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Trends of Project Based Learning in Engineering Education from 2008 to 2023: A Systematic Literature Review Approach

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Abstract

This research aims to find and analyze international publications on trends as well as the advantages and disadvantages of applying Project Based Learning in engineering education over the past 16 years (2008-2023). This research is limited to review and research articles only, as well as in the title and articles that have the words Project Based Learning and Engineering Education as many as 100 articles. This research uses bibliometric analysis using VOSviewer software and Microsoft Excel to analyze data taken from Science Direct. The results of the analysis show that the distribution of publications from Project Based Learning in engineering education continues to increase every year. The study results also show that the most published journal about PjBL in engineering education is Procedia - Social and Behavioral Sciences and Pengyue Guo from is the author with the highest number of citations.

Keywords: *Project Based Learning, Engineering Education, Systematic Literature Review, Bibliometric Analysis*

INTRODUCTION

Technical education occupies a central position in the educational structure as an integral element in the preparation of individuals for professional careers that require technical expertise [1]. The main focus of this education is not only to provide a theoretical knowledge base, but also to emphasize practical application through technology exploration, design and engineering projects [2], [3]. Technical education is becoming increasingly important as technology advances and industry dynamics change, providing a foundation for students to understand and master skills that match the needs of the rapidly evolving industrial sector. Moreover, the key role of engineering education is reflected in its contribution to innovation, productivity and economic growth, where engineering education graduates become the driving force in the formation of globally competitive business and industrial ecosystems [4], [5]. Thus, engineering education not only plays a strategic role in producing technically skilled human resources, but also as an important pillar in advancing a country's competitiveness at the global level.

The evolution of engineering education reflects a significant journey, undergoing conceptual and methodological struggles that reflect the changing dynamics of industry demands and societal needs [6]. Initially, engineering education may have been more vocational in nature, focusing on teaching technical skills without a strong emphasis on conceptual understanding. However, along with technological developments and changes in the industrial landscape, the paradigm of engineering education is changing. The shift emphasizes the integration between strong conceptual understanding and practical application of skills [7], [8]. Today, engineering education not only demands in-depth mastery of technical skills, but also fosters critical thinking, creativity and problem-solving abilities. The engineering education paradigm now leads to the formation of graduates who are not only technically proficient but also able to adapt to rapid changes in the world of technology and industry, creating professionals who are competitive in a dynamic global job market.

The increasing complexity of industrial demands and rapid technological developments place engineering education under increasing challenges to prepare students with relevant and contextually applicable skills [9], [10]. In response to this need, Project-Based Learning (PjBL) has emerged as an educational approach that provides significant advantages [11]. PjBL allows students to combine theory with practice through carefully designed projects, creating authentic and contextualized learning experiences [12]. By emphasizing problem solving, teamwork, and industry engagement, this approach method will create a qualitative leap in the preparation of students to face real-world challenges in engineering, making it a vital strategy in supporting the relevance and quality of engineering education in the contemporary era.

Project-Based Learning (PjBL) is a learning approach that emphasizes knowledge construction through practical experience and team collaboration [13], [14]. The key principles in this learning approach involve designing contextual and meaningful project tasks, emphasizing problem-solving through independent inquiry, as well as encouraging teamwork to achieve tangible results. It promotes holistic learning by integrating different aspects of skills and knowledge, while providing students with opportunities to develop critical thinking, creativity and communication skills [15]. Thus, PBL creates a learning environment that is reflective of real-world conditions, preparing learners to face complex challenges in the professional world, which is very different from conventional approaches.

The fundamental difference between conventional approaches and PjBL lies in the focus, method, and context of learning [16]. Conventional approaches tend to be instructive and are often centered on the linear delivery of information by teachers to students [17]. On the other hand, PjBL emphasizes learning through projects or practical tasks that provide real context and problem-solving challenges [18]. While conventional approaches may be more oriented towards imparting information, PjBL puts more emphasis on developing critical skills, problem solving and deep understanding through hands-on experience. PjBL also promotes team collaboration and contextualized learning, where students learn through real-world experiences that support the transfer of knowledge to everyday life situations [19], [20]. Thus, PjBL

creates a learning environment that is more dynamic and relevant to the complex demands of the real world.

This approach method presents substantial benefits in developing students' skills by embracing contextual and practical learning approaches [21], [22]. Through PjBL, students not only acquire theoretical knowledge, but also develop critical, problem-solving and creative thinking skills [23]. The in-depth inquiry process and projects allow students to hone their analytical skills while understanding the practical application of theoretical concepts in real-world situations. In addition, this method encourages team collaboration, builds effective communication skills, and enhances students' adaptability to multidisciplinary challenges. By emphasizing contextual understanding, PjBL creates opportunities for students to integrate and apply their knowledge in situational contexts, forming graduates who are not only technically skilled but also able to contribute significantly in complex professional environments [24].

The purpose of this research is to conduct an in-depth exploration of the trends of PjBL implementation in the context of engineering education [25]. By analyzing related literature and studies, this research aims to identify current patterns, changes and dynamics relating to the implementation of PjBL, so as to provide a deeper understanding of how this learning approach has evolved and impacted the field of engineering education. Through this research, it is hoped to uncover key factors that influence the successful implementation of PjBL, as well as provide a broader view of the potential role of this method in advancing the quality and relevance of engineering education in the future. The focus of this research is to conduct literature on the implementation of Project-Based Learning in engineering schools over the past 16 years. The following are some of the focus questions of this research:

a. What is the trend of implementing Project-Based Learning in technical schools over the past 16 years?
b. What is the distribution of the top 100 most-cited articles with the title and keywords Project-Based Learning in technical schools?
c. Which journals have published the most about Project-Based Learning in technical schools from 2008-2023?
d. Who are the top 20 authors of Project-Based Learning in vocational schools from 2008-2023?
e. What are the advantages and disadvantages of Project-Based Learning?

METHOD

This research is a quantitative study, with the source of metadata from Science Direct. Furthermore, this research also uses bibliometric analysis to review and visualize keywords from articles with VOSviewer software [26]. Bibliometrics is a field of research that uses statistical and mathematical methods to analyze and measure patterns of scientific publications, citations, and interrelationships between studies within a particular discipline or field. The main goal of bibliometrics is to provide an understanding of the extent to which a topic or research area has been explored, how often it is cited, and how it relates to other research in the same field. Bibliometric

analysis can involve using specialized software, such as VOSviewer or Citespace, to generate visualizations of research networks, map citation patterns, and identify key trends or foci within a knowledge domain [27]. The application of bibliometrics can help researchers, academics, publishers and policy makers to make more informed decisions based on a deeper understanding of the structure and dynamics of research within a field [28]. The restrictions in this study are only on review articles and research articles. The following is the identification of data on the application of PjBL in engineering education that has been collected.

Table 1. Data Identification

Description	Data
Keywords	Project-Based Learning in Engineering Education
Publication type	Review articles : Research articles
Documents (all years)	3.830: 46.146 Total: 49.943
Documents (2008-2023)	3.475: 37.145 Total : 40.620

This study uses a research procedure consisting of four stages, namely 1) identification, identifying data in Science Direct by selecting the title Project-Based Learning in engineering schools then filtering the year, which is only from 2008 to 2023. 2) filtering, filtering is done by focusing on review articles and research. After filtering, 100 articles were obtained and then 3) analysis, namely determining the title, year, author, number of citations, and journals that publish them one by one to be analyzed with Microsoft Excel and Vosviewer. The last 4) conclusion, which is drawing conclusions from the analysis that has been done. The procedure is shown in the figure below.

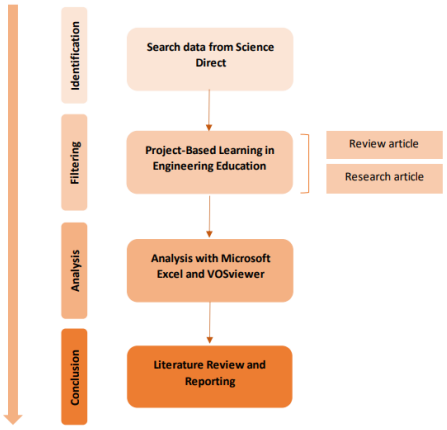

Fig 1. Research Procedure

RESULT AND DISCUSSION

3.1 Publikation tren

Throughout the year, there were 3,830 publications of review articles and 46,146 publications of research articles. Furthermore, in the focus of this research, from 2008 to 2023, there were 3,606 publications of review articles and 39,620 publications of research articles on Project Based Learning in Engineering Education.

a). Tren PjBL all years, **b)** Tren PjBL 2008-2023

Fig 2. Publiktionit Tren

Furthermore, Figure 3 shows the development of publications from the application of Project Based Learning in Engineering Education from 2008 to 2023. In 2008 there were about 756 articles, in 2009 there were 754 articles, in 2010 there were 883 articles, in 2011 there were 1095 articles, in 2012 there were 1446 articles, in 2013 there were 1478 articles, in 2014 there were about 1728 articles, in 2015 there were 2299 articles, in 2016 there were 2010 articles, in 2017 there were 2085 articles, in 2018 there were 2422 articles, in 2019 there were 2756 articles, in 2020 there were 3775 articles, in 2021 there were about 4907 articles, in 2022 there were 5670 articles, and in 2023 there were 6561 articles. The graph is shown below.

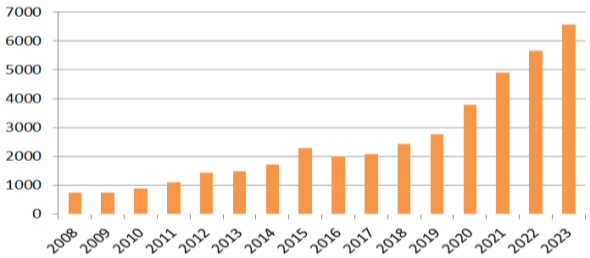

Fig 3. Pjbl Publication Development (2008-2023)

3.2 Top 100 articles with the most citations (2008-2023)

After analyzing the development of PjBL from year to year, the researcher selected 100 articles that were in accordance with the researcher's objectives, namely about Project-Based Learning in Engineering Education, both in the title and keywords, which were focused from 2008 to 2023.

Table 2. Data Identification

Description	Data
Keywords	Project-Based Learning in Engineering Education
Documents (2003-2023)	2 : 98

Total citations	Total: 100 660 : 4.620 Total: 5.280

Table 2 shows that, out of a total of 100 articles, there are 2 articles that are reviews and there are 98 articles that are research articles. Each citation is 660 : 4.594, with a total of 5.254 citations for both. Furthermore, the distribution of article publications from 2008 to 2023 is shown in table 3.

Tabel 3. Publication Distribution

Year	Number of publications	Number of citations
2008	1	4
2009	3	18
2010	5	491
2011	4	251
2012	3	369
2013	4	53
2014	7	487
2015	7	674
2016	4	119
2017	3	143
2018	1	81
2019	7	723
2020	15	1.324
2021	11	289
2022	21	351
2023	4	13
	100	5.287

Table 3 shows that the publication of Project Based Learning in Engineering Education there was 1 article in 2008, there were 3 articles in 2009, there were 5 articles in 2010, there were 4 articles in 2011, there were 3 articles in 2012, there were 4 articles in 2013, there were 7 articles in 2014, there were 7 articles in 2015, there were 4 articles in 2016, there were 3 articles in 2017, there was 1 article article in 2018, there were 7 articles in 2019, there were 15 articles in 2020, there were 11 articles in 2021, there were 21 articles in 2022, and there were 4 articles in 2023 that researchers chose to analyze. As seen in the table, the most citations were in 2020, with a total of 1,324 citations. This distribution is also illustrated by the graph shown in the figure below.

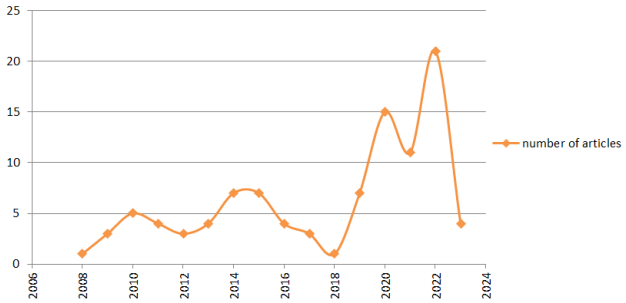

Fig 4. Publication Distribution Chart (2008-2023)

Figure 4 shows that the highest publication is in 2022, followed by 2020 and then 2021.

3.3 Distribution of journals that published the 100 collected articles

After the distribution of article publications per year, journal analysis was then carried out. The following are the journals that publish 100 selected articles, from the most published ones.

Tabel 4. Journal Distribution

	Journal	Number of publications
1.	Procedia - Social and Behavioral Sciences	27
2.	Procedia Computer Science	20
3.	Education for Chemical Engineers	13
4.	IFAC-PapersOnLine	8
5.	Procedia CIRP	4
6.	Thinking Skills and Creativity	4
7.	Computers in Human Behavior	3
8.	IFAC Proceedings Volumes	3
9.	Journal of Parallel and Distributed Computing	2
10.	Procedia Engineering	2
11.	Procedia Manufacturing	2
12.	Acta Astronautica	1
13.	Computers & Education	1
14.	Computers & Industrial Engineering	1
15.	Development Engineering	1
16.	Educational Research Review	1
17.	Heliyon	1
18.	Information and Software Technology	1
19.	International Journal of Educational Research	1
20.	International Review of Economics Education	1
21.	Learning and Motivation	1
22.	Library & Information Science Research	1
23.	The Internet and Higher Education	1
		100

Table 4 shows that of the 100 articles selected, the most publications are from the Procedia - Social and Behavioral Sciences journal with 27 articles, then the second is the Procedia Computer Science journal with 20 publications, and so on.

3.4 20 authors with the most citations

After analyzing the journals, from the 100 articles selected, the researchers analyzed the 20 authors with the highest number of citations from 200 to 2023. This analysis is shown in the table below.

Tabel 5. Authors With The Most Citations

Author	Year	Number of citations	Author	Year	Number of citations
Pengyue Guo	2020	761	Burcu Gulay Tasci	2015	110
Cheng-Huan Chen	2019	603	Gamze Sart	2014	107
Ignacio de los Ríos	2010	353	Dilek Karahoca	2011	94
Faridah Musa	2012	248	C. Villa	2017	87
Razali Sharifah Nadiyah	2015	244	Sonia Amamou	2018	81
Ting-Ting Wu	2020	163	Catalina Cort´ azar	2021	72
Jolanta Lasauskiene	2015	157	Utku Köse	2010	70
Sandra Raquel Gonçalves Fernandes	2014	146	Awad A. Younis	2021	66
Sandra Raquel Gonçalves Fernandes	2014	146	Patrick Balve	2015	64
Robert Pucher	2011	112	Yupeng Luo	2015	64

Table 5 shows the most citations obtained by Pengyue Guo, with the article title A review of project-based learning in higher education: Student outcomes and measures in 2020, with a total citation of 761. The following also shows the relationship analysis based on keywords from the 100 articles that have been selected.

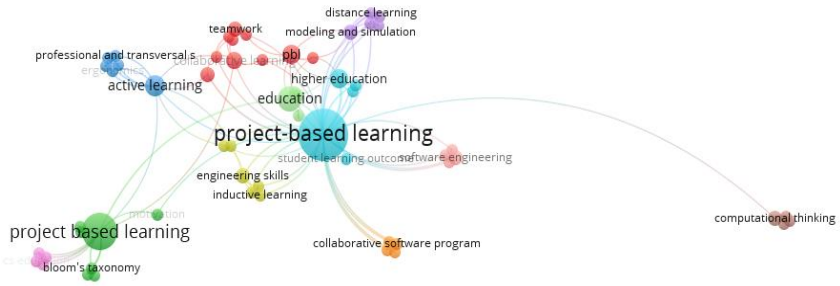

Figure 5. Network Analysis Of Keywords

Figure 5 shows that project-based learning is the most frequently mentioned keyword, followed by project-based learning. The figure also shows that there are several keywords related to project-based learning such as education, engineering skills, teamwork, and others.

3.5 Advantages and disadvantages of implementing Project Based Learning (PjBL)

Project-Based Learning (PjBL) in engineering education offers a number of significant advantages. First of all, PjBL provides students with practical experience, allowing them to apply theoretical knowledge in the context of a technical project [29], [30]. This not only enhances their understanding of critical concepts, but also builds the practical skills required in the world of work. In addition, the PBL approach promotes team collaboration, developing students' social skills through cooperation in completing projects together. This creates a learning environment that reflects the reality of industry, where the ability to work in teams is key to success.

However, there are some disadvantages to consider in implementing PBL. One of them is the time required to complete the project. PjBL requires a greater investment of time than traditional learning methods, and this can be a bottleneck in an already crowded curriculum. In addition, PBL project evaluation tends to be subjective and difficult to measure consistently. A less objective assessment process can create challenges in ensuring fairness and consistency in student assessment.

Teacher monitoring and preparation are also challenges that need to be addressed in implementing PjBL. Teachers need to carefully design projects, provide adequate guidance and regularly monitor student progress. This can add to teachers' workload and require a high level of management skills. In addition, limited resources, such as technology or specialized equipment, can be an obstacle in providing optimal PjBL learning experiences in all schools or educational institutions. Therefore, while recognizing its advantages, the implementation of PjBL in engineering education also requires careful attention to the challenges that may arise.

Tabel 3. Elemental Compositions Of Sampling Sites

Site	TiO_2 (wt%)	Al_2O_3 (wt%)	MnO (wt%)	MgO (wt%)	Na_2O (wt%)
GIJ	0.5	16.4	0.19	2.74	3.00
GPW	0.78	19.0	0.18	4.57	2.55
GSR	0.62	16.3	0.17	3.09	3.09
KLB	0.67	15.7	0.14	5.07	2.59
KSG	1.90	17.1	0.15	3.79	3.33
PWH	0.58	20.9	0.12	1.55	3.00
SKP	0.68	17.8	0.16	3.12	2.75

COONCLUSION

The emergence of a number of articles reflects the need to align curricula with real-world demands, emphasizing practical relevance for students in an engineering context. This trend also illustrates the interest in evaluating the effectiveness of PjBL in improving students' understanding, practical skills and problem-solving abilities. Institutional support reflected in the large number of publications confirms the importance of PjBL integration in engineering school settings. Overall, these articles reflect a positive shift in learning practices, highlighting the importance of relevance, effectiveness, innovation and institutional support in implementing Project-Based Learning in engineering schools.

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