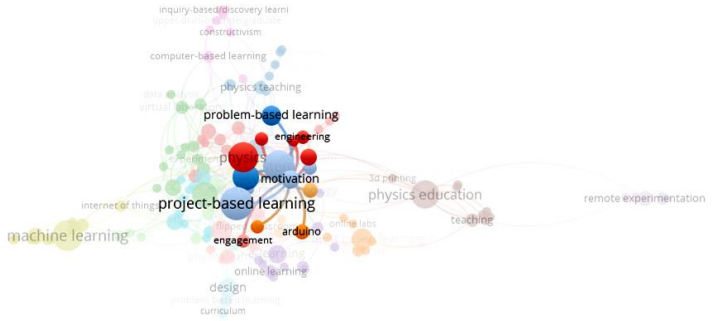

Fig. 9. PjBL related to motivation

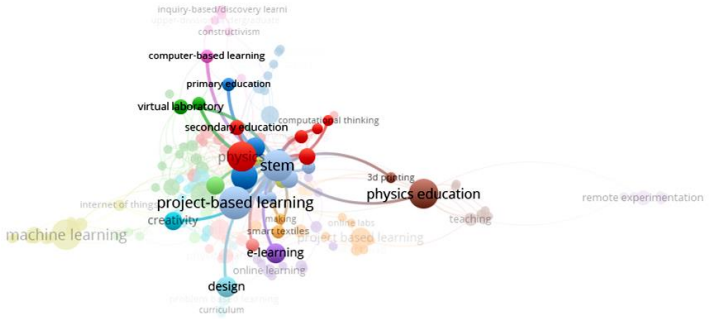

Fig. 10. PjBL related to STEM

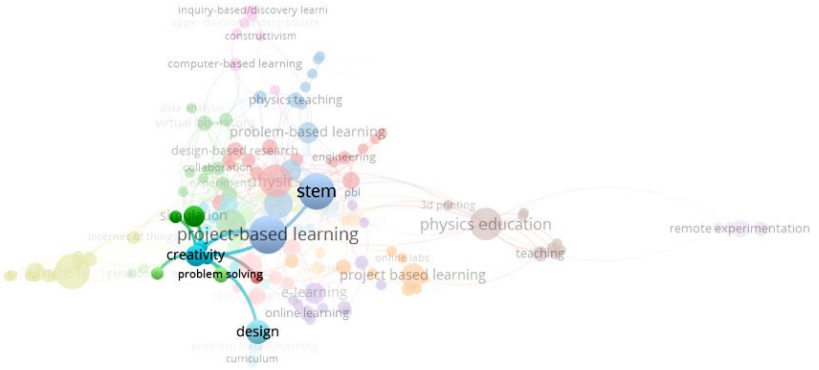

Fig. 11. PjBL related to creativity

Figures 12 and 13 illustrate project-based learning and physics education, respectively. Both of them contributed to the development of STEM education, which can be used to increase the effectiveness of physics and physics education through project-based learning [30], [31]. In physics education, remote experimentation is associated with a

considerable distance. Remote experimentation is the optimal method for collaborative teaching and learning [52].

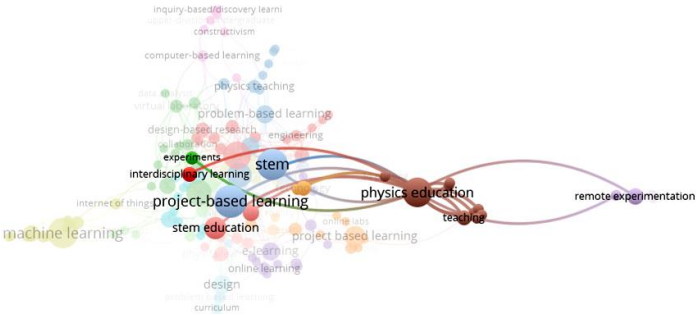

Fig. 12. PjBL related to physics education

As shown in Figure 14, if global researchers produce 16 clusters related to research trends in project-based learning in physics, Indonesian researchers produce 5 clusters. In this article, physics learning, STEM education, research design, PjBL models, and the skills gained through the application of PjBL to physics learning are discussed. Creativity and problem-solving are demonstrated to be among the acquired skills.

It is anticipated that teachers will consider the findings of this study when applying PjBL learning to physics and relating it to the 4C learning concept in the 21st century. Because the issues raised are urgent, global, and require discussion. The research on physics PjBL trends has not uncovered an upward trend in student collaboration and communication. It can also serve as a starting point for additional research.

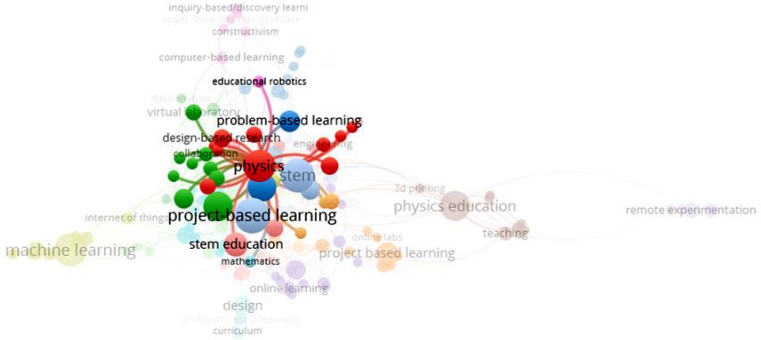

Fig. 13. PjBL related to physics

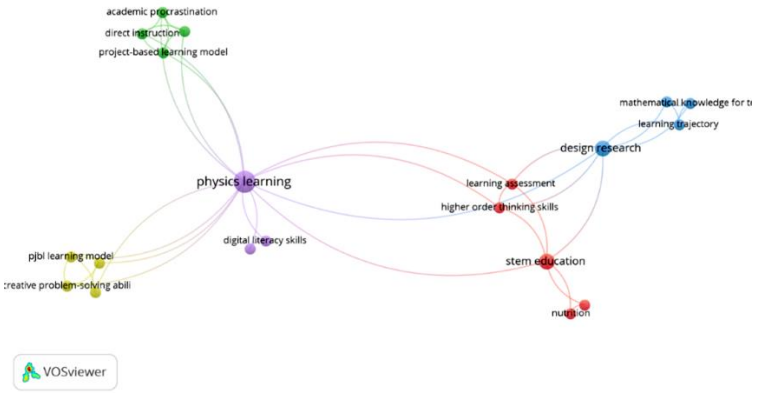

Fig. 14. Research on PjBL in physics performed by Indonesia researchers during 2012-2021

4 Conclusion

Based on the results and discussions regarding the use of bibliometric analysis to identify trends in project-based learning in physics, it can be concluded that project-based learning has become both a trend and an option over the past decade. Despite fluctuations in the number of cross-border documents over the past decade, there has been a substantial increase from 2018 to 2019. In addition, the United States contributed the most documents, a total of 189 out of a total of 604. However, Universitas Pendidikan Indonesia contributed the most documents, a total of twelve, and Yohandri was the topic's most prolific researcher. The implementation of PjBL in physics has substantial ties to the prevalent STEM methodology. It is known that incorporating PjBL into physics education can enhance students' critical thinking, problem-solving, creative thinking, and creativity. This research is anticipated to aid educators in implementing PjBL learning with STEM and identifying students' 4C skills. In addition, this research reveals that PjBL STEM learning can be accomplished with the Arduino Uno microcontroller and Remote Experimentation, which can offer new opportunities to both teachers and students. In future research, the implementation of PjBL with student collaboration and communication will be discussed further.

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