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Technology-supported Project-based Learning: Trends, Review and Future Research in Science, Technology and Engineering Education

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ABSTRACT

This research investigates trends in technology-supported project-based learning (PjBL) in science, technology, and engineering education and also provides future research directions in this field. Bibliometric analysis with Scopus database sources in the period 2004-2023 was used in this investigation. 541 publications met the criteria, with the annual growth of publications increasing based on the number of documents and citations. American and Asian countries are the most productive countries and affiliates in publications in this field. Most publications are produced from international conferences. The publication's conceptual structure shows four research clusters with 81 terms, 1029 links, and a total link strength of 3492. The term "project-based learning" is the central node in the cluster, connecting several essential terms related to the use of technology in PjBL. The discussion at the end of this study leads to recommended further research paths for developing technology-supported PjBL.

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1. INTRODUCTION

Technological advances can be a factor in expediting the learning process. Thus, it is necessary to implement more advanced educational facilities (Al Husaeni *et al.* 2024). Several technology-based learning frameworks were developed to adapt and prepare students for the 21st century. Through technology-based learning in the 21st century, students are trained to have various thinking and practical skills. One constructivist learning strategy with great potential to improve 21st-century skills is project-based learning (PjBL) (Haatainen, & Aksela, 2021). PjBL explicitly focuses on engineering solutions. It combines hands-on and mind-on, which aims to learn essential knowledge and skills, so it can be applied to real-world problems. Several educational institutions implement PjBL as the primary curriculum program in terms of pedagogy and assessment (La Prad, & Hyde, 2017).

Several studies on PjBL supported by technology have been carried out with objectives including making the learning process more effective (Kim, 2021), improving the results of learning products (Made *et al.* 2023), and making learning assessments more efficacious (Gülbahar, & Tinmaz, 2006). Although much research has been conducted on using technology to support PjBL, opportunities to develop further research by discovering new topics in this field are still open, especially in science, technology, and engineering education.

Bibliometric analysis becomes a critical approach to explain research trends and identify new research avenues. Bibliometric analysis techniques to determine future research opportunities are shown in **Tables 1** and **2.**

Table 1. Previous research used bibliometric analysis studies.

Author	Title
Nordin (2022)	Correlation between process engineering and special needs from bibliometric analysis perspectives.
Nordin (2022)	A bibliometric analysis of computational mapping on publishing teaching science engineering using VOSviewer application and correlation.
Nandiyanto & Al Husaeni (2021)	A bibliometric analysis of materials research in Indonesian journal using VOSviewer
Al Husaeni (2022)	Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022.
Al Husaeni (2022)	Bibliometric analysis of briquette research trends during the Covid-19 pandemic.
Nandiyanto *et al.* (2023)	Particulate matter emission from combustion and non-combustion automotive engine process: review and computational bibliometric analysis on its source, sizes, and health and lung impact
Al Husaeni & Nandiyanto (2022)	Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer
Ramdhani et al. (2023)	A comprehensive study on biochar production, bibliometric analysis, and collaborative teaching practicum for sustainable development goals (SDGs) in Islamic schools
Fauziah et al. (2022)	Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis
Nandiyanto *et al.* (2023)	Bibliometric data analysis of research on resin-based brakepads from 2012 to 2021 using VOSviewer mapping analysis computations
Nandiyanto et al. (2023)	Involving particle technology in computational fluid dynamics research: a bibliometric analysis
Suherman et al. (2023)	How to improve student understanding in learning science by regulating strategy in language education? Definition, factors for enhancing students comprehension, and computational bibliometric review analysis

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Table 1 (continue). Previous research used bibliometric analysis studies.

Author	Title
Al Husaeni et al. (2022)	How language and technology can improve student learning quality in engineering? Definition, factors for enhancing students comprehension, and computational bibliometric analysis
Ruzmetov & Ibragimov (2023)	Past, current and future trends of salicylic acid and its derivatives: A bibliometric review of papers from the Scopus database published from 2000 to 2021

Table 2. Previous research on PjBL used bibliometric studies.

Author	Titles	Result
Reis *et al.* (2017)	A bibliometric and classification study of project-based learning in engineering education	Using PjBL method to teach engineering has benefits, such as helping students learn more technical information and build soft skills and cross-disciplinary knowledge.
Ahmad *et al.* (2023)	Project-based learning in vocational education: A Bibliometric Approach.	It showed current state of PjBL in vocational education in the study. It also shows how educational computers can help students learn better.
Guo *et al.* (2020)	A review of project-based learning in higher education: Student outcomes and measures.	There are four main types of outcomes for learning in PjBL in higher education, with seven subtypes each. There are also eight ways to measure these outcomes: self-reported surveys, rubrics, tests, observations, interviews, self-reflection journals, and artifacts.
Lin *et al.* (2023)	A Bibliometric Analysis of Project-Based Learning Research in and Outside Mainland China.	PjBL is mixed with maker STEM education in mainland China, and teachers look for more ways to teach to improve their students' core skills and higher-level skills.

Although many bibliometric studies explore research trends on PjBL, bibliometric studies on the use of technology to support PjBL in science, technology, and engineering education have never been carried out. This research aims to investigate research trends regarding the use of technology in supporting PjBL and outline opportunities for future research paths.

2. METHOD

The bibliometric methods were used in this investigation, including the stages of preparing tools and materials, data collection, data screening, data visualization, and analysis (Al Husaeni *et al.* 2024). Tools and materials for analysis and visualization in this bibliometric study use Microsoft Excel, VOSviewer, and Biblioshiny (Al Husaeni & Nandiyanto, 2022). Publication data was collected from the SCOPUS Database in the period 2004-2023 with the Query: "(TITLE-ABS-KEY (technology) AND TITLE ("project-based learning")) AND PUBYEAR>2003 AND PUBYEAR<2024".

3. RESULTS AND DISCUSSION

Based on bibliometric analysis, 752 documents were found. Data was filtered with a focus on education (science, technology, engineering) and language (English). The final results were 541 documents, which would be described, visualized, analyzed, and interpreted.

3.1. Annual Growth of Scientific Publications

Organizational publication data regarding technology integration in PjBL is shown in **Figure 1**. The annual growth of publications on technology-integrated PjBL tends to increase yearly

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based on the number of documents and citations. The lowest number of publications was in 2004, and the highest in the 2019-2022 range. The large number of publications during this year was due to the rise in research into technology development to support learning during the COVID-19 pandemic. The highest number of citations was in 2016 and tends to decrease.

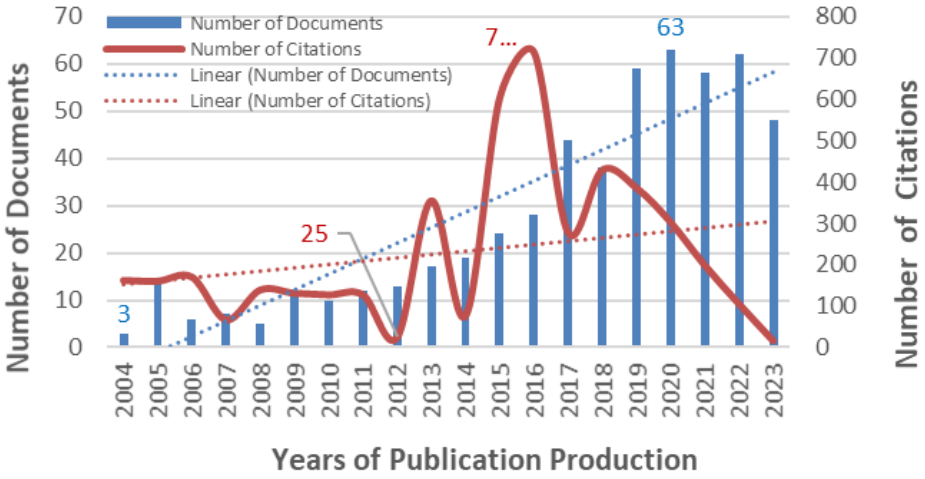

Figure 1. Annual growth of publications by number of documents and citations.

3.2. The Most Productive Countries and Affiliates

As shown in **Table 3**, the most productive country in publications about technology-integrated PjBL is the United States of America (26.80%). Indonesia, Spain, Japan, and China followed. Asian countries, especially developing countries, dominate the top ranking as productive countries in publications.

Table 3. Top five countries and affiliates productive in publications (Total documents 541, total countries 70, and total affiliates 160).

Country	ND	%	Name of Affiliation	ND	%
USA	145	26.80	Universiti Teknologi Malaysia	10	1.85
Indonesia	48	8.87	Texas A&M University	9	1.66
Spain	33	6.10	Univ. Pendidikan Indonesia	9	1.66
Japan	25	4.62	Purdue University	8	1.48
China	24	4.44	Delft University of Technology	7	1.29

3.3. The Most Impactful Published Articles

The most impactful publications in PjBL is shown in **Table 4**. Kokotsaki *et al*. (2016) was the most impactful article, followed by Han *et al*. (2015) and Tseng *et al*. (2013), as well as (Gulbahar & Tinmaz, 2006) and Beier et al. (2019) about authentic PjBL in STEM.

Table 4. Top five Articles with the Highest Number of Citations

Authors (Year)	Titles	number
Kokotsaki *et al.* 2016	Project-based learning: A review of the literature	438
Han *et al.* 2015	How STEM project-based learning affects high, middle, and low achievers differently: The impact of student factors on achievement	254
Tseng *et al.* 2013	Attitudes towards STEM in a project-based learning (PjBL) environment	245
Gülbahar & Tinmaz, 2006	Implementing PjBL and E-portfolio assessment in an undergraduate course	125
Beier *et al.* 2019	The effect of authentic PjBL on attitudes and career aspirations in STEM	115

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3.4. Conceptual Structure of Technology-Supported PjBL

The minimum occurrence of 7 keywords is used as the threshold. 81 terms are in 4 clusters (colored red, green, blue, and yellow) with 1029 links and a total link strength of 3492 (see **Figure 2**). The larger the size of the item node, the greater the frequency of appearance of the keyword. Based on node analysis, technology used in PjBL include computer programming, Internet of Things (IoT), automation, ICT, artificial intelligence, machine design, software design, online learning, robotics, and microcontrollers. This technology can be a facility or platform for carrying out the learning process, as a learning medium, or as a product in learning projects. Several skills can be improved through technology-supported PjBL, including critical thinking, problem-solving, innovation, and professional skills.

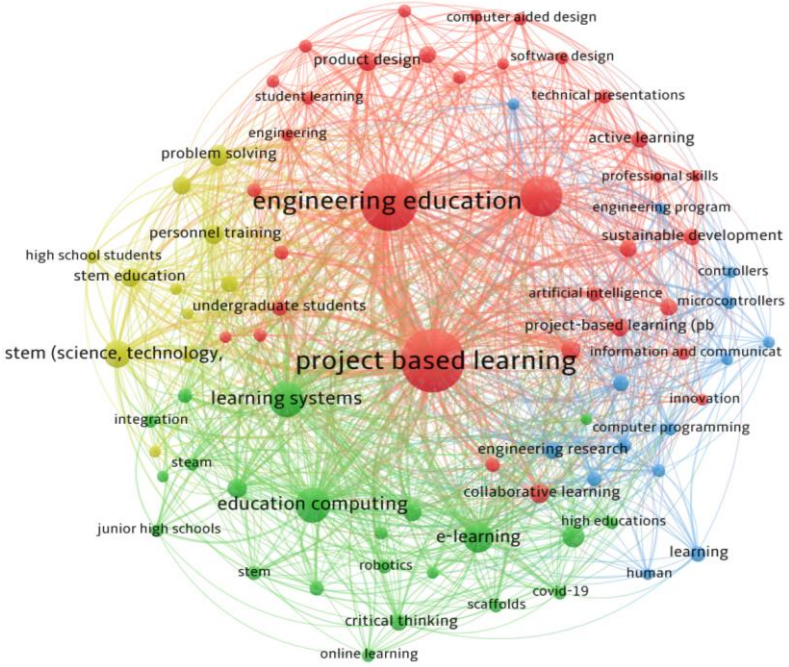

Figure 2. Network visualization in publication on technology-supported PjBL.

The thematic analysis map of keywords is carried out based on the level of relevance (centrality), which is limited by vertical lines, and the level of development (density), which is limited by horizontal lines. Centrality shows the level of correlation between topics, while density measures the alignment between terms/nodes. Topics such as "assessment", "engineering education", "science education", "higher education", and "collaborative learning" are in Q-IV. Thus, they are fundamental topics that are very important for the development of this field. Meanwhile, topics such as "educational technology", "automation", "augmented reality", "experiential learning", "action research", "case study", "curriculum", and "21st-century skills" are around Q-II. These topics still contribute little to technology-based PjBL research. The topics have the potential to be better connected to technology-based PjBL research. Further research can be carried out by exploring these topics further, such as developing IT to carry out project learning processes using augmented reality media in learning or as products in projects. In addition, some topics are very relevant in technology-supported PjBL research as 21st-century skills. Several studies show that 21st-century skills are important for students to train. Therefore, 21st-century skills including 4C skills (creative thinking, collaboration, and communication), digital literacy, and interpersonal skills can be developed in further research related to technology-supported learning projects.

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In addition to the connection of PjBL with the use of IT, another important finding from this research is the relationship of PjBL with creative thinking skills. One of the obstacles in PjBL is the relatively long time it takes to complete the entire series of project learning (Beier *et al.* 2019). Therefore, it is crucial to deliver PjBL using IT. However, IT still needs to appear as a term in research clusters. Likewise, "creative thinking" still has a small node weight in the theme cluster. Creative thinking skills are one of the 21st-century skills necessary for students to train. Although creative thinking skills can be improved through PjBL, creative thinking skills still need to be the focus of further research.

4. CONCLUSION

Research trends in the field of technology-supported PjBL were investigated. Annual publication growth increases over the past two decades based on the number of documents and citations. American and Asian countries are the most productive countries and affiliates in publications in this field. Thematic analysis reveals that several topics have great potential to be explored in future research such as the development of IT in PjBL such as computer programming, IoT, automation, ICT, artificial intelligence, machine design, software design, online learning, robotics, and microcontrollers and development of 21st century skills such as 4C skills, digital literacy, and interpersonal skills through technology-supported PjBL.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Ahmad, S. T., Watrianthos, R., Samala, A. D., Muskhir, M., and Dogara, G. (2023). Project-based learning in vocational education: A bibliometric approach. *International Journal of Modern Education and Computer Science*, *15*(4), 43–56.

Al Husaeni, D. F., Al Husaeni, D. N., Nandiyanto, A. B. D., Rokhman, M., Chalim, S., Chano, J., Obaidi, A. S. M. Al, and Roestamy, M. (2024). How technology can change educational research? Definition, factors for improving quality of education and computational bibliometric analysis. *ASEAN Journal of Science and Engineering*, *4*(2), 127–166.

Al Husaeni, D. F., Al Husaeni, D. N., Ragadhita, R., Bilad, M. R., Al-Obaidi, A. S. M., Abduh, A., and Nandiyanto, A. B. D. (2022). How language and technology can improve student learning quality in engineering? Definition, factors for enhancing students' comprehension, and computational bibliometric analysis. *International Journal of Language Education*, *6*(4), 445-476.

Al Husaeni, D. F., and Al Husaeni, D. N. (2022). Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022. *ASEAN Journal of Religion, Education, and Society*, *1*(1), 39-48.

Al Husaeni, D. F., and Nandiyanto, A. B. D. (2022). Bibliometric using Vosviewer with Publish or Perish (using Google Scholar data): From step-by-step processing for users to the practical examples in the analysis of digital learning articles in pre and post Covid-19. *ASEAN Journal of Science and Engineering*, *2*(1), 19–46.

Al Husaeni, D. F., and Nandiyanto, A. B. D. (2022). Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer. *Journal of Engineering Science and Technology*, *17*(2), 1135-1149.

Al Husaeni, D. N. (2022). Bibliometric analysis of briquette research trends during the covid-19 pandemic. *ASEAN Journal for Science and Engineering in Materials*, *1*(2), 99-106.

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S., & Gilberto, J. M. (2019). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching*, *56*(1), 3-23.

Fauziah, S. P., Suherman, I., Sya, M. F., Roestamy, M., Abduh, A., and Nandiyanto, A. B. D. (2021). Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis. *International Journal of Language Education*, *5*(4), 409-425.

Gülbahar, Y., and Tinmaz, H. (2006). Implementing project-based learning and e-portfolio assessment in an undergraduate course implementing project-based learning and e-portfolio assessment in an undergraduate course. *Journal of Research on Technology in Education*, *38*(3), 309–327.

Guo, P., Saab, N., Post, L. S., and Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*(2019), 101586.

Haatainen, O., and Aksela, M. (2021). Project-based learning in integrated science education: Active teachers' perceptions and practices. *Lumat*, *9*(1), 149–173.

Han, S., Capraro, R., and Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, *13*(5), 1089–1113.

Kim, Y. (2021). The problem/project-based learning (PBL/PjBL) at online classes. *International Journal of Advanced Culture Technology*, *9*(1), 162–167.

Kokotsaki, D., Menzies, V., and Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277.

La Prad, J. G., and Hyde, A. M. (2017). IDEAS: A qualitative inquiry into project-based learning. *The Qualitative Report*, *22*(2), 479–498.

Lin, S., Tan, Z., and Guo, W. (2023). A bibliometric analysis of project-based learning research in and outside mainland China. *International Journal of Engineering Education*, *39*(2), 376–396.

DOI: https://doi.org/10.17509/ajse.v4i1.67532
p- ISSN 2776-6098 e- ISSN 2776-5938

Made, D., Srie, A., and Devy, D. (2023). Technology-based project-based learning to teach English in university level: Need analysis. *Linguistic, English Education and Art (LEEA) Journal*, *6*(2), 299–314.

Nandiyanto, A. B. D., Al Husaeni, D. F., and Ragadhita, R. (2023). Bibliometric data analysis of research on resin-based brake-pads from 2012 to 2021 using VOSviewer mapping analysis computations. *ASEAN Journal for Science and Engineering in Materials*, *2*(1), 35-44.

Nandiyanto, A. B. D., and Al Husaeni, D. F. (2021). A bibliometric analysis of materials research in Indonesian journal using VOSviewer. *Journal of Engineering Research*, *2021*, 2307-1877.

Nandiyanto, A. B. D., Ragadhita, R., and Aziz, M. (2023). Involving particle technology in computational fluid dynamics research: A bibliometric analysis. *CFD Letters*, *15*(11), 92-109.

Nandiyanto, A. B. D., Ragadhita, R., Setiyo, M., Al Obaidi, A. S. M., and Hidayat, A. (2023). Particulate matter emission from combustion and non-combustion automotive engine process: review and computational bibliometric analysis on its source, sizes, and health and lung impact. *Automotive Experiences*, *6*(3), 599-623.

Nordin, N. A. H. M. (2022). A bibliometric analysis of computational mapping on publishing teaching science engineering using VOSviewer application and correlation. *Indonesian Journal of Teaching in Science*, *2*(2), 127-138.

Nordin, N. A. H. M. (2022). Correlation between process engineering and special needs from bibliometric analysis perspectives. *ASEAN Journal of Community and Special Needs Education*, *1*(1), 9-16.

Ramdhani, M.R., Kholik, A., Fauziah, S.P., Roestamy, M., Suherman, I., Nandiyanto, A.B.D. (2023). A comprehensive study on biochar production, bibliometric analysis, and collaborative teaching practicum for sustainable development goals (SDGs) in islamic schools. *Jurnal Pendidikan Islam, 9*(2), 123-144.

Reis, A.C.B., Barbalho, S.C.M., and Zanette, A. C. D. (2017). A bibliometric and classification study of project-based learning in engineering education. *Production*, *27*(Special Issue), 1–16.

Ruzmetov, A., and Ibragimov, A. (2023). Past, current and future trends of salicylic acid and its derivatives: A bibliometric review of papers from the Scopus database published from 2000 to 2021. *ASEAN Journal for Science and Engineering in Materials*, *2*(1), 53-68.

Suherman, I., Fauziah, S. P., Roestamy, M., Bilad, M. R., Abduh, A., and Nandiyanto, A. B. D. (2023). How to improve student understanding in learning science by regulating strategy in language education? Definition, factors for enhancing students' comprehension, and computational bibliometric review analysis. *International Journal of Language Education*, *7*(3), 527-562.

Tseng, K.-H., Chang, C.-C., Lou, S.-J., and Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87–102.

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