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Exploring Research Trends and Future Works of Process-oriented Guided Inquiry Learning in Organic Chemistry: A Bibliometric Study

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Abstract

This study aimed to investigate research trends and future works concerning the implementation of the Process Oriented Guided Inquiry Learning (POGIL) approach in organic chemistry learning. Employing the PRISMA protocol for systematic literature review and bibliometric analysis using VOSviewer software, the researchers identified and analyzed 97 relevant journal articles indexed in the Scopus database. The analysis revealed an upward trend in POGIL-related publications since 2016, with a significant concentration in the United States and in chemistry education journals. Key thematic clusters emerged around cognitive and affective learning domains such as engagement, academic achievement, reasoning, teamwork, and self-efficacy, indicating the predominance of student student-centered and active learning practices in POGIL implementations. However, the study found limited exploration of knowledge retention, misconceptions remediation, anxiety management, and the integration of digital learning tools in POGIL-based organic chemistry learning. The study concluded that POGIL holds strong potential for enhancing curriculum design and learning outcomes in chemistry education. It implied that future research should explore under-investigated areas, including the integration of appropriate technological innovations, to optimize the impact of POGIL on student learning in organic chemistry.

Keywords: *Bibliometric analysis, Organic chemistry, POGIL, PRISMA, VOSviewer*

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INTRODUCTION

The literature shows that studies on Process Oriented Guided Inquiry Learning (POGIL) have been conducted in a variety of fields and subjects. These studies generally focused on chemistry (Farrell et al., 1999; Koron et al., 2023; Moon et al., 2017; Qureshi et al., 2017; Schmidt-Mccormack et al., 2019), biology (Bailey et al., 2012; Murray, 2014; Prince et al., 2018; Rosadi & Sunarno, 2018), Psychology (Rumain & Geliebter, 2020), science (Ellinger, 2019), computer science (Howley, 2020). However, the quantity of review studies in the literature that investigate the changing research subjects to exhibit trends in POGIL-related organic chemistry topics is not sufficient. The only review studies concerning POGIL available in the literature are those by (Rodriguez et al., 2020; Şen, 2024; Walker & Warfa, 2017). Despite their contributions, these reviews exhibit notable limitations. Rodriguez et al., (2020) lack an explicit presentation of distribution and trends of affective-cognitive domains in the reviewed studies. Şen (2024) despite using a bibliometric approach, relies solely on the Web of Science database and does not explore discipline-specific trends such as organic chemistry. Walker and Warfa (2017) conducted a meta-analysis that was limited to achievement and graduation rates, excluding broader thematic developments and failing to map the evolution of research variables. Therefore, a more focused bibliometric analysis, particularly in the context of organic chemistry, is needed to uncover deeper research patterns and future works.

Based on this, studies regarding the exploration of POGIL across various disciplines and topics within chemistry, particularly in organic chemistry, should prioritize comprehensive review efforts to identify emerging trends. The use of innovative approaches such as bibliometric analysis is encouraged to provide deeper insight. Furthermore, interdisciplinary collaboration is essential to integrate diverse perspectives, while exploring under-researched areas can significantly enhance understanding of POGIL's implementation and impact in chemistry education, especially in the context of organic chemistry learning.

Bibliometric analysis is widely recognized as a method for assessing the impact of academic publications within a field. According to Ellegaard and Wallin (2015), bibliometric analysis across multiple fields and countries aims to quantify the influence of scholars' contributions and offer an overview of publications within specific disciplines or subjects. Such evaluations enable practitioners to contextualize relevant publications for application in their own work, and the ensuing discussion facilitates an examination of publication trends and identifies gaps in specific evaluation areas within the literature (Heberger et al., 2010). According to Li et al. (2023), bibliometric analysis studies will significantly enhance the literature by offering insights into changes, citations, co-occurrences, and co-citation trends in the research under review.

Identifying influential publications and authors in a study enhances understanding of core concepts and helps researchers uncover hot research topics, knowledge gaps, and future trends (Wei et al., 2022). The findings will inform future research and guide scholars by pinpointing areas needing further investigation. Therefore, this study uses bibliometric analysis to assess the current status of POGIL research and its position in the study of teaching and learning methods, especially in organic chemistry learning. Bibliometric analysis plays an important role in a variety of fields by exploring and analyzing trends, evolution, and the significance of publications (Öztürk et al., 2024)

Guided inquiry-based learning has been widely investigated in previous studies. However, as noted by Joshi and Lau (2023), there remains a limited number of studies that specifically explore the impacts of the POGIL approach. Meanwhile, bibliometric analyses play a significant role in mapping the progress and development of a particular research area (Y. Song et al., 2019).

An increase in the volume of research on the POGIL approach is likely to enhance its visibility and encourage more researchers and educators to adopt this instructional approach. Furthermore, explaining how the POGIL approach has been implemented in the literature and assessing its impact on student performance can provide valuable insights into which components of the approach most effectively support academic achievement (Chase et al., 2013). Nevertheless, recent developments concerning the POGIL approach have not yet been thoroughly visualized or conceptually explored. In response to this gap, the present study employs a bibliometric analysis to investigate the influence of the POGIL approach on chemistry education, with a particular focus on its application in organic chemistry courses, by analyzing citation patterns in relevant literature.

A search conducted in the Scopus database revealed that studies on the POGIL approach are distributed across a range of categories. The diversity of publications and contributing authors reflects the adaptability of the POGIL approach across multiple disciplines. However, this broad application may lead to a lack of comprehensive understanding among researchers and educators regarding the development of the POGIL approach and its effective implementations in instructional settings. Therefore, bibliometric analysis enables new researchers to identify trends in POGIL studies and address gaps, particularly in chemistry education. This research aims to highlight trends in POGIL-based learning within chemistry education, with a focus on organic chemistry courses.

This research allows researchers to quickly and accurately analyze large data sets using computer algorithms, providing deep insight into international collaborations, organizations, and authors, as well as identifying key foundational studies and tracking research progress (P. Song & Wang, 2020). As a result, this approach offers distinct advantages over conventional experience-based techniques by enabling the efficient collection and processing of large volumes of technical data (Huang et al., 2020).

This analytical approach is employed to systematically review research across a wide range of disciplines, particularly in response to the growing number of studies and advancements in various quantitative statistical methods (Esen et al., 2020). As noted by Donthu et al. (2021), the increasing functionality and accessibility of bibliometric tools and databases, such as Scopus and Web of Science (WoS), have contributed to the rising popularity of bibliometric analyses. These analyses also allow researchers to explore relevant publications and identify relationships among different elements of scientific communication (Esen et al., 2020). According to Ellegaard and Wallin (2015) note that researchers in diverse scientific fields can discover opportunities for collaboration, as well as new trends and groups, by studying bibliometric analyses. For instance, there are examples of bibliometric research aimed to identify research trends on certain chemical compounds (Liandi et al., 2024), identify the universities that are most productive and influential in innovation research (Cancino et al., 2017), publications by researchers from a specific country (Gülmez et al., 2021), publications related to a specific journal (Gaviria-Marin et al., 2018), university-industry cooperation (Mascarenhas et al., 2018), and those focused solely on authors (Nosek et al., 2010), as well as publications examining variables in learning domains (Nasrudin et al., 2023). Our review of POGIL literature is guided by the following questions:

1. What are the publication trends and research hotspots related to POGIL in organic chemistry learning?
2. How are the research keywords on POGIL interconnected in terms of topic cluster and co-occurrence patterns?
3. What gaps and future research directions can be identified regarding the implementation of POGIL in organic chemistry learning?

METHOD

This research is a literature study that uses the bibliometric method to analyze the studies concerning POGIL. Bibliometric analyses are mostly done to obtain a general view of the literature in several scientific areas. There are two methods employed in this research, namely the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) procedure for data collection (Moher et al., 2010) and bibliometric for data analysis uses VOSviewer software. PRISMA-P is a recommended framework for planning and reporting systematic reviews and meta-analysis protocols. Its main objective is to improve the quality and transparency in the reporting of systematic review protocols (Nasrudin et al., 2023). Sources of information obtained from the Scopus database. The research steps are shown in Figure 1.

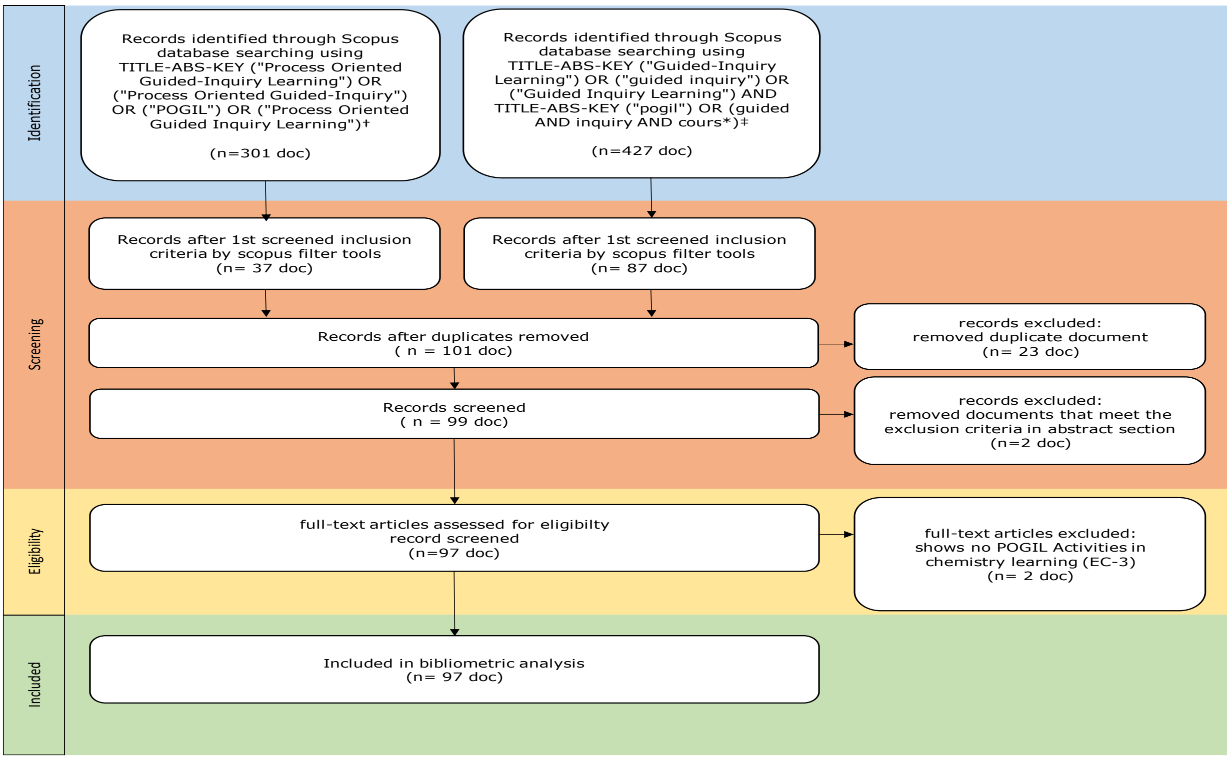

Figure 1. PRISMA-P flow phases diagram

The first phase is to carry out the identification process. This process activity consists of searching for documents on the Scopus database page using certain keywords. There are two search strategy formulas, the first has the following formula TITLE-ABS-KEY ("Process Oriented Guided-Inquiry Learning") OR ("Process Oriented Guided-Inquiry") OR ("POGIL") OR ("Process Oriented Guided Inquiry Learning")† and the second formula is TITLE-ABS-KEY ("Guided-Inquiry Learning") OR ("guided inquiry") OR ("Guided Inquiry Learning") AND TITLE-ABS-KEY ("pogil") OR (guided AND inquiry AND cours*)‡. The search for documents was carried out in February 2025.

At the initial identification stage, 728 documents were obtained. The search filter process is not carried out based on a certain year range on Scopus filter tools. In this way, the search is carried out starting from the earliest documents to the most recent articles with a publication year limit in 2024, because 2025 is still ongoing. This treatment is intended to maximize the search for as many documents as possible related to the specified keywords (Mengist et al., 2020).

The second phase is to carry out a screening process. This process activity takes the form of identifying and selecting relevant studies from a large pool of search results. Then an initial sorting process is carried out using the filter tool in Scopus adjusting the inclusion criteria (IC), especially in the subject area limited to chemistry, document type: limited to article, publication stage: limited to final, source type: limited to journal, language: limited to English.

This initial sorting process produced 124 documents with the following description: the first keyword formula had the symbol †, resulting in 37 documents and the second keyword formula had the symbol ‡, resulting in 87 documents. At the screening stage, duplicate documents are also removed. There were 23 duplicate documents reported, so the number of documents eligible for further processing was 101 documents. The next process is to carry out a short screening process for each document that meets the inclusion criteria or the exclusion criteria in both the abstract and methodology sections. In this process, it was reported that 2 documents met the exclusion criteria and were released, thus the number of documents that could be forwarded to the next stage was 99 documents.

Inclusion and exclusion criteria are predefined parameters that ensure a systematic review or meta-analysis is focused, unbiased, and relevant to the research question by determining which studies will be included or excluded (Patino & Ferreira, 2018). The inclusion criteria (IC) and exclusion criteria (EC) are presented in Table 1.

Table 1. Inclusion criteria and exclusion criteria

Inclusion criteria (IC)	
IC-1	The study presents POGIL instructions or activities in the form of worksheets or other learning activities in chemistry learning.
IC-2	The study presents POGIL activities in other branches of chemistry such as in the fields of pharmacy, geology, engineering, and so on are permitted.
IC-3	The study presents POGIL activities in chemistry learning at secondary education levels such as high school and equivalent which are permitted.
IC-4	The type of research document must be a final article only and sourced from a journal indexed by Scopus.
Exclusion criteria (EC)	
EC-1	The study is written in a language other than English.
EC-2	The full text of the study is not available.
EC-3	The study shows no POGIL Activities in chemistry learning.
EC-4	Conference paper, book chapter, conference review, review, editoral, book, textbook.
EC-5	Articles originating from journals that are not indexed by Scopus.

The third phase is to carry out the eligibility process. This processing activity takes the form of full-text retrieval, namely obtaining the full texts of studies that passed the initial screening; detailed assessment, namely evaluating the full texts against the predefined inclusion and exclusion criteria; and documentation, namely recording reasons for exclusion of studies that do not meet the criteria. This phase ensures that the selected studies are relevant and of high quality, contributing to the reliability and validity of the review's conclusions (Page et al., 2021). In this process, there were 2 documents that met the exclusion criteria, specifically not showing POGIL learning activities. As a result, there were 97 documents that were reported as being able to be forwarded to the next stage.

The fourth phase is Included. At this stage, the 97 documents that have met eligibility will be forwarded for bibliometric analysis using VOSviewer software. The subsequent stage involves conducting a bibliometric analysis, specifically employing a co-occurrence analysis. This analytical technique is intended to map the relationships among keywords and evaluate the strength of their associations. The unit of analysis includes all keywords, encompassing both author keywords and index terms. Full counting is applied as the selected counting method. To address variations in keyword usage, such as differences in singular and plural forms or alternative spellings, a thesaurus was developed to consolidate equivalent terms. The thesaurus utilized in this phase is presented in Table 2.

Table 2. Thesaurus

No.	Label	Replaced by
1.	process oriented guided inquiry learning	POGIL
2.	process oriented guided inquiry learning (pogil)	POGIL
3.	process-oriented guided inquiry learning	POGIL
4.	pogil activities	POGIL
5.	process-oriented guided inquiry learning research	POGIL
6.	process-oriented guided inquiry learning (pogil)	POGIL
7.	guided inquiry	guided inquiry learning
8.	first-year undergraduate	first-year undergraduate/general
9.	first year undergraduate/general	first-year undergraduate/general
10.	first-year undergraduate / general	first-year undergraduate/general
11.	high school	high school/introductory chemistry
12.	high school students	high school/introductory chemistry
13	high school / introductory chemistry	high school/introductory chemistry
14.	inquiry-based learning	inquiry-based/discovery learning
15.	inquiry learning	inquiry-based/discovery learning
16.	inquiry based learning	inquiry-based/discovery learning
17.	inquiry-based / discovery learning	inquiry-based/discovery learning

RESULT AND DISSCUSION

Mapping research trends in chemistry education using the process-oriented guided inquiry (POGIL) learning approach aims to see the number of annual publications. This information can be used as a reference regarding the extent of interest of researchers and practitioners in the field of chemistry education, especially chemistry learning using the POGIL approach. The pattern of publication productivity highlights ongoing research efforts and offers a useful reference point for evaluating future research opportunities in the field (Abdullah & Naved Khan, 2021). Trends in research publications on the POGIL learning approach in chemistry learning were obtained from the publication of scientific articles in journals indexed by Scopus.

Figure 2 shows the distribution of publications over the last 25 years. Based on this distribution, it can be interpreted that there has been a steady growth in research interest toward POGIL approach in chemistry education, particularly evident over the last decade. The peak occurred in 2020. This scenario is in line with the results of previous research which shows an increase in the number of studies related to POGIL in the field of education (Jegstad, 2023; Şen, 2024).

The earliest research paper on the POGIL approach in the field of education dates back to the year 1999 and appeared in the *Journal of Chemical Education* (Farrell et al., 1999). Interestingly, the research paper was the forerunner of the birth of this learning approach framework, such as the size of the student group and the role of each member in completing the worksheet. At that time, the term POGIL had not been introduced and was still using the basic theory of modified guided inquiry learning. The term POGIL was officially used after a funding proposal for the project's founders was approved in 2003 (Simonson, 2019).

Research on the POGIL learning approach stagnated until 2016. From 2017 to 2020, research on POGIL seems to have attracted the attention of practitioners and research results in the form of articles have increased significantly. The number of annual publications began to increase rapidly in 2018 and has continued to fluctuate upwards until 2020. There was a change in the learning system from face-to-face to remote learning during the adjustment period of the Covid-19 pandemic and it was a challenge for every teacher and researcher to adapt the POGIL approach during 2020 to 2023 (Fateh et al., 2024; Reynders & Ruder, 2020). The average annual scientific production growth of around 39.74% shows a fairly high increase in scientific production, but it should be noted that the data is very volatile, so it is important to look not only at the average but also at the overall trend.

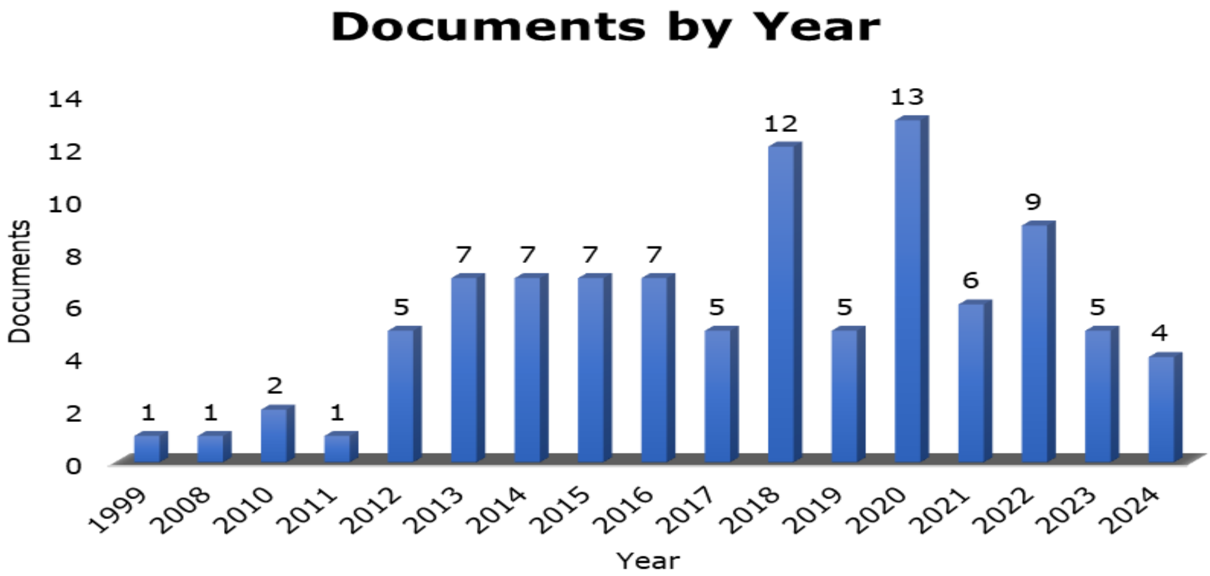

Figure 2. Number of documents by year on POGIL in chemistry course

Based on Figure 3, the most productive country conducting research on POGIL in chemistry learning is the USA. The global COVID-19 pandemic, including in this country, has contributed to a relative decrease in research output from 2021 onward. The World Health Organization (WHO) officially announced the end of the pandemic in September 2023 (Sarker et al., 2023). According to Reynders and Ruder (2020), the large organic POGIL class at Virginia Commonwealth University, USA, transitioned online in response to the pandemic in the Spring of 2020, resulting in significant course format changes and challenges such as motivational, organizational, and technological issues. Similar adjustments occurred in other types of learning approaches, as reported by Gemmel et al. (2020) making the transition from face-to-face collaborative learning to remote collaborative learning.

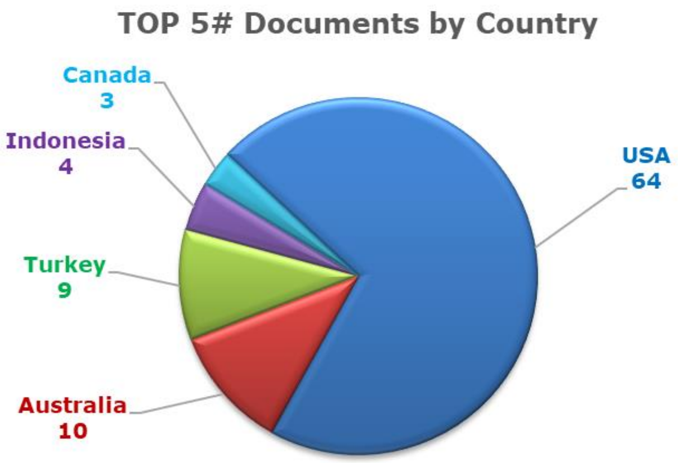

Figure 3. Number of documents by Country on POGIL in the chemistry course

Based on the results of document analysis using VOSviewer and EXCEL software from the two sources of data information above, it is known that the publication of research articles related to the development of the POGIL teaching approach in chemistry learning first appeared in 1999. According to Farrell et al. (1999), the POGIL teaching approach was based on guided inquiry learning with pedagogical and philosophical aspects of the learning cycle and cooperative learning. Furthermore, this teaching approach was initially implemented at Franklin and Marshall College, USA, especially in the teaching of first-year general chemistry courses.

Research on guided inquiry in the scope of chemistry learning was first reported by Allen (1986) in connection with experiment activities in the laboratory, with the article titled "Guided Inquiry Laboratory". Based on that article, the teaching approach of guided inquiry was originally introduced to change traditional laboratory experimental learning in the form of "verification" experiments to guided inquiry-based experiments. The first official use of the term POGIL was in an article entitled "Process-Oriented Guided Inquiry Learning: POGIL and the POGIL Project" written by Moog et al. (2006) which has been cited more than a hundred times to date. Thus, it can be concluded that the POGIL teaching approach and the Guided Inquiry teaching approach have a close relationship with each other, where POGIL is a development of the teaching approach from the Guided Inquiry teaching approach.

The POGIL teaching approach is applied to chemistry learning in the classroom, as in general, and learning using the Guided inquiry approach is more widely used in experiment activities in the laboratory. However, because this teaching approach is still relatively new, several researchers have reported applying the POGIL teaching approach to chemistry learning related to laboratory experimental activities. Based on the results of the analysis, POGIL's activities in the scope of experiment activities in several chemistry subjects in the laboratory are reported as follows: Physical Chemistry (Beck & Miller, 2022; Hunnicutt et al., 2015; Singleton et al., 2022; Stegall et al., 2016); Organic Chemistry (Latimer et al., 2018; Schroeder & Greenbowe, 2008); Analytical Chemistry (Doughan & Shahmuradyan, 2022).

As illustrated in Figure 4, each keyword is represented by a distinct node. The size of each node reflects the frequency of the corresponding keyword, with larger nodes indicating higher occurrences and smaller nodes indicating fewer occurrences. Furthermore, the distance between nodes reflects the strength of the relationship between the keywords, with closer nodes signifying stronger connections (van Eck & Waltman, 2020).

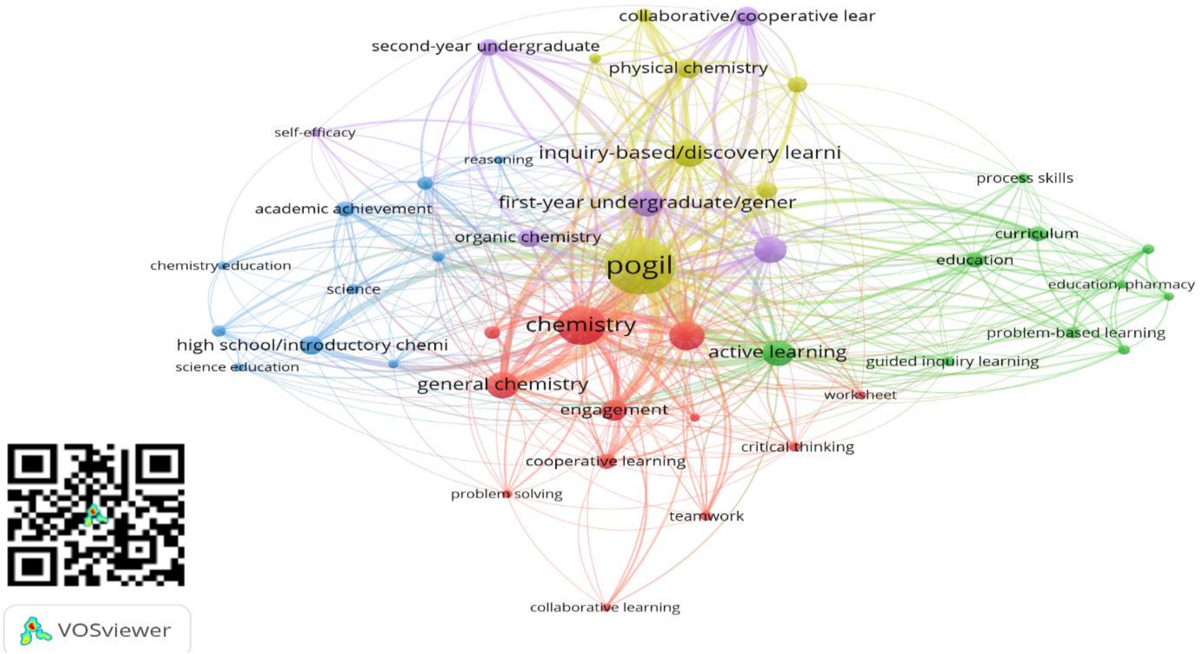

Figure 4. Co-word/co-occurrence network visualization map

For example, in the red cluster, 'chemistry' and 'general chemistry', are the most common keywords, while in the green cluster, the most common keywords are 'active learning' and 'curriculum', and yellow cluster, 'POGIL' are the most frequently used keywords. The size of the nodes varies according to the frequency of keywords used by authors in publications. The lines, on the other hand, show the relations between two nodes (between two keywords).

The thickness of the lines connecting the nodes indicates the strength of the relationship or level of collaboration between them. In essence, each line not only represents a connection but also conveys the intensity of that connection. Nodes that are closely related within the network are positioned near one another and are displayed in the same color. Similar nodes naturally group together to form clusters, with each cluster distinguished by a unique color.

The co-occurrence analysis results demonstrate the relations between the keywords used in publications related to POGIL on chemistry education. One of the features of the vosviewer is co-occurrence analysis. Using the unit of analysis of all keywords with the full counting method and the minimum number of occurrences of a keyword is 3, from 283 keywords obtained, 61 meet the threshold. By setting the number of keywords in one cluster in default values, resulting in 5 clusters on Table 3.

Table 3. Mapping the relationship between keywords within one cluster and between clusters

Cluster	Keyword (occurrence)
Cluster 1 (red color) 12 items	chemistry (47), collaborative learning (3), conceptual building (6), cooperative learning (8), undergraduate students (26), general chemistry (22), engagement (15), learning cycle (3), critical thinking (4), cooperative learning (8), problem solving (3), collaborative learning (3), teamwork (4), worksheet (3)
Cluster 2 (green color) 10 items	active learning (21), guided inquiry learning (4), education (8), problem-based learning (5), educational measurement (4), education, pharmacy (3), pharmacy (3), medicinal chemistry (4), curriculum (8), process skills (4)
Cluster 3 (blue color) 10 items	high school/introductory chemistry (12), science education (3), particulate nature of matter (5), chemistry education (3), stoichiometry (3), science (4), multimedia (4), academic achievement (8), student performance (6), reasoning (3)
Cluster 4 (yellow color) 7 items	POGIL (93), biochemistry (10), inquiry-based/discovery learning (25), upper-division undergraduate (9), physical chemistry (13), argumentation (4), thermodynamics (7)
Cluster 5 (purple color) 6 items	student-centered learning (23), first-year undergraduate/general (22), organic chemistry (11), collaborative/cooperative learning (12), second-year undergraduate (10), self-efficacy (3)

The total link strength is associated with the number of sources in which two keywords together are available. An examination of the number of links and total link strength for each word makes it clear that the keyword "POGIL" was used with the other 44 keywords (total link strength: 394). "Chemistry" was used with the other 42 keywords (total link strength: 214), whereas "Active learning" was used with the other 39 keywords (total link strength: 125), "undergraduate students" was used along with the other 39 keywords (total link strength: 129), "inquiry-based/discovery learning" was used along with the other 33 keywords (total link strength: 128), "Student-centered learning" was used along with the other 31 keywords (total link strength: 113).

Based on the data on the relationship between the number of interconnected keywords and the total link strength above, it can be concluded that the POGIL teaching approach in chemistry learning is widely applied to undergraduate students. This POGIL teaching approach is part of inquiry-based learning and supports active learning and student-centered learning. According to Vincent-Ruz et al. (2020), POGIL is a type of active learning based on a learning cycle where students explore a concept through scientific models, then invent the concept, and finally apply it.

Based on Table 3, first-year undergraduate/general with keyword occurrence: 22, linked with other keywords: 35, and total link strength: 120 is the keyword that has the closest relationship with POGIL compared to other student levels. This means that POGIL is mostly applied to first-year students in chemistry courses. According to Birzina et al. (2019), First-year science students face challenges such as academic rigor, independent learning, lack of foundational knowledge, time management, poor study habits, and academic preparedness. Additionally, addressing these issues through targeted support, resources, and guidance can help them adapt and excel. Thus, it is not surprising that many chemistry learning researchers and practitioners are implementing the POGIL learning activity approach with their first-year students.

Based on Figure 5 shows a report regarding the implementation of POGIL in various branches of chemistry subject. There are eight branches of chemistry that have implemented teaching using the POGIL teaching approach. General chemistry courses are the subjects that have implemented the POGIL teaching approach more than other chemistry subjects. In line with the findings discussed previously, POGIL is widely applied to first-year chemistry students. Thus, it is not surprising that general chemistry courses are one of the courses that are suitable for applying this teaching approach. According to Gulacar et al., (2022) construction of knowledge and expertise in general chemistry courses are important for novice chemistry students, especially for first-year chemistry students to become experts in future careers. Based on this data, it can also be highlighted that there is still a lot of space available for chemistry education researchers and practitioners to implement the POGIL teaching approach in their classes.

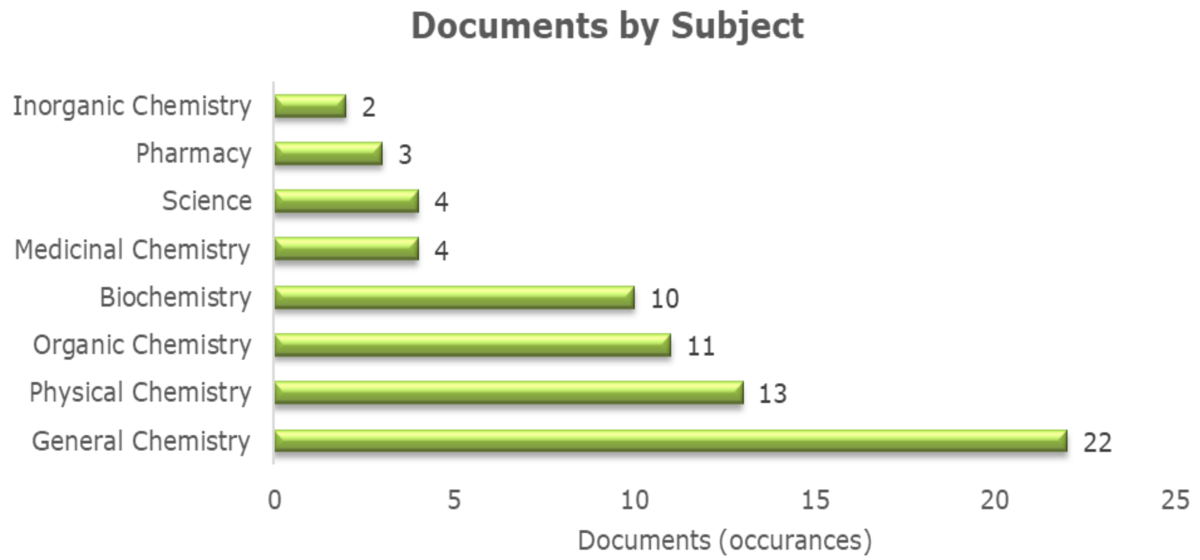

Figure 5. Number of documents by Subject on POGIL in chemistry course

Based on Figure 6 shows a report An examination of the publication/Source Titles showed that the greatest number of publications was in the journal entitled *Chemistry Education Research and Practice* (26 articles) and the second greatest number of publications was in *Journal of Chemical Education* (25 articles), the third greatest number of publications was in the journal entitled *Biochemistry and Molecular Biology Education* (5 articles).

Since the journals shown in Figure 4 are significant academic publications from various research domains, it can be said that many researchers are interested in POGIL's teaching approach. When examining the top three journals, such as *Chemistry Education Research and Practice*, the *Journal of Chemical Education*, and *Biochemistry and Molecular Biology Education*, it is not surprising that all three are related to chemistry education and learning. This is because the POGIL teaching approach was first implemented in general chemistry courses in the 1990s.

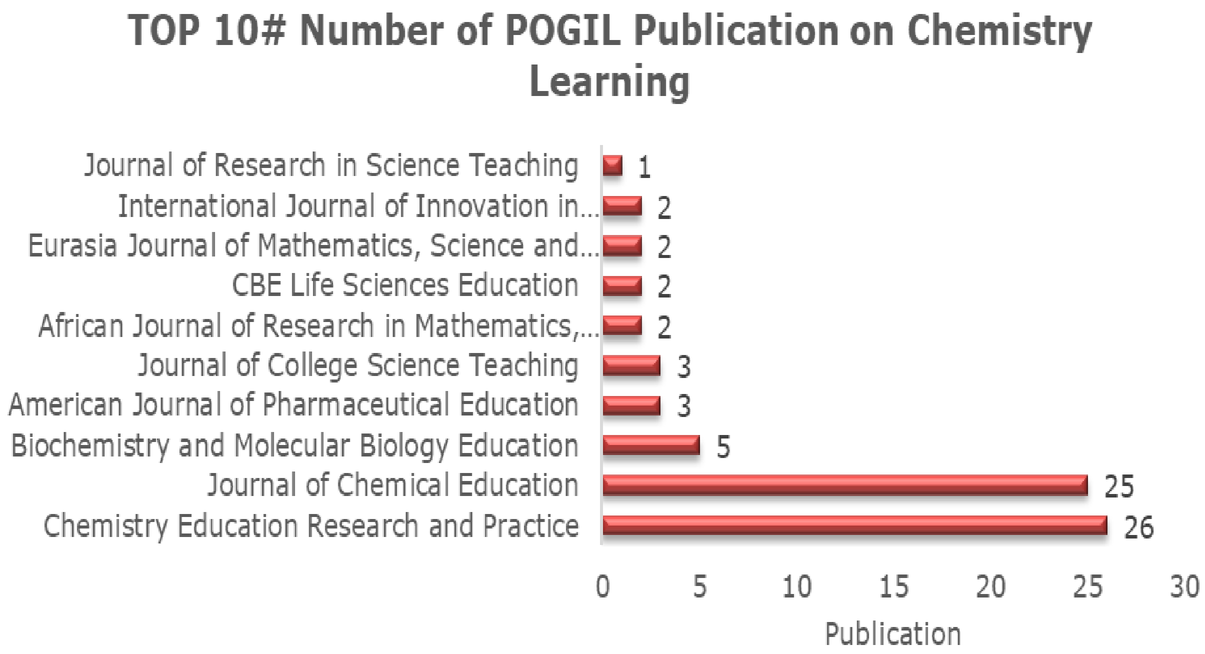

Figure 6. Number of POGIL publications on chemistry learning by source/publication title

Figure 7 presents a report on trends in learning domains for POGIL-based learning in chemistry courses. The data reveal that the engagement variable is the most frequently researched learning domain by both researchers and practitioners. According to (Nennig et al., 2023) social and cognitive engagement play a vital role in promoting effective learning, collaborative interactions, critical thinking skills, disciplinary reasoning, and overall student motivation and attitudes towards learning.

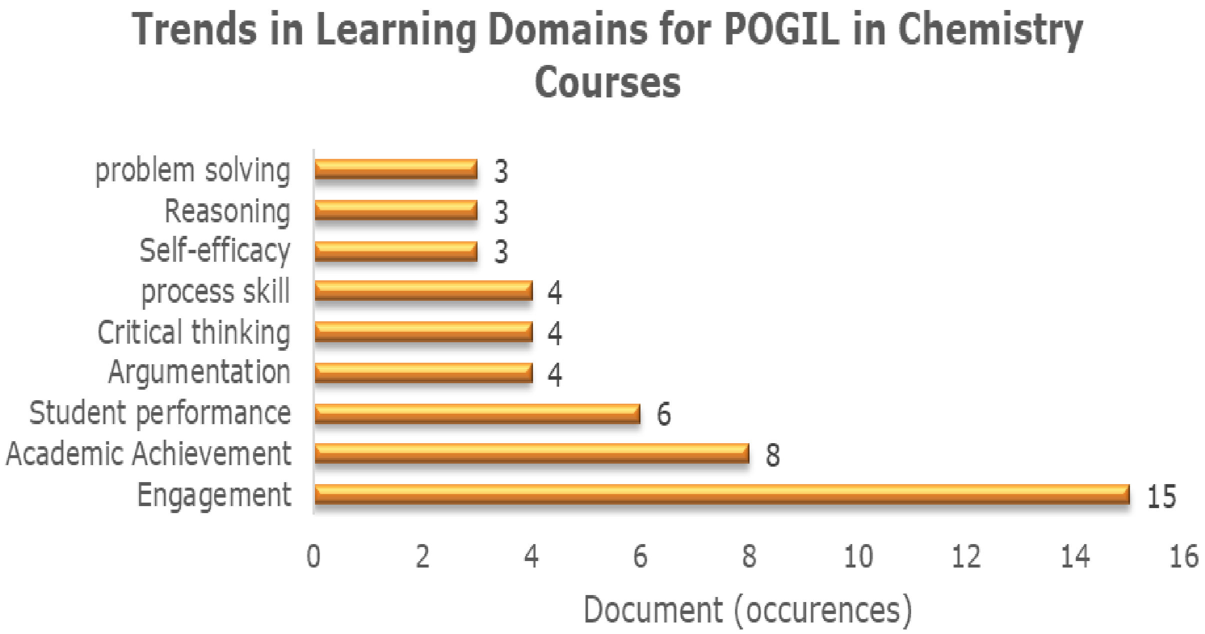

Figure 7. Number of documents by learning domains on POGIL in chemistry course

Based on Figure 8, overlay visualization is selected as a reliable tool for verifying recent trends in an academic field based on timescale and striking color differences to indicate publication years (Shvindina, 2019). VOSviewer highlights topic connections and distinguishes between old and recent issues, with a dark-blue color indicating older topics. For example, research publications regarding the application of POGIL in the scope of pharmaceutical education were on average, and research on critical thinking was on average in 2014. In this way, information was obtained that there was a lack of research in these two fields and opened up opportunities for researchers to fill this gap. On the other hand, the yellow-greenish color indicates the most recent research variables topics, such as problem-solving, academic achievement, reasoning, teamwork, engagement, conceptual building, and process skills.

Choosing the yellow-greenish color topic as the central issue is a sage choice for following trends. However, it does not rule out the possibility of researchers conducting research in dark blue areas and even empty areas, not because this research was abandoned, but because the POGIL teaching approach is still very young and not yet widely known by practitioners.

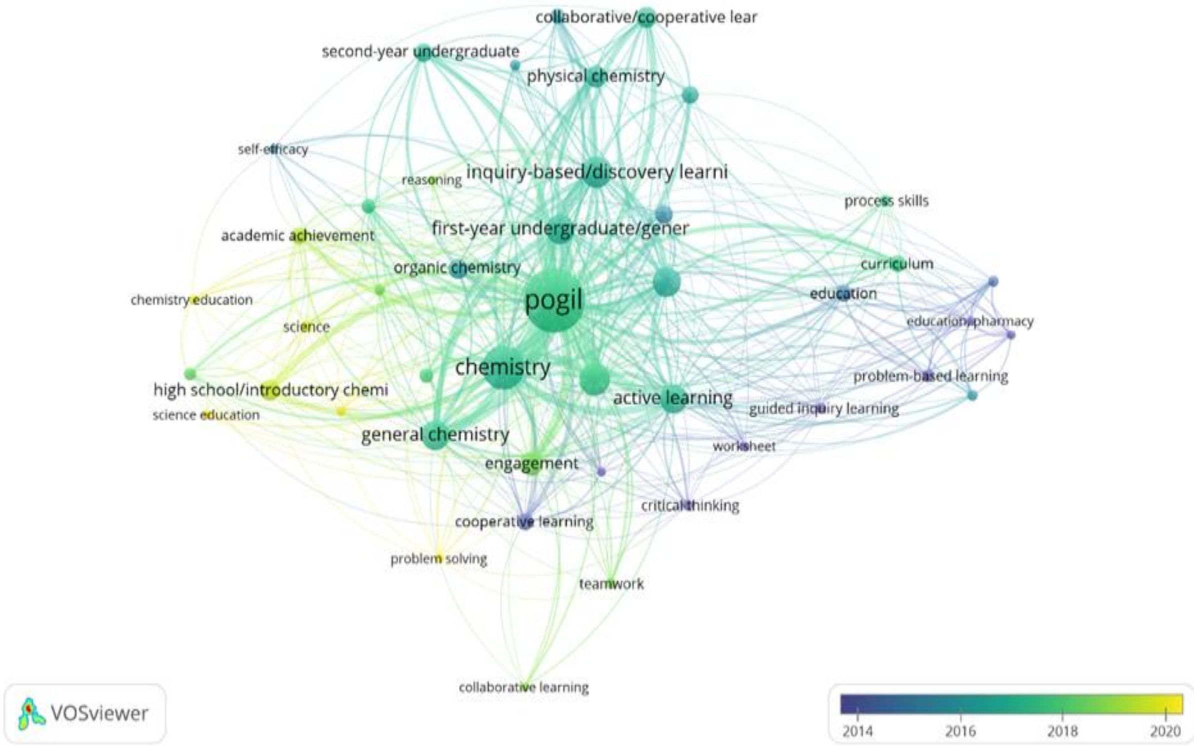

Figure 8. Visualization of overlays

The organic chemistry course that is the focus of this research has great opportunities for conducting research using the POGIL teaching approach. Based on Figure 5, it is known that research using this subject keyword appeared 11 times, connected with 22 other keyword links and the average publication regarding this study was in 2016. Based on Figure 4 the co-occurrence network visualization map shows that the keyword Learning domains that have been connected to organic chemistry courses in the POGIL teaching approach are self-efficacy, academic achievement, student performance, problem-solving, engagement, critical thinking, and teamwork. Thus, it can be highlighted there is still a lot of room to conduct research in each educational domain because the number of keyword occurrences for each is still relatively small.

The results of the VOSviewer study on POGIL in organic chemistry course show that several pieces of research are worth doing in the future by searching for and selecting the desired issue. Several of the intriguing issues to discuss, especially in organic chemistry related to POGIL activities, are engagement, student performance, self-efficacy, academic achievement, teamwork, problem-solving, and critical thinking.

Figure 9 below shows some future work that can be chosen regarding POGIL on organic chemistry learning. However, our opinion remains consistent that, research outside this trend is still wide open for research, such as connecting teaching with the POGIL approach in learning organic chemistry with ICT integration such as electronic teaching material devices that are currently popular such as the use of PhET, Augmented Reality, etc. which have not been recorded and are a void that can be considered by chemistry education researchers and practitioners in the current era of digital education.

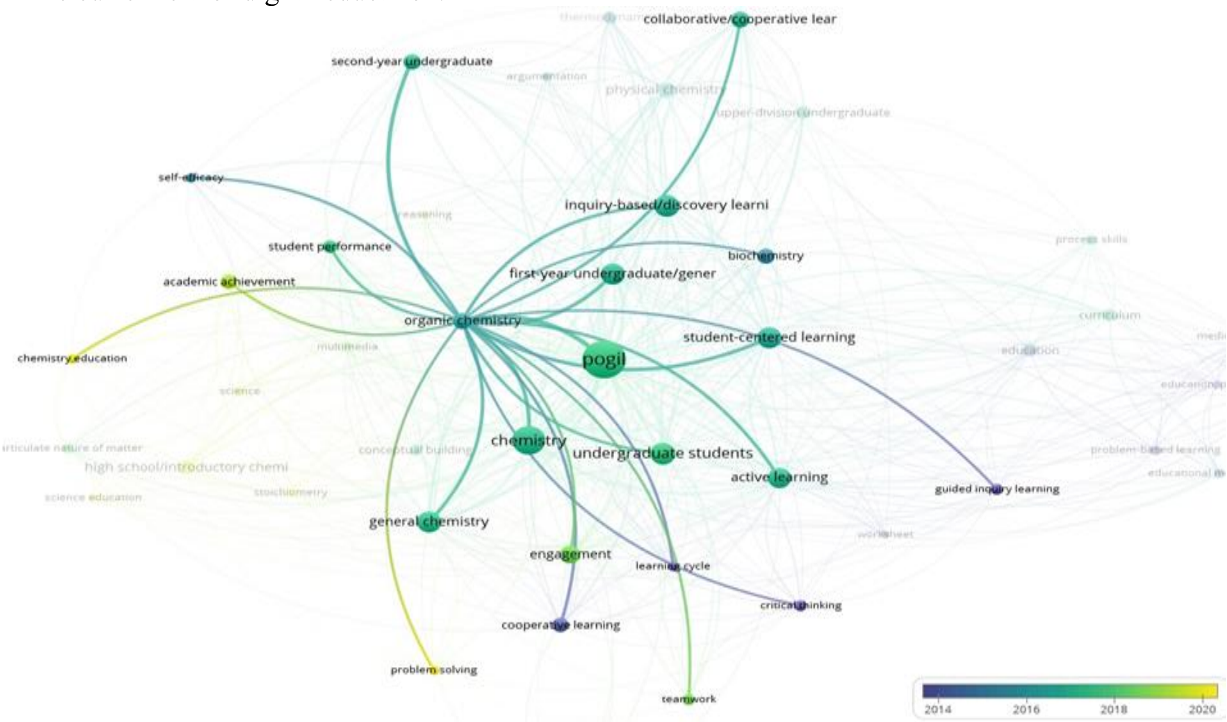

Figure 9. Future Work of POGIL on Organic Chemistry Course

To get future work related to POGIL activities on organic chemistry learning, it is through the help of the open-refine software on the output (excel) obtained from the Scopus database (Kusumasari & Fitria, 2016). After typing the word "Organic Chemistry," the researcher was directed to several articles that were considered relevant, as shown in Table 4.

Table 4. Several alternative future works relate to POGIL on Organic Chemistry Course

No.	Title	Authors	Cited	Keywords	Future Works
1.	Participation in a High-Structure General Chemistry Course Increases Student Sense of Belonging and Persistence to Organic Chemistry	Casey, Jennifer R., Supriya, K. Shaked, Shanna Caram, Justin R. Russell, Arlene Courey, Albert J.	(Casey et al., 2023)	First-Year Undergraduate/General; Learning Assistant (LA); Organic Chemistry; POGIL; Peer-Led Team Learning (PLTL); Second-Year Undergraduate; Student centered	There is a need for a research examined on learning domain such as retention, grade received, and belonging
2.	Students who prefer face-to-face tests outperform their online peers in organic chemistry	Beatty, Abby E. Esco, Abby Curtiss, Ashley B. C. Ballen, Cissy J.	(Beatty et al., 2022)	COVID-19; Chemistry; Engagement; Organic Chemistry; POGIL; Second-Year Undergraduate; remote learning; student performance	Why students who took exams online underperformed relative to face-to-face students, Future research will delve into whether these results were due to the use of a computer or the physical space in which students took exams, and how these experiences led to lower performance and value they placed on chemistry as a field.

No.	Title	Authors	Cited	Keywords	Future Works
3.	Making sense of sensemaking: using the sensemaking epistemic game to investigate student discourse during a collaborative gas law activity	Hunter, Kevin H Rodriguez, Jon-Marc G Becker, Nicole M	(Hunter et al., 2021)	Collaborative learning; Engagement; POGIL; gas law, multimedia	This work analyzes student engagement in sensemaking with multimedia call "Sensemaking epistemic game" through interactions in three student groups during a collaborative learning activity. However, since the data was collected from a small sample in clinical interviews rather than a classroom, the results have limited generalizability.
4.	Effects of guided inquiry versus lecture instruction on final grade distribution in a one-semester organic and biochemistry course	Conway, C J	(Conway , 2014)	Biochemistry; Inquiry-Based/Discovery Learning; Nonmajor Courses; Organic Chemistry; Student-Centered Learning; Testing/Assessme nt	Guided inquiry- (POGIL) requires altering course content because it takes more time for students to learn material in depth, resulting in less material being covered compared to traditional lectures. Thus, Future researchers should explore strategies to balance depth and breadth in guided inquiry (POGIL) to optimize learning outcomes, possibly by integrating selective traditional lectures or focusing on essential core concepts to enhance overall course effectiveness.
5.	Student perceptions of immediate feedback testing in student centered chemistry classes	Schneider, Jamie L Ruder, Suzanne M Bauer, Christopher F	(Schneid er et al., 2018)	General chemistry; Organic Chemistry; POGIL; Student centered; chemistry; assestment	Future researchers should examine the correlation between students' perception of learning and their actual performance on future exam questions, considering both quantitative performance data and qualitative feedback to gain a comprehensive understanding of this relationship

Based on Table 4 shows that several alternative research topics can be taken related to the issue of POGIL on organic chemistry learning. There are three options for researchers, namely (1) continuing each of the existing studies, (2) trying to combine two or more studies, and (3) opening a new research space based on existing research results. From the five articles, several new keywords can be combined into new topics in the future when implementing of POGIL teaching approach, including multimedia-based ICT-integrated learning on chemistry learning. Opening up new research that applies POGIL teaching in the fields of environmental chemistry, radiochemistry, analytical chemistry. Learning domains that can be researched in the future include retention, remediation of misconceptions, motivation, self-confidence, interest, communication skills, collaboration skills, creativity abilities, conceptual understanding, and remediating anxiety.

CONCLUSION

This bibliometric study explored research trends, keyword patterns, and future work of POGIL in organic chemistry learning. The analysis of publication trends indicates a steady increase in POGIL-related studies, especially since 2016, with the highest publication output in 2020. Most publications originate from the United States (US) and are concentrated in journals focused on chemistry education, such as *Chemistry Education*

Research and Practice and *Journal of Chemical Education*. Despite this growth, the application of POGIL in organic chemistry learning remains underrepresented compared to general chemistry, suggesting a research gap in this specific context. Through co-occurrence and cluster mapping, this study identified five major thematic clusters, with dominant focuses on cognitive and affective domains such as engagement, academic achievement, reasoning, teamwork, and self-efficacy. These keyword interconnections indicate a strong emphasis on active and student-centered learning, particularly for undergraduate students. However, important gaps persist, including limited attention to knowledge retention, remediation of misconceptions, anxiety management, and technology integration in POGIL-based organic chemistry learning. In response, future studies are encouraged to investigate these areas while leveraging digital learning tools such as PhET simulations, augmented reality, virtual reality, etc to enhance the effectiveness of POGIL. These insights provide a foundation for researchers and curriculum developers to expand the implementation of POGIL and optimize its impact on chemistry education.

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