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Mapping research trends on STEM-integrated project-based learning in physics education: a bibliometric review

Syaifuddin[1], Sarwi[2], Hartono[2], Murbangun Nuswowati[3]
[1]Doctoral Program of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia
[2]Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia
[3]Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia

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ABSTRACT

This study presents a bibliometric review analysis of science, technology, engineering, and mathematics (STEM) integrated project-based learning (PjBL) used in promoting meaningful physics learning at the secondary education level. It aims to provide in-depth information about the research landscape of STEM-integrated PjBL models in physics learning outcomes in senior high schools and its contribution to implementing the Merdeka Curriculum in Indonesia. For this purpose, 72 articles published between 2013 and 2023 from the Scopus database were selected based on predetermined criteria. The selected articles were analyzed regarding publication trends, key research themes, citation analysis, and keywords. The findings of this study highlight a network of actively participating authors, institutions, and research groups in this field. In addition, this comprehensive review offers an understanding of the current state and opportunities in this research field and identifies further exploration areas and gap analysis. The implication of the results of this literature review is to critically know the existence of a gap analysis so that one of the next studies is to be able to develop a STEM integrated PjBL model with a contextual, cultural and multidisciplinary approach to promote sustainable development.

Corresponding Author:

Sarwi
Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang
Sekaran, Gunungpati, Semarang, Indonesia
Email: sarwi_dosen@mail.unnes.ac.id

1. INTRODUCTION

The learning process is not merely a knowledge transfer from educators to students textually. It is also a process by which education can facilitate students to develop their knowledge, attitudes, personality, and independence. Education must be implemented to cultivate a nation's honor and dignity, as well as its skills and personality traits. This emphasizes the significance of learning quality in ensuring the success of the educational process. In contemporary education, the competency approach is gaining popularity, involving the implementation of educational programs designed to foster individuals' ability to apply the acquired knowledge and skills in professional activities independently.

Each country has distinct indicators of successful learning implementation. However, these indicators seek to enhance the overall competencies that students must have following the development of the 21st-century [1]–[5]. The components related to learning success indicators are directly proportional to the implementation of innovative learning methods that foster the development of global wisdom values that are imparted to teachers as a form of moral responsibility [6].

The COVID-19 outbreak, which emerged in 2020, is a recent worldwide pandemic that has significantly impacted education. One of the impacts is a shift in learning methods, as all activities rely on online learning. However, most students continue to encounter challenges in demonstrating experimental scenarios even after completing online learning courses. Accordingly, teachers need to provide appropriate learning media to assess students' competencies in accordance with learning goals and outcomes. This is crucial since teachers are the frontline in producing high-quality learning, which directly affects students' learning outcomes [7], [8].

Furthermore, the industrial era 4.0 provides challenges that require developing 21st-century skills in education. The existing literature reveals some learning strategies that are considered adequate for enhancing 21st-century skills, namely flipped learning or blended learning, metacognitive learning, independence-based learning, science, technology, engineering, and mathematics (STEM), cultural and multicultural-based education, and cooperative learning [9]–[13]. These findings provide an opportunity enabling students to navigate globalization effectively. Through innovative learning models, students can become more dynamic and become problem solvers in real conditions.

The factor determining the success rate of project-based learning (PjBL) implementation is the preparation of essential inquiries related to the subject matter. Learning the syntax of a proper and systematic project model is necessary to apply learning in line with the action plan. On the other hand, STEM education is a multi-disciplinary learning approach carried out in three ways, namely: separate subject of STEM, STEM with integrative subject approach, and separate and integrative STEM [14]. Several countries, including Australia, China, Korea, and Taiwan, have developed STEM that incorporates a cross-disciplinary and integrated approach [15]. According to Nurmaliah *et al*. [16] implementing PjBL with a STEM approach yields significant enhancements in problem-solving skills.

Integrating the STEM approach with the PjBL model is an effective strategy for modern education regarding 21st-century learning. Such a synergistic learning approach has a significant influence on various aspects of student's growth, such as critical thinking skills, creative thinking, students' efficacy, conceptual understanding, self-confidence, and the contextualization of learning [6], [17]–[20]. In short, employing the PjBL and STEM model in distant learning has significantly impacted students' problem-solving skills.

Despite the numerous studies that have revealed valuable findings about the effects of projects and STEM learning model, there is still a gap in the existing literature, particularly in the scope of learning in high school. Thus, a comprehensive systematic review of this issue is vital. Secondary/high-level teachers have specific qualities that differentiate them from elementary-level teachers and university lecturers. Therefore, conducting an in-depth study to identify the influential factors is crucial. In addition, the varying levels of students' responses demand teachers to employ different behaviors despite utilizing the same learning model across different educational levels. Consequently, there is a need for reformative skills in learning approaches [21].

In this literature review, researchers aim to investigate evidence pertinent to PjBL and STEM learning models. This study is enhanced by systematic and reliable literature investigations leveraging the Scopus database. The results of this research study are expected to produce reports on the efficacy of the practical learning model and its effects, thereby enabling its adaptation into other similar forms of competence. With this regard, the study is guided by the following research questions: i) what is the influence of PjBL and STEM learning model research trends? and ii) what key elements need further research on the PjBL and STEM learning model?

2. METHOD

2.1. Research design

Bibliometric analysis is a research methodology that assesses research papers by doing thorough evaluations and providing feedback on current studies, which can serve as references for a novelty analysis [22], [23]. It entails systematic literature reviews integrating study findings with transparency, replication, and comprehensiveness, using clear criteria. It allows researchers to conduct comparisons, interventions, and diagnostic assessments [24]–[26]. In this study, the researchers evaluate all articles that fit the category using the following criteria: number of publications, citations of article sources and publishers, affiliation, country of origin, language use, adjustment of the research theme, and many more. Additionally, this study systematically searched relevant scientific articles, conference papers, and publications on PjBL and the STEM learning model.

2.2. Sample and data collection

Scopus was the central database due to its established validity and prominence in education. The articles were sourced from Scopus-indexed journals, adhering to the specified eligibility criteria. A literature

search was conducted using *Boolean* logic to retrieve articles containing the following keywords: ("project-based learning" and "STEM"). The advantage of using a Scopus database is that it can display a correlation system between article publications, allowing researchers to engage in comprehensive discussions. The articles from 2013 to 2023 were obtained using specific keywords and publication years. The data retrieval was performed on November 14, 2023.

Figure 1 shows the PRISMA flowchart used in article search and refinement. Using the specified keywords, 801 articles were obtained from the Scopus database. The search was limited to publications published between 2013 and 2023. The researchers conduct thorough evaluations of the complete text to ascertain its feasibility, as a detailed examination of the papers cannot be deduced solely from the title or abstract. The inclusion criteria that become references are as follows: i) the type of article is research, ii) written in English, iii) year 2013-2023, iv) scopus indexed journals, v) STEM integration of at least two disciplines, vi) the scope of high school, and vii) include a description of the learning program.

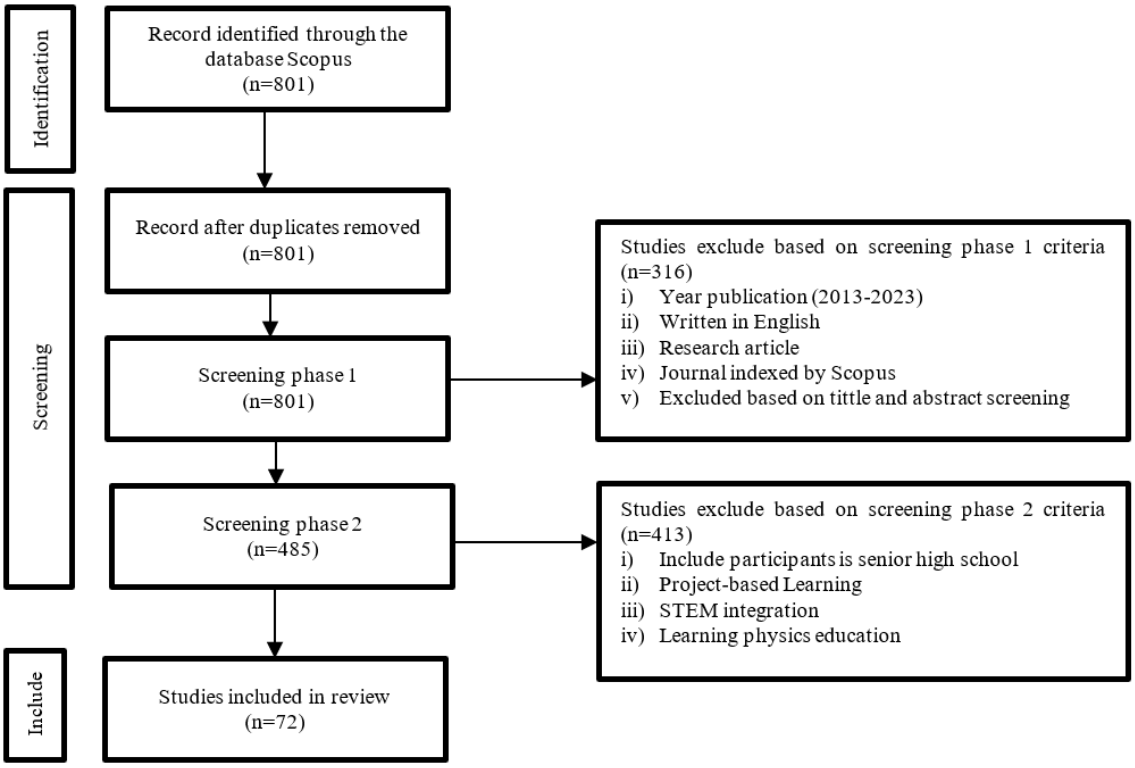

Figure 1. Diagram of the screening process adaptation from [27]

2.3. Analyzing of data

In conducting the analysis, the articles were systematically examined based on the categories in the Scopus database. Each article was carefully read, and its information was recorded, including the publication year, research location, methodology, research background, and articles cited the most. The VOSviewer application analyzed subjects related to the latest research trends. The literature acquired underwent screening based on certain inclusion criteria. The exclusion criteria involved extracting relevant data from selected publications, including the year of publication, title, affiliation, and abstract adjusted to this study. This analysis can be used as a representation of how various disciplines describe dynamic aspects. It can provide a conceptual and intellectual foundation through science mapping [28]. Finally, the extracted data were analyzed using VOSViewer, considering the type of citation pattern and author network and investigating the appropriate theme. Coding was then carried out to address the research questions. This kind of analysis can contribute to conducting a comprehensive literature review.

A systematic screening was carried out with three independent assessors to ensure the validity and reliability of the data in this research. They provided feedback and recommendations on which certain parts were revised and improved. In addition, the assessors engaged in discussions to resolve any divergent viewpoints until a consensus was achieved. The assessment of the research quality of the review analysis involves systematically and consistently examining the intra-rater reliability values [25].

3. RESULTS AND DISCUSSION

The bibliometric analysis process in this study is based on the PRISMA method through document sources from Scopus. The creating categories based on subject area, document type, language, keywords, country, source type and affiliation. These categories are then critically analyzed so as to produce a conclusion related to the impact of PjBL and STEM learning model. Based on the bibliometric analysis of the research publications on PjBL and STEM learning model, the following findings were obtained:

3.1. Publication trends

Analysis of publication trends indicates a consistent increase in the PjBL and STEM learning model over the past decade. This rise in popularity shows that PjBL and STEM are still in high demand among educators and have been empirically proven to positively impact learning outcomes. Accordingly, the learning model, prioritizing contextual-based learning, is still relevant in the educational disruption era. These findings were analyzed based on the type of publication, a comparison of the number of documents published from Scopus indexed journals and the number of countries that often publish PjBL and STEM by year on Scopus data 2013-2023.

Figure 2 explains that the greatest number of article publication years was in 2021, with 16 documents. The second-highest year was 2020, with 12 documents, followed by 2019, with 11 documents. There was a significant increase from 2018 to 2019 before experiencing a significant decrease from 2021 to 2022. Figure 3 illustrates an analysis of publication patterns by comparing several documents from 2013 to 2023. The ten documents were derived from the top 5 sources, namely Journal of Physics Conference Series (15 documents), Proceeding Frontiers in Education Conference (6 documents), IEEE Transactions on Education (3 documents), Proceeding of The International Astronautical Congress (3 documents), and Eurasia Journal of Mathematics Science and Technology Education (2 documents). The Journal of Physics Conference Series was the leading publisher of articles related to the PjBL and STEM learning model from 2019 to 2023.

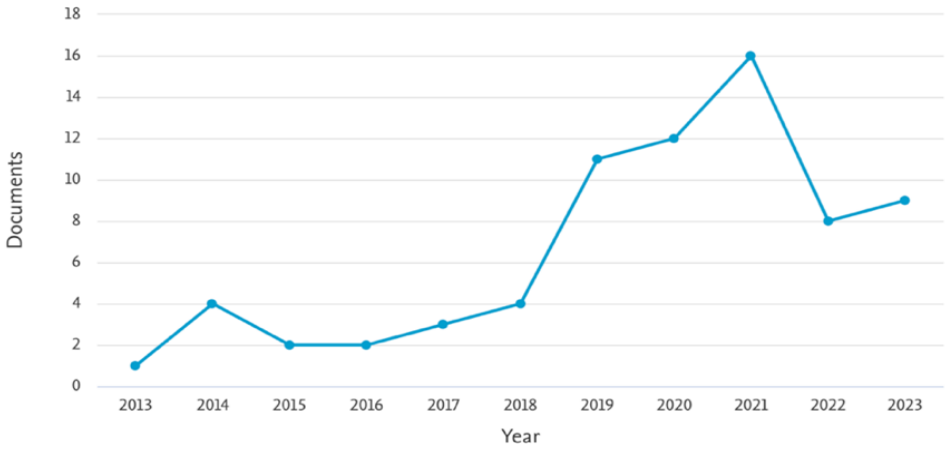

Figure 2. Publication documents PjBL and STEM by year on scopus data 2013-2023

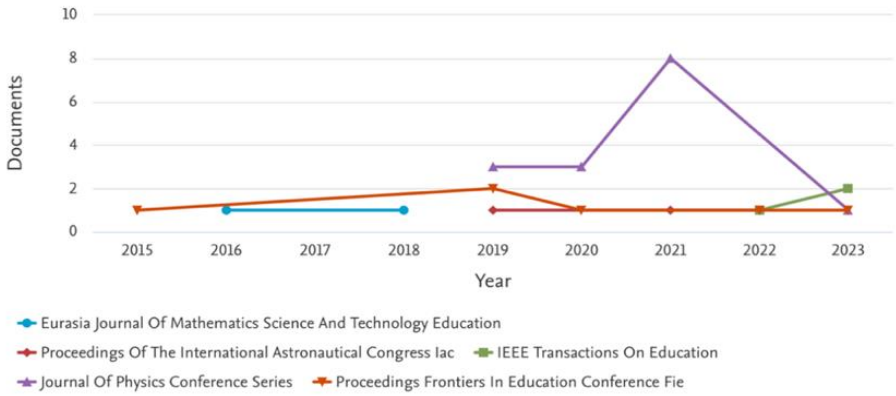

Figure 3. Comparison of the number of documents PjBL and STEM up to 10 sources

The Journal of Physics Conference Series has gained considerable attention for its comprehensive analysis of scientific manuscripts with the theme of the PjBL and STEM learning paradigm. This journal is a fast-track open-access category that focuses on various themes, including education and communication. It has an SJR value of 0.18. The subsequent Proceeding Frontiers in Education Conference, with a particular focus on social studies and education, has an SJR value of 0.22. The IEEE Transactions on Education was ranked third in terms of significant and original scientific contributions to education in engineering. It acquired an SJR score of 0.73. The International Astronautical Congress, which covers engineering, physics, and astronomy topics, received an SJR score of 0.12. The journal's low SJR score and focus on works unrelated to education have resulted in its fourth position concerning learning models. The fifth journal source was the Eurasia Journal of Mathematics Science and Technology Education, published 12 times yearly. It is an open-access journal focusing on mathematics and science education with an SJR value of 0.51. This category aligns seamlessly with the theme of this research on the project and STEM learning model. The analysis of this section provided an overview of how the subject area and journal category affected the selection of journal targets, which were adjusted to the specific field of research study.

Research trends in education related to PjBL and STEM learning models were analyzed by comparing the top 10 countries that actively contributed to submitting scientific papers from 2013 to 2023. The analysis revealed that the United States of America made the most contributions to scientific manuscript submissions related to PjBL and the STEM model, with 23 manuscripts. Indonesia secured the second position by submitting a total of 15 published articles. Recognized for implementing the Merdeka Curriculum, Indonesia underscores the incorporation of project-based and contextual learning. Furthermore, Malaysia achieved the third position with seven documents, significantly lower than the first rank. This becomes crucial owing to the proximity of Malaysia and Indonesia. More importantly, both countries have nearly identical cultures, resulting in comparable approaches to education. The following order of countries was as follows: Taiwan with 6, Spain with 4, Italy with 3, Turkey with 3, Austria with 2, Columbia with 2, and Germany with 2. Figure 4 presents a comparative list of the most significant number of scientific paper submissions within the last decade.

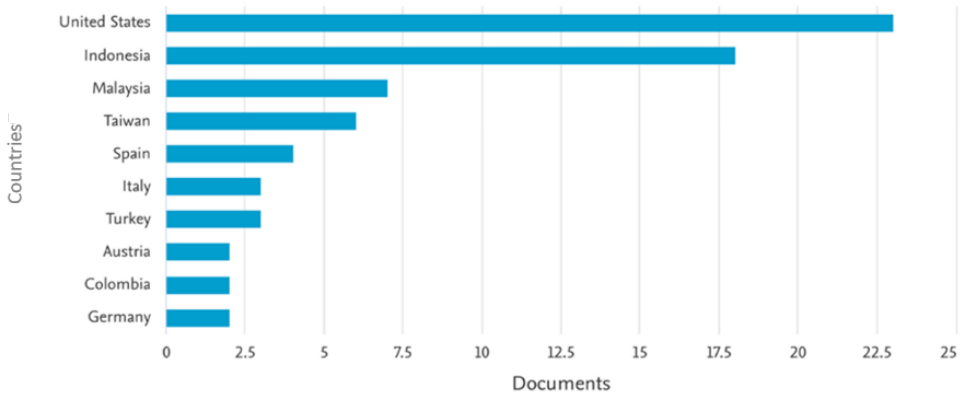

Figure 4. Comparison of the number of documents PjBL and STEM up to 10 countries

3.2. Key research themes

This analysis section identifies the main research categories related to PjBL and the STEM learning model. The mapping was adjusted to reflect the relationship between educational research models and scientific studies, leading to types of research outputs relevant to the education field. These outputs included educational strategies, educational psychology, humanities, and integrated science education. All of which are integrated into learning at the senior high school level. The analysis results are presented in Figure 5.

The theme of social science was frequently used in as many as 50 documents, as depicted in Figure 5. This theme is in accordance with studies in the field of education, especially the learning model. The second place was computer science with a total of 29 documents, followed by engineering with 26 documents, physics and astronomy with 24 documents, mathematics with ten documents, psychology with four documents, chemistry with three documents, decision science integration studies with three documents, earth, and planetary sciences with three documents, and the arts and humanities with two documents, respectively. In addition, analysis of the theme revealed that the implementation of effective learning can be influenced by the study of PjBL and the STEM learning model. This can be conducted across disciplines. The

exploration focused on the pivotal role of PjBL and the STEM learning model and revealed other variables that influence the implementation of this model.

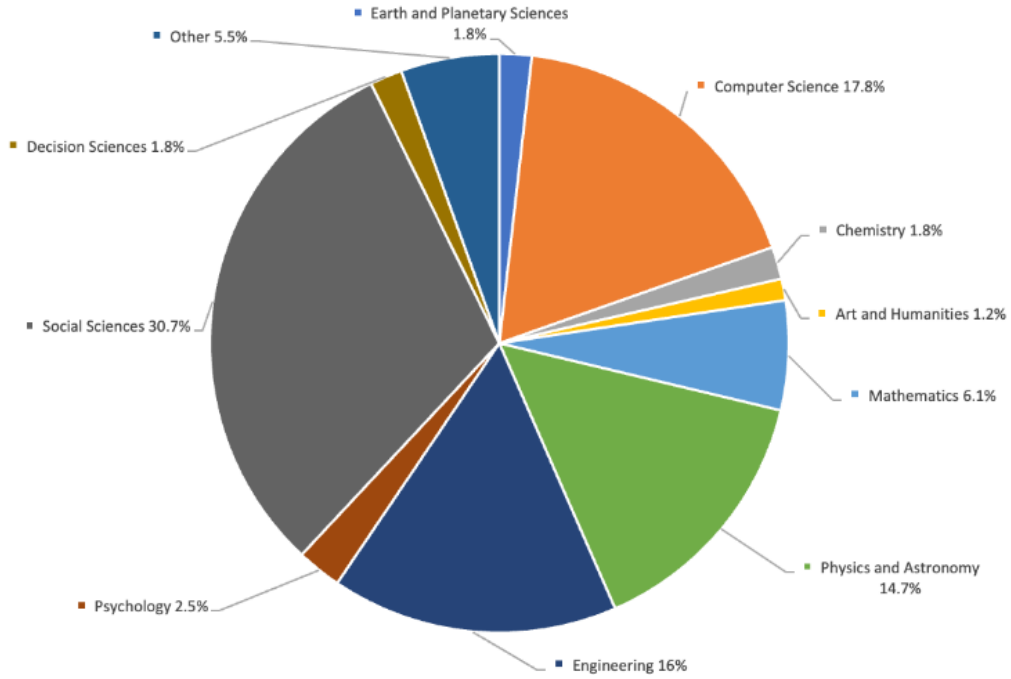

Figure 5. Documents PjBL and STEM by subject area

3.3. Citation analysis

This section aims to identify the most cited types of scientific papers following the latest research themes. Based on the results, it can be concluded that these publications positively impact developing literacy and mindset as well as real action in implementing PjBL and STEM learning models. The analysis of this section is presented in Table 1, illustrating the development of citations of the top 10 documents from 2013 to 2023.

Table 1 shows the top 10 ranked journals with the most citations related to project-based and STEM learning models. There was a variation in the journals used as a reference for each level. The highest number of citations was in the Thinking Skills and Creativity Journal, with 95 citations. This journal profoundly influences others because of its emphasis on educational research studies and its impact. The second most cited was the EEE Integrated STEM Education Conference, with a total of 70 citations. This was in accordance with the type of journal and the focus of the study. The third was Computers and Education with a total of 43 citations. The fourth was TechTrends, with 40 citations. The journals ranked fifth to tenth were the Eurasia Journal of Mathematics Science and Technology Education (27 citations), the Journal of Turkish Science Education (20 citations), International Journal of Distance Education Technologies (19 citations), South African Journal of Education (18 citations), Eurasia Journal of Mathematics, Science and Technology Education (17 citations), and European Journal of STEM Education (15 citations).

Subsequently, the analysis focused on a network of researchers who actively contributed to educational studies, particularly those involving the project-based and STEM learning models. This form of collaboration becomes a benchmark for the importance of scientific investigations that are multidisciplinary, interdisciplinary, and transdisciplinary, producing a comprehensive discussion. The analysis of this section identified the involvement of well-known and active authors by showing research findings that demonstrate a significant degree of expertise in their respective scientific fields. The results of the analysis are shown in Figure 6.

According to Figure 6, Yang from the United States had the highest number of publications in this study, with a total of 4 papers and an h-index of 13. Baek from the United States ranked second with 3 documents and an h-index of 15. Swanson from the United States secured the third position with a total of 3 papers and an h-index of 4. In fourth place, Ali and Marlina from Malaysia contributed 2 papers with an h-index of 7. Capraro is a researcher from the United States who has published 2 documents and has an h-index of 23. Ching, also from the United States, has 2 documents and an h-index of 17. Chitori has 2

documents and an h-index of 18. Kazula is a researcher from Germany with 2 documents and an h-index of 5. Kuo is from Taiwan and has 2 documents and an h-index of 6. At last, Lou has 2 documents and an h-index of 19. Overall, most authors who were actively engaged in disseminating the most up-to-date material on PjBL and the STEM learning model originated from countries in America, Asia, and Europe.

Table 1. List of top 10 citations and discussion points

No	Authors	Journal	Total citations	Discussion point
1	[29]	Thinking Skills and Creativity	95	Cognitive processing patterns in collaborative problem-solving in PjBL STEM.
2	[30]	EEE Integrated STEM Education Conference	70	Transdisciplinary learning pedagogy in improving students' programming skills.
3	[31]	Computers and Education	43	Energy-efficient environmental planning using computer-aided design (CAD).
4	[32]	TechTrends	40	The challenge of designing a curriculum with a new approach in the form of utilizing technology and its application in learning increases cross-disciplinary understanding to be more significant.
5	[33]	Eurasia Journal of Mathematics, Science and Technology Education	27	The influence of STEM-project learning in improving students' achievement.
6	[6]	Journal of Turkish Science Education	20	The effect of STEM-project learning in increasing students' self-efficacy in the problem-solving process.
7	[34]	International Journal of Distance Education Technologies	19	The STEM-Imagination learning model affecting the effectiveness of gender learning.
8	[35]	South African Journal of Education	18	Gender learning to facilitate cognitive and self-efficacy.
9	[36]	Eurasia Journal of Mathematics, Science and Technology Education	17	The development of learning methods to improve students' self-efficacy.
10	[37]	European Journal of STEM Education	15	Computational thinking as an important part of teachers' professional development.

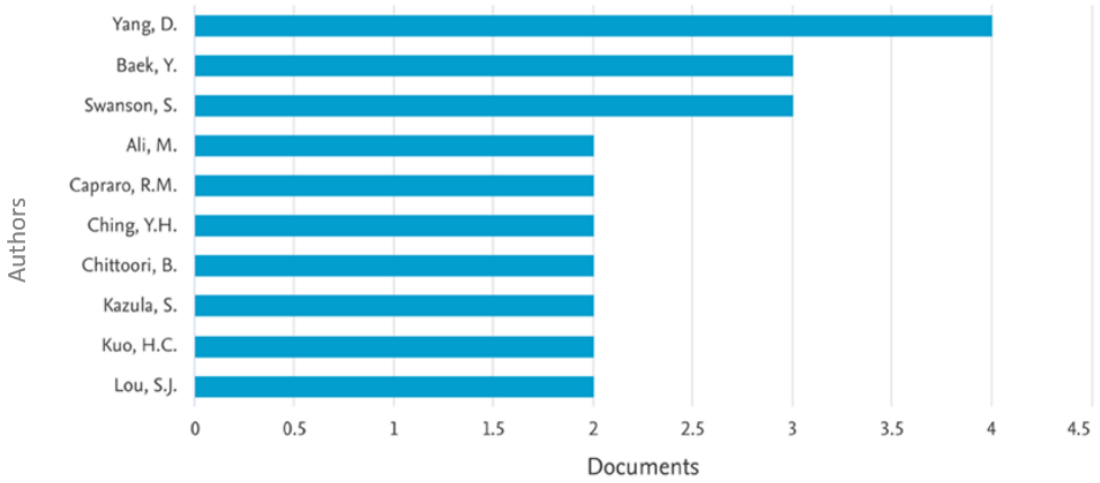

Figure 6. Comparison of number of documents PjBL and STEM up to 10 authors

Figure 7 illustrates the identification of 10 affiliations with the contribution of scientific manuscripts in the fields of PjBL and STEM studies. The top three rankings were affiliates from Boise State University, Universiti Teknologi Malaysia, and Universitas Negeri Malang, with 3 documents each. The next 7 rankings were National Pingtung University of Science and Technology, National Cheng Kung University, Texas A&M University, Syiah Kuala University, Jember University, Indonesia University of Education, and College of Engineering, with each contributing 2 documents. This analysis illustrated that the Asian continent contributed significantly to the implementation of learning and evaluation.

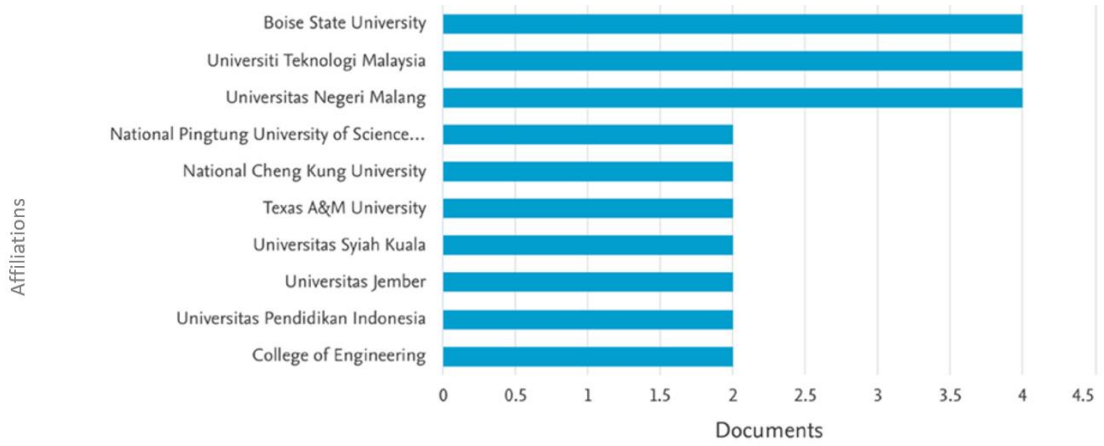

Figure 7. Comparison of the number of documents PjBL and STEM up to 10 affiliations

3.4. Emerging research directions

The network visualization and overlays on several PjBL and STEM learning model studies revealed 7 clusters representing the latest research topics and interest from 2013 to 2023. The clusters depict the formation of multidisciplinary, interdisciplinary, and transdisciplinary scientific networks that support learning. The seven clusters were color-coded yellow, light green, dark green, dark blue, and purple. More specifically, the yellow clusters were among the most common types of research conducted in 2021, while the purple cluster showed past research trends. The network visualization analysis is shown in Figure 8.

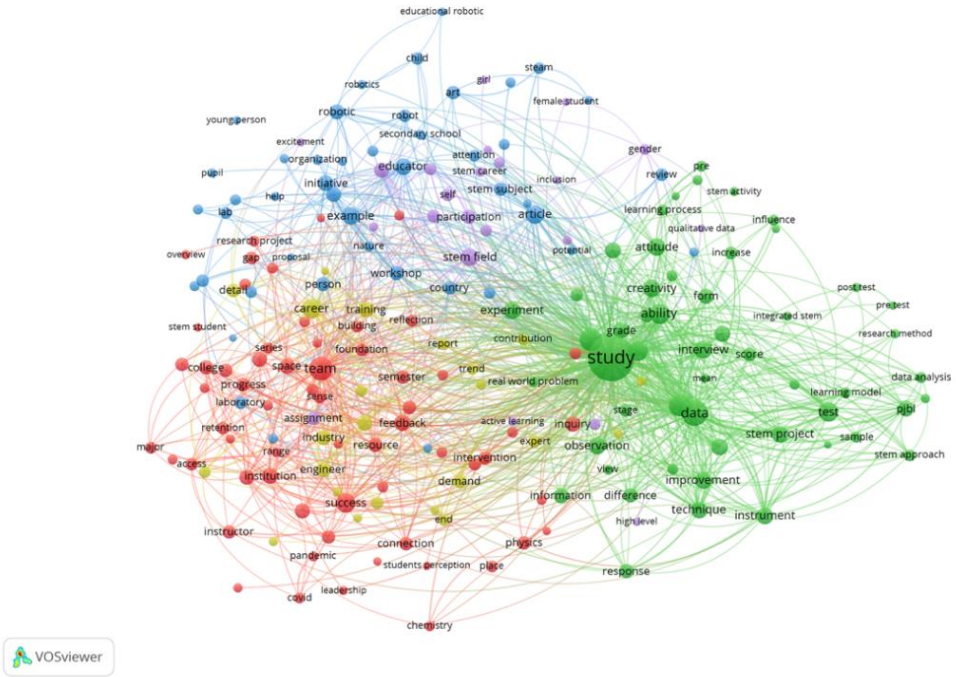

Figure 8. Network visualization of several studies in the overall PjBL and STEM domain from 2013 to 2023 based on scopus data with 605 articles

Figure 8 represents the analysis conducted in VOSViewer utilizing 605 Scopus articles. These articles were selected based on the screening results and served as the foundation for the literature evaluation in this research. The manuscript in VOSviewer was grouped into 5 clusters, with cluster 1 containing 62 themes, cluster 2 containing 54 themes, cluster 3 containing 45 themes, cluster 4 containing 23 themes, and

cluster 5 containing 22 themes. These findings provide an opportunity to identify research gaps, making them useful for advancing research on PjBL and STEM, especially in high school. There are 3 underexplored variables in project-based and STEM learning, namely enhancing physics literacy, fostering scientific products, and shaping global attitudes as the essential outcomes of physics education. These areas should be prioritized to align with the core competencies of science learning, which aim to cultivate students' scientific processes, products, and attitudes.

The analysis presented in Figure 9 identified research gaps in the scope of PjBL and STEM learning models over the past decade. These gaps can serve as a valuable material in improving new works that have not been widely researched. This overlay visualization analysis firmly provided detailed information regarding research themes that were closely related to a project and STEM learning model, especially regarding emerging educational themes such as curriculum, teaching, and creativity. The results of research network visualization mapping depicted a strong correlation between the mentioned themes and the project-based-STEM learning model.

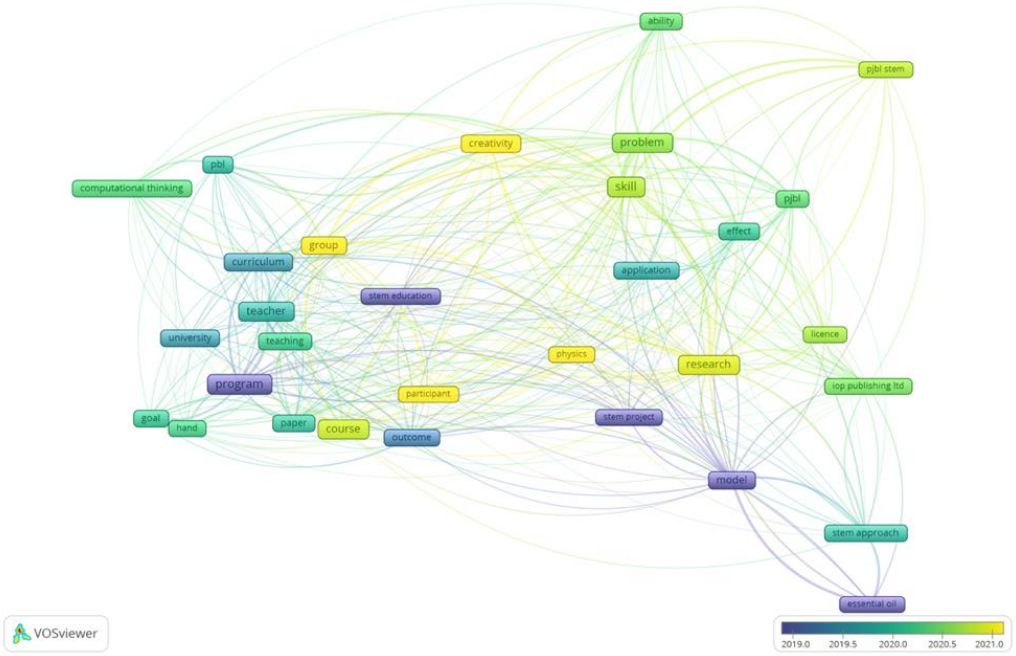

Figure 9. Overlay visualization of several studies in the overall PjBL and STEM domain from 2013-2023 based on scopus data with 72 special articles

The analysis in VOSViewer was conducted using a total of 72 Scopus-indexed which were selected based on the screening results. They were grouped into 3 large clusters and adapted to this type of research, including the fields of curriculum, STEM education, teacher, teaching, physics, STEM approach, STEM project, creativity, and PjBL and STEM. These findings provided benefits in understanding the status of research on PjBL and STEM. In addition, the findings provided insight into research trends, research networks, and subject areas that require further exploration, since they have not been extensively investigated. Also, these findings can serve as a valuable resource for policymaking and the development of advanced research design.

3.5. Discussion

3.5.1. What is the influence of PjBL and STEM learning model research trends?

The results of the study revealed significant contributions across various domains, including cross-disciplinary integration, the learning and evaluation process, and curriculum development. These elements constitute the basis for student activities and associated policies. The research consolidated findings from 72 articles, emphasizing their contributions to the field of education, specifically in the use of project-based and STEM learning approaches. Several key themes were discussed based on the findings are 21st-century skills, technological innovation, education and teaching, disaster mitigation, and future career choices.

The capacity to thrive in 21st-century competition is an essential aspect of education that must be cultivated in order to enhance the following: scientific reasoning, creativity, problem-solving, cultural innovation, literacy, soft skills, and leadership [15], [38]–[44]. One of the effects of PjBL and STEM on 21st-century skills is the gap in access to technology in learning. These problems can be anticipated by taking a contextual, cultural and local wisdom learning approach so that learning study materials can be described based on real conditions in students' lives so that students gain factual and actual knowledge.

The technological innovation is part of the development of instructional techniques to improve technological proficiency and growth was the focus of research in this discipline, with the goal of equipping students with the necessary skills for the future. This study elucidated the significance of transdisciplinary learning as a critical component of the PjBL-STEM model. Consequently, students can enhance their computational thinking skills, increase their motivation, practicality, and the production of tangible products that are suitable for everyday use [45]–[51].

Education, teaching and selection of future career are an important part of the implementation of PjBL and STEM because it not only focuses on the development of educational content but also the development of soft skills and hard skills. The primary factor that influences the implementation of diverse learning models is the emphasis on gender education and meaningful teaching that is multidisciplinary and incorporates technology. Consequently, these models are effective in enhancing students' cognitive, self-efficacy, and creative abilities [52]–[56]. The present study indicates that students acquire both emotional and hard skills during the learning process. Consequently, it can serve as a basis for future career decisions that are informed by their current level of expertise [57], [58].

The implementation of PjBL and STEM in the field of disaster mitigation education, namely contextual learning integrated with natural phenomena and technology so that students can develop skills in solving problems about the importance of disaster preparedness. The accompanying impact of disaster mitigation education includes improving critical and innovative thinking skills in every problem-solving. This study claimed that integrated STEM-PjBL can serve as a scenario for addressing a variety of risks, disaster mitigation, and planning that arise in the context of various disciplines [59], [60].

3.5.2. What are the key elements that need further research on the PjBL and STEM learning model?

The core competencies that are essential for learning science include scientific thinking, inquiry, an attitude of scientific responsibility, and big ideas. These four core competencies are standard objectives that must be achieved in physics learning, especially at the senior high school level. Scientific thinking competency refers to the use of cognitive methods for internalizing the process of questioning, criticizing, giving examples, changing variables, and putting forward innovative ideas. These include scientific modeling, scientific reasoning, scientific argumentation, and innovation. Inquiry competency refers to the ability to formulate scientific questions, generate hypotheses, design investigation protocols, collect and analyze data, and construct evidence. Such proficiency enables individuals to evaluate, communicate, and reflect on the process and results of scientific investigations. Scientific attitude and responsibility competence refers to a positive attitude toward science and the responsibility to explore and apply knowledge based on the nature of science and the relationship between science, technology, society, and the environment. Finally, the big idea competency in science itself expects students to possess the ability to generalize facts, concepts, and theories. Through these, students are able to effectively explain natural phenomena and solve real problems in life [61], [62].

Moreover, the review of scholarly articles as a form of accommodation for these problems revealed that there is a gap between ideal conditions and the actual circumstances during practical learning in the field. The qualitative results justified that there are several aspects within the application of PjBL and STEM learning models that are not optimal and still require further extensive explorations. In fact, these three aspects are manifestations of outcomes from the implementation of physics learning. This raises the question of how to improve literacy skills while demonstrating a scientific and global attitude as a form of cultural implication that students must have in accordance with the customs and traditions developed in their environment.

The significance of this research is elaborated in more detail in the description of gap analysis of the research of PjBL and STEM learning model. The study of the results of the research identifies further research that can be carried out in the next period. The follow-up research identifies a long-term analysis in the form of a longitudinal study that focuses on student development using authentic evaluations. The results of the study that requires further research, including: probabilistic reasoning and control variables, the need for a digital learning platform in the form of computer aided design (CAD) to facilitate students in 3-dimensional learning, the importance of technical education becoming a major area of decline in America, technology-based cultural innovation, STEM-Imagination to facilitate gender education, sustained professional development program, and gender sensitivity in facilitating differentiated learning.

4. CONCLUSION

The current literature suggests that teachers' primary objective is to enhance students' attitudes, knowledge, and comprehension to address real-life problems. Integrating the PjBL model into the curriculum has demonstrated a beneficial effect on students' development, particularly when used alongside differentiated learning techniques. This method highlights that teachers do not necessarily become the center of classroom learning. In this regard, it is crucial to develop students' knowledge, attitudes, and skills through interdisciplinary scientific collaborations. Such collaborations foster the development of a convergent mindset and comprehensive knowledge base in students. To sum up, the significance of mastering both basic and advanced concepts is underlined by the results of science education, particularly in high school physics, which equips students to effectively address problems in everyday life.

The suggestion for further research from the results of this literature review is to develop a PjBL model integrated with science, technology, engineering and mathematics (STEM) with a contextual, multidisciplinary and cultural approach so as to provide a holistic learning experience and relevant to education in the 4.0 era. The importance of this advanced research is because it can facilitate the exchange of best practices and collaboration between subject concepts to improve sustainable development. Comparative studies between schools are an important part of the implementation of PjBL and STEM to expand how learning can be effectively used in learning.

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Syaifuddin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Sarwi	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓
Hartono				✓	✓	✓				✓		✓	✓	✓
Murbangun Nuswowati				✓	✓	✓				✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article with reference number [6, 29, 30, 31, 32, 33, 34, 35, 36, 37].

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BIOGRAPHIES OF AUTHORS

Syaifuddin is student Doctoral Program of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. In addition, he is active in research in the field of PjBL, STEM, science education, and physics education. He can be contacted at email: syaifuddin19891022@students.unnes.ac.id.

Sarwi is professor in the Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. He is also the board editor for the Nationally accredited Indonesian Physics Education Journal (JPFI) Sinta 2 and a peer reviewer for the international journals of F1000Research, IJESE, TUSED, and IJESDC Journal. In addition, he is active in research projects in the field of Physics learing innovation in STEM education. He can be contacted at email: sarwi_dosen@mail.unnes.ac.id.

Hartono is professor in the Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. In addition, he is active in research projects in the field of physics learing innovation in STEM education and professional development. He can be contacted at email: hartono@mail.unnes.ac.id.

Murbangun Nuswowati is professor in the Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. In addition, she is active in research projects in the field of chemical education, environmental chemistry, conservation education and learning development. She can be contacted at email: mnuswowati@mail.unnes.ac.id.