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Research Trends of Project-Based Learning Model in Chemistry Learning Through Bibliometric Analysis

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Abstrak

Pembelajaran kimia telah berkembang menjadi berbagai kegiatan praktikum laboratorium yang bersifat interdisipliner. Model Pembelajaran Berbasis Proyek merupakan salah satu strategi inovatif yang dapat meningkatkan keterampilan tingkat tinggi siswa dalam menguasai konsep dan aplikasi kimia secara luas dan mendalam. Penelitian ini bertujuan untuk melakukan analisis bibliometrik mengenai perkembangan penelitian, topik-topik yang relevan, dan peluang penelitian di masa depan terkait penggunaan model pembelajaran berbasis proyek dalam pembelajaran kimia yang diterapkan dalam satu dekade terakhir (2014-2024). Kata kunci yang digunakan adalah pembelajaran berbasis proyek, pembelajaran kimia, dan pendidikan kimia. Hasil penelusuran melalui database Scopus diperoleh 365 artikel yang diterbitkan selama tahun 2014-2024, kemudian terseleksi sebanyak 319 artikel berdasarkan kriteria yang telah ditentukan. Hasil penelitian menunjukkan bahwa frekuensi penelitian tentang pembelajaran berbasis proyek dalam pembelajaran kimia mulai meningkat secara signifikan sejak tahun 2018 dan mencapai puncak pada tahun 2021. Topik kimia yang banyak diteliti dengan menggunakan model pembelajaran berbasis proyek adalah kimia organik, kimia analitik, kimia hijau, dan praktikum kimia. Penelitian yang potensial di masa depan terkait dengan model pembelajaran berbasis proyek berbantuan TIK seperti augmented reality dalam pembelajaran kimia, implementasi model pembelajaran berbasis proyek pada konten kimia anorganik, dan kaitan antara model PjBL dengan pengembangan kurikulum di bidang pendidikan kimia. Penelitian ini diharapkan dapat membantu para peneliti yang akan melakukan dan menentukan topik-topik utama yang relevan dengan domain pembelajaran berbasis proyek dalam konteks pembelajaran kimia.

***Kata kunci*:** *Pembelajaran Kimia, Project-Based Learning, PjBL, VOSViewer, Analisis Bibliometrik*

Abstract

Chemistry learning has evolved into various interdisciplinary laboratory practicum activities. The Project-Based Learning (PjBL) Model is one of the innovative strategies that can improve students' high-level skills in mastering chemical concepts and applications broadly and deeply. This research aims to conduct a bibliometric analysis of research developments, relevant topics, and future research opportunities related to the use of project-based learning models in chemistry learning applied in the last decade (2014-2024). The keywords used are project-based learning, chemistry learning, and chemistry education. The results of the search through the Scopus database obtained 365 articles published during 2014-2024, then 319 articles were selected based on predetermined criteria. The results showed that the frequency of research on project-based learning in chemistry began to increase significantly in 2018 and reached a peak in 2021. Chemistry topics that are mainly researched using the project-based learning model are organic chemistry, chemical analysis, green chemistry, and chemistry practicum. The potential research in the future are related to ICT-assisted with project-based learning model such as augmented reality in chemistry learning, the implementation of Project-Based Learning model in inorganic chemistry content, and the link between the PjBL model and curriculum development in the field of chemistry education. This study is expected to help researchers who will conduct and determine the main topics relevant to the domain of project-based learning in the context of chemistry learning.

Keywords: Chemistry Learning, Project-Based Learning, PjBL, VOSViewer, Bibliometric Analysis.

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1. INTRODUCTION

Current teaching and learning activities are centered on students. One learning approach that supports this is the project-based learning (PjBL) model. PjBL was chosen as a means to increase student engagement (Cifrian et al., 2020; Juuti et al., 2021). Project-based learning is a learning approach that functions to promote 21st-century learning in K-12 science education with a future orientation. PjBL refers to problem-oriented and student-

centered learning, which is organized based on projects (Markula & Aksela, 2022; Misbah et al., 2024). Another research study also found that teachers consider project-based learning to be an approach that encourages student and teacher learning in terms of motivation, collaboration, and a sense of togetherness at the school level, student-centered learning, connecting theory with practice, and providing benefits to teacher instruction (Herranen & Aksela, 2019; Markula & Aksela, 2022). In this case, new skills and content are expected to emerge through projects carried out by pupils and students in learning groups. Therefore, PjBL is a collaborative inquiry-based learning method where students can integrate, apply and build knowledge while working together to create solutions to complex problems (Guo et al., 2020; Vergara-Castañeda et al., 2021).

The main characteristics of PjBL are teamwork, problem-solving in context and ownership of learning, which enables students to be able to overcome global problems. So, PJBL can overcome real-world problems, generate many hypotheses, problem-solving skills, and critical thinking, require specific knowledge and skills, and integrate various scientific disciplines (Bopegedera & Coughenour, 2021; Syahril et al., 2020). Other prominent characteristics of PjBL include PjBL centered on questions that encourage the creation of the final product, involving students in the learning and investigation process (Chistyakov et al., 2023; Choi et al., 2019), students will gain experience through scientific practice, developing skills cognitive and build their understanding of the material. Topic Learning objectives enable learning new topics and skills, and students conduct research collaboratively (Markula & Aksela, 2022; Simbolon & Koeswanti, 2020). The characteristics of the PjBL model are closely related to chemistry learning. The current curriculum emphasizes the subject of chemistry, which involves various interdisciplinary practicum activities so that learning outcomes can be optimized (Ling et al., 2024; Markula & Aksela, 2022).

Project-based learning aims to provide students with a deeper understanding of theoretical concepts by being exposed to real problem situations. PjBL practice in the laboratory trains students in handling various devices and working in teams, as well as increasing their understanding of concepts through direct experience (in line with Vygotsky's constructivism theory). Findings in previous research show that students agree that PjBL helps increase knowledge and trains cooperation and collaboration in teams. PjBL can improve learning outcomes and high-level skills (Gomez-del Rio & Rodriguez, 2022). Project-based learning has contributed a lot to improving the quality of student learning based on evidence from previous studies. However, the diversity and complexity of project-based learning implementation, especially influenced by the research methods used and the research findings, make the effectiveness of project-based learning on student learning outcomes in chemistry diverse as well. This can make it difficult to generalize the impact of project-based learning on chemistry learning. Therefore, it is essential to know the impact of the PjBL model on the quality of chemistry learning.

Among the many studies that have been conducted regarding the implementation of the PjBL model in chemistry learning, it is necessary to review and analyze literature related to the development of research regarding the PjBL model in chemistry learning using bibliometric analysis. Previous studies have previously carried out bibliometric analysis to explore science learning topics using project-based learning models (Konu Kadirhanogullari & Ozay Kose, 2023; Misbah et al., 2024). However, these studies are limited in scope because they focus on something other than chemistry learning. Thus, the novelty of this research complements previous research. This research aims to analyze research developments, relevant topics, and future research opportunities related to the use of project-based learning models in chemistry learning applied in the last decade (2014-2024).

This study specifically, the study seeks to identify key trends and innovations in PBL methodologies as applied to chemistry learning, evaluate the effectiveness of these models in

enhancing student engagement and understanding, and assess the impact of PBL on various educational outcomes, such as critical thinking, problem-solving skills, and academic performance. Furthermore, the research intends to map out the prevalent topics and themes that have emerged in the literature, highlighting areas that have received significant attention as well as those that still need to be explored. By synthesizing findings from existing studies, the research aims to uncover gaps in the current body of knowledge and propose future research opportunities that could address these gaps, ultimately contributing to the advancement of chemistry education through more effective and innovative PjBL approaches.

2. METHODS

The research methodology was carried out in various stages, starting from the identification stage. At this identification stage, data was collected from the Scopus database using the keywords: "project-based learning", "chemistry learning", and "chemistry education" (Constantinou et al., 2018). This process produced 365 relevant documents. Articles collected from the Scopus database are stored in comma-separated values (*.csv) format. Next, the collected articles were re-selected according to the inclusion-exclusion criteria, which have been arranged in Table 1.

Table 1. Inclusion-Exclusion Criteria

No	Aspects	Inclusion Criteria	Exclusion Criteria
1.	Unit of Analysis	Undergraduate students and high school students.	Apart from undergraduate students and high school students.
2.	Scopes/Context	Project-Based Learning, Chemistry Learning, Chemistry Education.	Not related to Project-Based Learning in Chemistry Learning or Chemistry Education.
3.	Language	English	Apart from English.
4.	Years	2014 - 2024	<2014
5.	Article Qualification	Scopus database, from international journals indexed by Scopus.	Not included in Scopus database.
6.	Types of Publication	Research Articles and Conference Proceedings.	Book review, Book Chapter, Review Article, Perspective, Communication, Essay.

Based on the article selection process using inclusion-exclusion criteria, 319 documents were obtained. Then documents that have passed these stages are visualized in VOSviewer software for bibliometric analysis. Next, data analysis was carried out to determine the main topics discussed in the latest research developed regarding project based learning in chemistry learning. The steps and criteria in the research methodology used can be described in Figure 1.

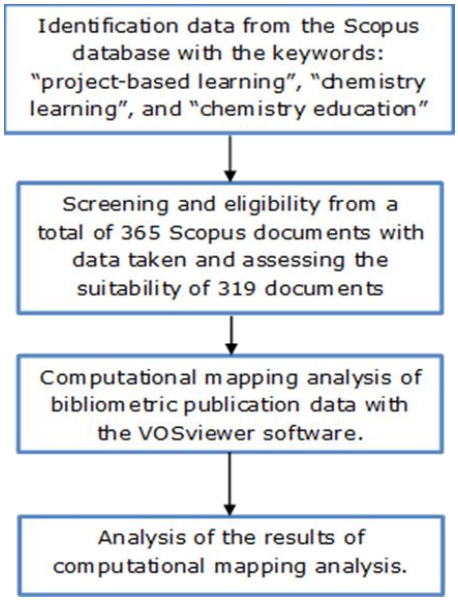

Figure 1. Steps and Criteria Used in Research Methodology

3. RESULTS AND DISCUSSION

Results

Research Development of Project-Based Learning Models in Chemistry Learning

The development of project-based learning research in chemistry learning, based on the Scopus database using the keywords "project-based learning," "chemistry learning," and "chemistry education," has resulted in the number of documents published in the last ten years (2014-2024) increasing and fluctuating, as in Figure 2.

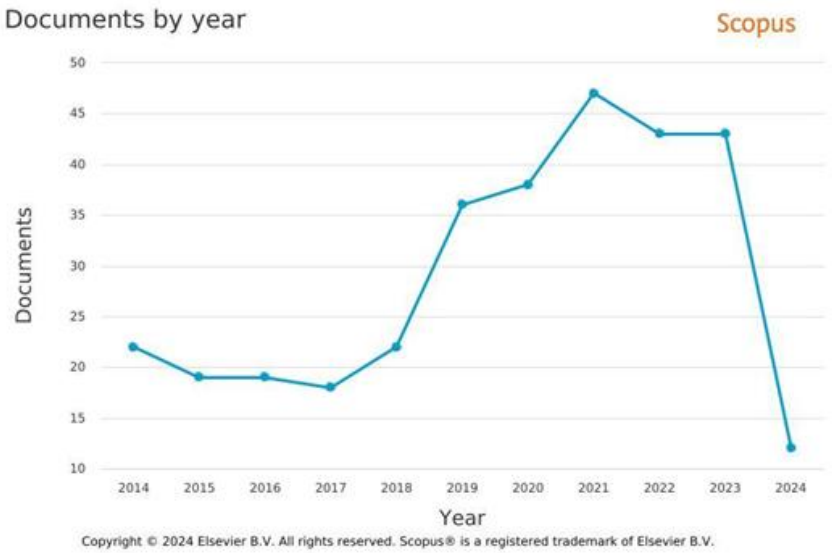

Figure 2. Level of Research Development on Project-Based Learning Models in Chemistry Learning

Base on Figure 2, project-based learning research in chemistry learning was analyzed starting from research from 2014 to 2024. Based on the number of published documents, there was a continuous increase from 2017-2021. Then, it decreased after 2021. However, at

the beginning of 2024, there is still a high level of research in this field, so there is potential for further research related to the project-based learning model in chemistry learning. Based on the Scopus database for 2014-2024 in the Project-Based Learning sector in chemistry learning, which is the most productive country, the results are obtained in Figure 3.

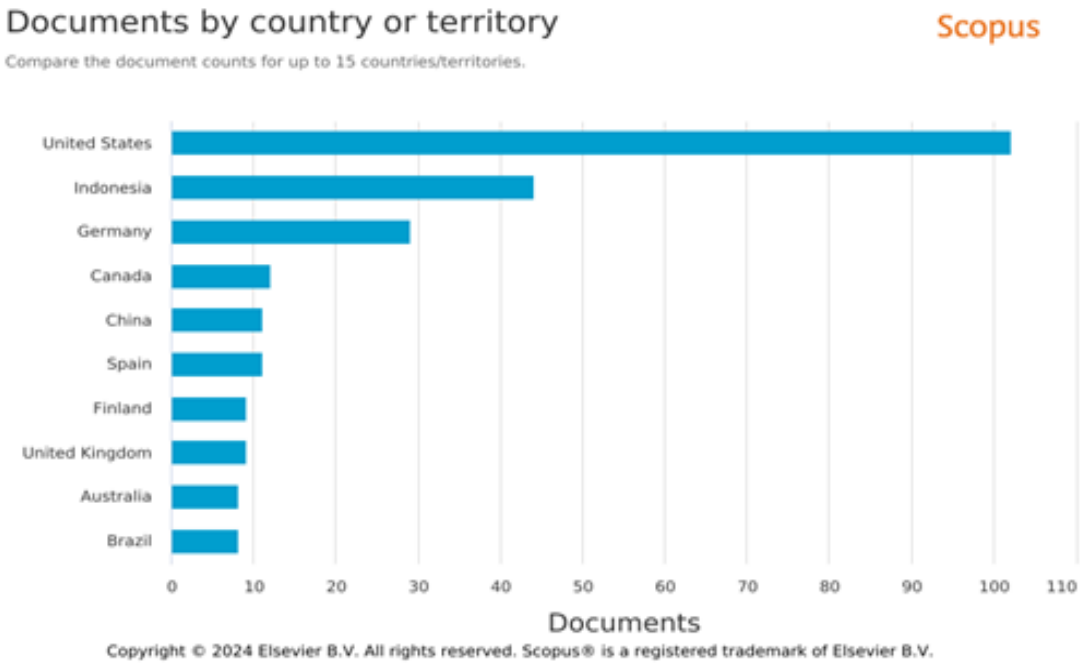

Figure 3. Productive Countries in The Field Of Project-Based Learning in Chemistry Learning

Figure 3 shows the ten most productive countries that publish the most articles in the field of Project-Based Learning in chemistry learning. The top three contributors were the United States, Indonesia, and Germany, with the United States totalling 102 publications, Indonesia 44 publications, and Germany 29 publications. Of the ten countries, Indonesia, as the only developing country that has conducted the most research on the topic of project-based learning in chemistry, is an exciting finding that needs to be studied more deeply.

Trends of Project-Based Learning in Chemistry Education Context

The number of clusters obtained from VOSviewer mapping with the keywords "project-based learning", "chemistry learning", and "chemistry education" is 3 clusters with different numbers, types of items and colors. Supported by the minimum number of relationships between terms in VOSviewer determined by two terms (Al Husaeni & Nandiyanto, 2022). The mapping of each cluster consists of items that form circles of varying sizes determined based on their frequency of appearance. Larger circles indicate more frequent use of keywords, while smaller circles indicate less frequent use (Mulyawati & Ramadhan, 2021).

The mapping results of the three clusters obtained from VOSviewer with the keywords "project-based learning", "chemistry learning", and "chemistry education" are as follows: 1) Visualization of the graduate education/research network in cluster 1 is show in Figure 4.

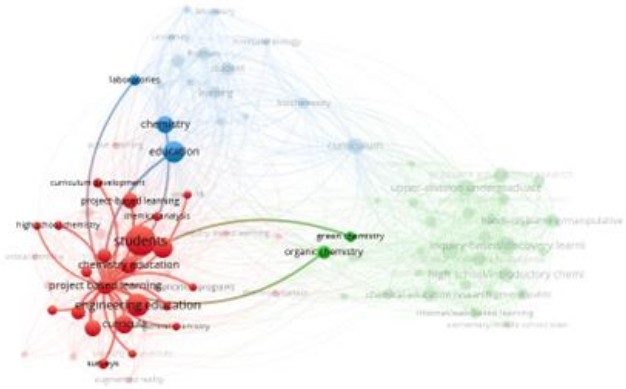

Figure 4. Visualization of The Graduate Education/Research Network in Cluster 1

Base on Figure 4, cluster 1 consists of 36 items and is marked in red; these 36 items are active learning, application programs, augmented reality, chemical analysis, chemistry education, covid-19, critical thinking, curricula, curriculum development, design, design-based research, e-learning, education computing, educational technology, engineering education, general chemistry, high school chemistry, high school students, higher education, inquiry-based learning, learning experiences, learning systems, product design, professional aspects, project-based learning, project-based learning, project-based learning models, science and engineering, stem, stem (science, technology, engineering, and mathematic), stem education, students, surveys, sustainability, teaching, thermodynamics. Visualization of the project-based learning network in cluster 2 is show in Figure 5.

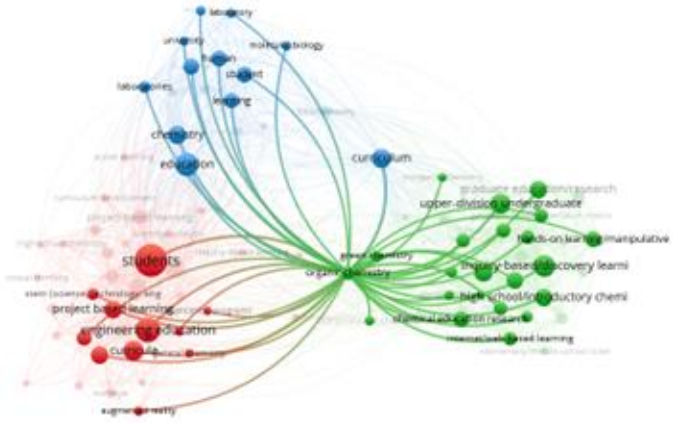

Figure 5. Visualization of The Project-Based Learning Network in Cluster 2

Figure 5 is show Cluster 2 consists of 32 items and is marked in green, these 32 items are analytical chemistry, chemical education research, chemical engineering, collaborative/cooperative learning, computational chemistry, computer-based learning, constructivism, distance learning/self-instruction, elementary/middle school science, environmental chemistry, first-year undergraduate, the general public, graduate education/research, green chemistry, hands-on learning/manipulative, high school/introductory chemical, inorganic chemistry, inquiry-based/discovery learning, interdisciplinary/multidisciplinary, internet/web-based learning, laboratory instruction, multimedia-based learning, organic chemistry, physical chemistry, problem-solving/decision making, professional development, public understanding/outreach, second-year undergraduate, student-centered learning, testing/assessment, undergraduate research, upper-

division undergraduate. Visualization of the chemistry network in cluster 3 is show in Figure 6.

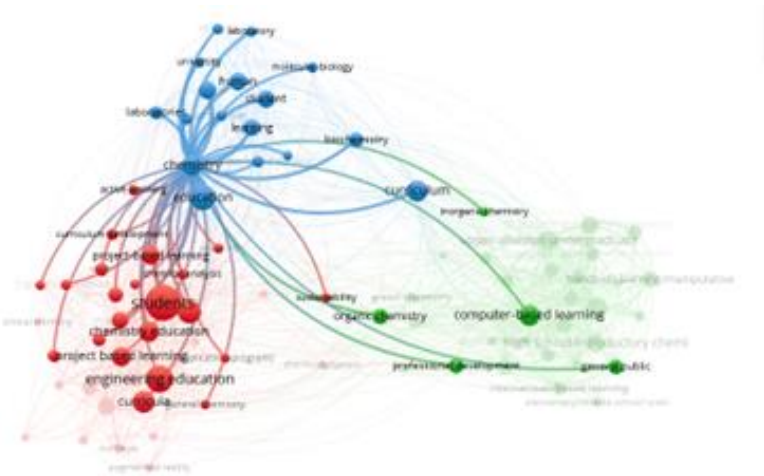

Figure 6. Visualization of The Chemistry Network in Cluster 3

Base on Figure 6 show cluster 3 has 17 items and is marked in blue; the 18 items, namely article, biochemistry, chemistry, curriculum, education, human, humans, laboratories, laboratory, learning, molecular biology, problem-based learning, problem-based learning, procedures, research, student, university. The relationship between one term and another term can be seen in each cluster of each topic area studied in the form of a network visualization as show in Figure 7.

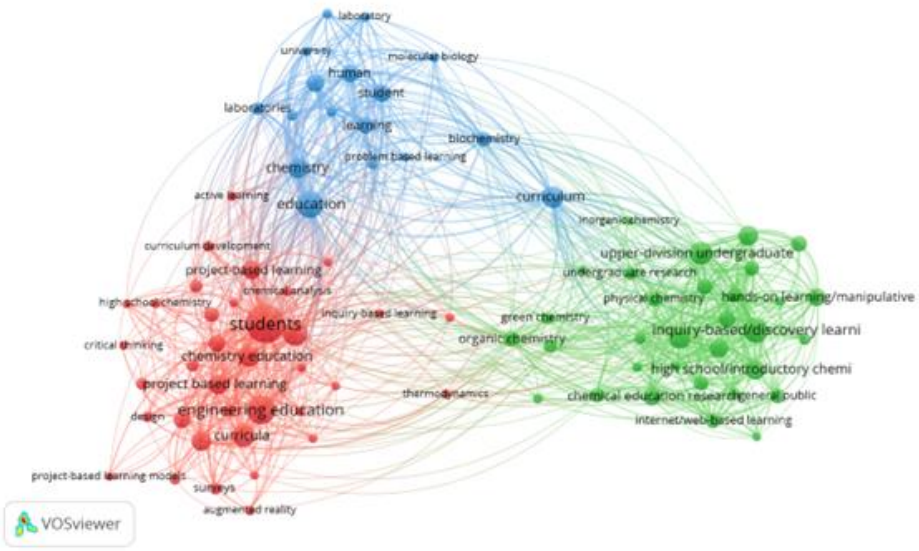

Figure 7. Project-Based Learning Network Visualization in Chemistry Learning Based on Co-Occurrence Analysis

Figure 7 is a network visualization with the keywords "project-based learning", "chemistry learning", and "chemistry education. Based on the three clusters, show how chemical topics are related in their application using the project-based learning model. Chemistry topics that are mainly researched using the project-based learning model are organic chemistry, chemical analysis, green chemistry, chemistry, laboratories, and chemistry education. The density visualization is show in Figure 8.

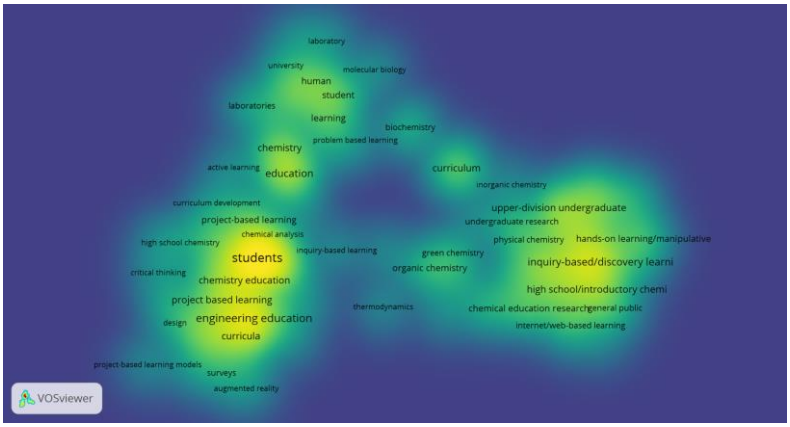

Figure 8. Density Visualization

Figure 8 is the density visualization. It shows that the Project-Based Learning model is most widely implemented in chemistry and engineering education. This can be seen in the high-density colors in the areas of the terms Project-Based Learning, chemistry education, and engineering education.

Discussion

Research Development of Project-Based Learning Models in Chemistry Learning

Based on the data show that the United States is the number one most productive country conducting research in the field of Project-Based Learning in chemistry with 102 documents. This is because the development of the Project Based Learning (PjBL) model in chemistry education has significant implications both for teaching methodology and student outcomes. First, the application of PjBL in the field of chemistry can improve students' critical thinking and problem-solving abilities because it encourages them to be involved in real-world problems and interdisciplinary learning (Misbah et al., 2024; Yanti et al., 2012). For example, existing research highlights how PjBL in undergraduate analytical chemistry laboratory courses fosters independent work and interdisciplinary thinking, which are essential skills for future scientists and professionals (Matilainen et al., 2021; Wen & Korsun, 2024). Then, other research was also carried out, the results of which showed that PjBL in chemistry education encouraged the development of scientific literacy and work-related competencies. By engaging in project design, students practice critical thinking, problem-solving, and applying theoretical knowledge to practical scenarios. This approach bridges the gap between classroom learning and real-world application (Mohafa & George, 2024; Torres-Gastelú & Kiss, 2016). Thus, this approach not only deepens students' understanding of chemical concepts but also prepares them to face the complexities of the modern scientific and professional environment.

The second productive country is Indonesia with 44 documents. The widespread implementation of PjBL in countries such as the United States and Indonesia reflects a global shift towards a more interactive and student-centered learning environment. In Indonesia, the integration of PjBL with the Independent Curriculum aims to develop students' competencies and character in line with Graduate Competency Standards (Fitriyani et al., 2023; Yamin et al., 2020). This alignment shows that the PjBL model can support national education goals and policies, encouraging holistic student development. This is in line with the Project-based learning model which supports the Merdeka curriculum by the curriculum applicable in Indonesia (Fahlevi, 2022). Currently, the Merdeka Curriculum in Indonesia that is being implemented includes Strengthening the Pancasila Student Profile, namely project-based co-curricular activities designed to strengthen the achievement of competencies and character

that are tailored to the student's profile and arranged based on Graduate Competencies Standards (Fitriyani et al., 2023).

Trends of Project-Based Learning in Chemistry Education Context

Project-based learning (PjBL) in chemistry education has shown significant promise across various sub-disciplines, enhancing student engagement and understanding by connecting theoretical knowledge with practical applications. Firstly, PjBL fosters more profound learning and critical thinking skills among students by requiring them to apply theoretical concepts to real-world problems. For instance, students investigating the optical properties of chemical compounds using a UV-vis spectrophotomete gain hands-on experience with analytical techniques, enhancing their practical skills and understanding of spectroscopy (Kolesnichenko et al., 2023; Partanen, 2018). Furthermore, the integration of green chemistry principles into project-based learning projects promotes sustainability and environmental awareness. Projects like comparing ICT-assisted organic compound synthesis processes to align with green chemistry principles not only educate students on sustainable practices but also prepare them for future roles in environmentally conscious industries (Khalid, 2011; Reyes et al., 2023). The PjBL approach also encourages collaboration and communication skills. Projects such as analyzing drinking water quality (Amer et al., 2022), combining expression, purification, crystallization, structure solving, and characterization of flavodoxin-like proteins (Hammerstad et al., 2019), carrying out Synthesis and Photovoltaic Applications of Photochromic Organic Sensitizers (Wang et al., 2024), and studying laser-induced breakdown spectroscopy of stainless-steel samples (Maher et al., 2021) require students to work in teams, share findings, and present their results. These experiences are invaluable in preparing students for professional, scientific environments where teamwork and effective communication are essential.

Project-based learning is most often implemented in organic and green chemistry subjects. In the realm of higher education, students can collaborate on projects comparing several ICT-assisted organic compound synthesis processes to obtain a process that meets the principles of green chemistry (Rahmawati et al., 2021; Reyes et al., 2023). Apart from that, project-based learning can also be applied to organic chemistry through the Chemistry for Community program and based on local wisdom. The PjBL model can stimulate students to be able to apply chemical knowledge and go directly into society (Bowe et al., 2023; Sudarmin et al., 2019). In this way, it can become a reference for other researchers who will conduct further research in chemistry related to project-based learning.

In addition, less researched areas regarding project-based learning in chemistry learning include augmented reality media, inorganic chemistry, and curriculum development. Research on ICT-assisted with project-based learning models such as augmented reality in chemistry learning, the implementation of Project Based Learning model in inorganic chemistry content, and the link between the PjBL model and curriculum development in the field of chemistry education can be a research topic that can be developed in the future because could provide a structured approach to integrating these projects into standardized educational frameworks.

4. CONCLUSION

Research in the project-based learning model in chemistry learning from 2014 to 2024 shows prominent variability in publication volume in the United States in terms of the number of publications. In this year's span, the peak of research on the project-based learning model in chemistry learning was mainly carried out in 2021. Keyword analysis shows that chemical topics that have been widely researched in their application using the project-based learning model are organic chemistry, chemical analysis, green chemistry, chemistry

practicum, and chemistry education. The potential research in the future is related to ICT-assisted project-based learning models such as augmented reality in chemistry learning, the implementation of the Project Based Learning model in inorganic chemistry content, and the link between the PjBL model and curriculum development in chemistry education.

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