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Trends in Research on Representation in Chemistry Learning: A Systematic Review

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Representation plays an important role in helping students understand chemistry learning. This is due to the many chemical concepts that require visualization. Representation is something that still needs to be studied. So this study aims to see the development of representation research in chemistry education. The articles used in this study are articles from 2018 to 2022. This Systematic Literature Review research used Publish or Perish software, then filtered and extracted data according to the criteria for the research objectives to create 30 relevant articles and combined using the Prisma Protocol. The results showed that research related to representation in chemistry learning is still frequently conducted in the last 5 years. This research often discusses related to cognitive ability, which is most associated with chemistry concepts and conceptual understanding. Students and teachers are commonly used samples in research. In addition, stated of matter is most widely used subject in chemistry research.

Keywords: chemistry education, chemistry representation, cognitive ability, conceptual understanding, systematic literature review

INTRODUCTION

Chemistry is one of the hardest subject because learning chemistry need a visualization to deliver chemistry phenomena. While studying chemistry, students face the complex task of having to understand the special of chemistry representations (Popova & Jones, 2021; Sim & Daniel, 2014). In addition, most students consider chemistry lessons to be a complicated science and are the least favorite because they involve concepts, symbols and abstract terms that must be memorized. (Sausan et al, 2021; Nidup et al, 2021). Learning phenomena of chemistry, students need multiple domains such as submicroscopic, macroscopic and symbolic (Herunata et al., 2023; Johnstone, 2010; Taber, 2013). While using representation can build on prior constructivist techniques but is framed in a novel way (Bruce et al., 2022) If students struggle with one of the three levels of representation (macroscopic, submicroscopic, or symbolic), or are unsure of which level to use, it could affect their ability to understand chemistry in the future (Herunata et al., 2023; Sim & Daniel, 2014).

Students need to be proficient in representational competence since it relates to chemical representations. The ability to reflectively use a variety of multiple external representations or visualizations, singly and together, to think about, and act on, the underlying physical entities and processes in a domain is known as representational competence (Patwardhan & Murthy, 2017). For specific domains of science, representational competence is ability to appropriately understand, create, and relate a set of disciplinary scientific representations of realworld phenomena to science concepts (Volkwyn et al., 2020).

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Representation Chemistry in complementary cognitive processes can promote chemical reasoning skills (Bruce et al., 2022), conceptual understanding (Herunata et al., 2023). Conceptual understanding and representation chemistry both contribute to one another. In other words, it is impossible to have strong representation chemistry while having no conceptual comprehension at all, and vice versa. In other words, mastery of the visualizations employed to describe and explain chemical concepts is attained simultaneously with that of the concepts themselves (Kozma & Russell, 2005). Previous Research using media in representing concepts like using ball-and-stick models for organic chemistry (Volkwyn et al., 2020) drawing (Chang, 2018) and, for the optimum development of this skill, the three levels of chemical representations can be incorporated into multimedia (Farida, 2009; Sausan et al, 2021). Learning using multimedia assistance can generate motivation and train multiple representations so that you can learn concepts more quickly, efficiently and more independently (Syahri et al, 2021).

Why is the study important because chemical representation is very closely related to students' understanding of concepts, if representations are not used then students' conceptual understanding will not develop. Moreover, representational competency on chemistry can improving student ability of chemistry concept and chemistry phenomena (Berg et al., 2019), examine of representative competency in chemistry subject (Chang, 2018), and development of student representative competency (Stull et al., 2012).

The literature review method is important for chemistry learning as it provides a systematic approach to gather and analyze relevant research findings (Murti & Hernani, 2023). It plays a crucial role in informing and improving chemistry education by providing evidence-based insights and recommendations for effective teaching and learning practices. By employing a systematic approach to gather and analyze these relevant research findings, the literature review allows for the identification of trends and patterns in representation studies within the context of chemistry education.

There is literature review about the relationship between the representational competence, conceptual understanding and chemical representation, however, there has been no literature review of studies about the development of representation in chemistry research for the last 5 years that teachers or instructors use to improve students' representation abilities in chemistry subject. The final result of this study is to answer the research question and provide direction for future studies about representation. Furthermore, this research question is 'how are the research trends on representations in chemistry learning?'

METHOD

This research design is qualitative with systematic literature review method to analyze research related to representation in chemistry, cognitive abilities and their samples are used in their represent in chemistry learning. Previous research states that the systematic literature review method is used to achieve the goal of studying and providing broad and in-depth insight (Savec & Mlinarec, 2021). It is important to discover as much prior research that has been done in the field being examined and that is most relevant to the research topic area as possible for a systematic literature review. As a result, systematic screening is required. In conducting a systematic literature review, this study followed the updated 2020 Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Page et al. 2021). Details of the process of the systematic literature review of this research can be shown in Figure 1.

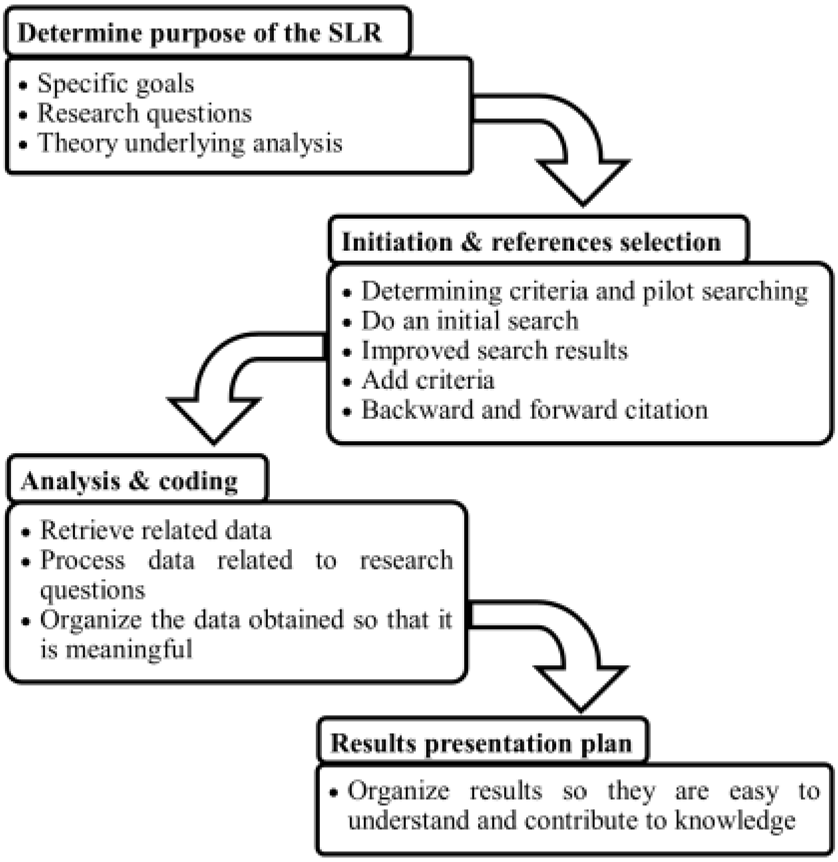

Figure 1. Systematic Literature Review Process

Search Strategy

In this Systematic literature review study, journal articles were screened using the PoP (Publish or Perish) software and data from Google Scholar. With the selection of the keywords Chemistry Education and Multiple Representation, filtered articles have a time period of 2018–2022.

Publication Selection & Data Extraction

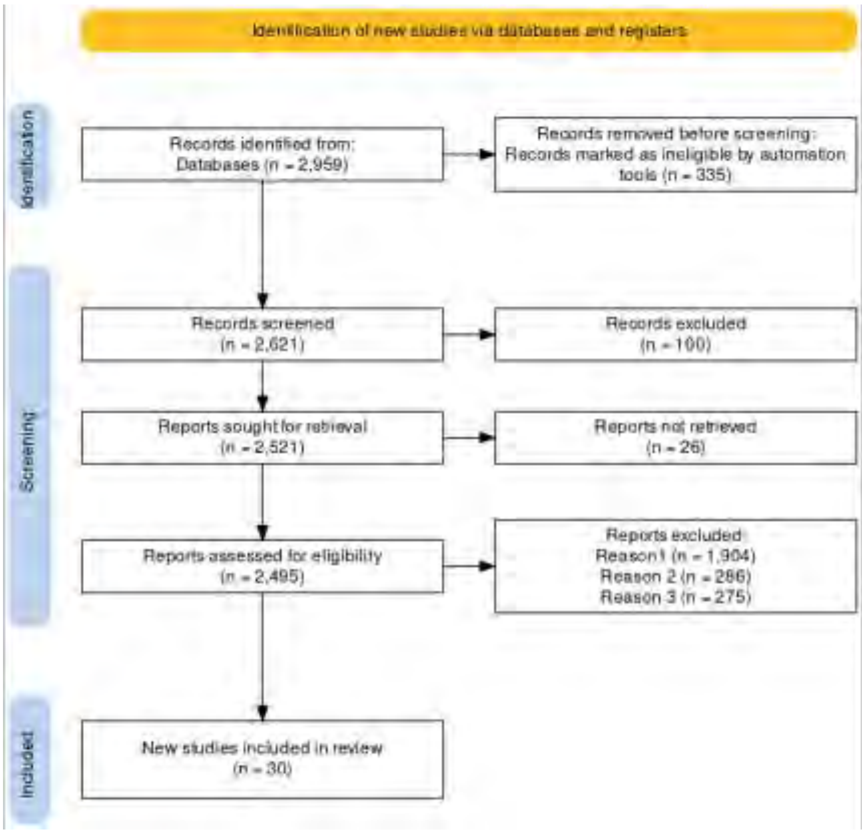

Figure 2
PRISMA Diagram

The process of selecting publications and extracting research data is explained in the form of a PRISMA 2020 Diagram (Page et al., 2021). Depend on Prisma Protocol in figure 2 showed the number of articles from Publish or Perish are 2959 articles. Screening was done during the identification phase by removing articles that had never been cited, resulting in a reduction of 335 articles. As many as 100 manuscripts that were not accepted by the journal were excluded from the screening process by using criteria that were especially taken for journal articles. The criteria for articles that use English language with complete data such as name of author, title, year, sources and publisher. The process of seeking out retrieval, resulting in the filtering of up to 26 items that published as book are filtered.

The first reason is to filter articles by stating the title contain chemistry when entering the examined for eligibility stage, reducing the number of articles significantly until 1904 articles are excluded. This was carried out because learning other than chemistry was discovered in the data base gathered by Publish or Perish. For the second reason, 286 articles also exclude because does not contain digital object identifier (doi) in their articles. Last reason is the title must contain representation.

Inclusion and Exclusion Criteria for Selection of Publication

For the study's inclusion of papers, we established clear criteria. Papers had to be published between January 2018 and December 2022 in international journals and international seminars to begin with. Second, the article had to be written in English, have undergone a review procedure, and be included in the Scopus and ERIC databases. Third, the Publish or Perish 7 application and the ERIC website were used to search Scopus-indexed papers. Fourth, the papers were only looked up using terms associated with the research theme. Fifth, the analysis did not include editorial articles, books, or book chapters.

The abstract of each publication was read when selecting publications according to the inclusion and exclusion criteria. Keywords in each publication were copied to be incorporated into Mendeley and VOSviewer for initial network mapping (Haddaway et al., 2022). In conclusion, only 30 articles that meet the criteria on inclusion

FINDINGS AND DISCUSSION

Article Characteristic

In this study, the results of screening are 30 articles with the topic representation in chemistry learning have been obtained. To determine the keywords that frequently appear in the research articles and their relationships with other terms, VoS viewer software was used to evaluate the research articles. The keyword mapping displayed in Figure 3 provides an overview of analysis performed using VoSviewer.

Figure 3 shows that the keywords "representation", “study”, “chemistry” and "student" are the most common in the articles obtained because they have a large circle, indicating that chemistry learning related to representation of student are frequently discussed in articles and have a relationship depicted by connected curved lines.

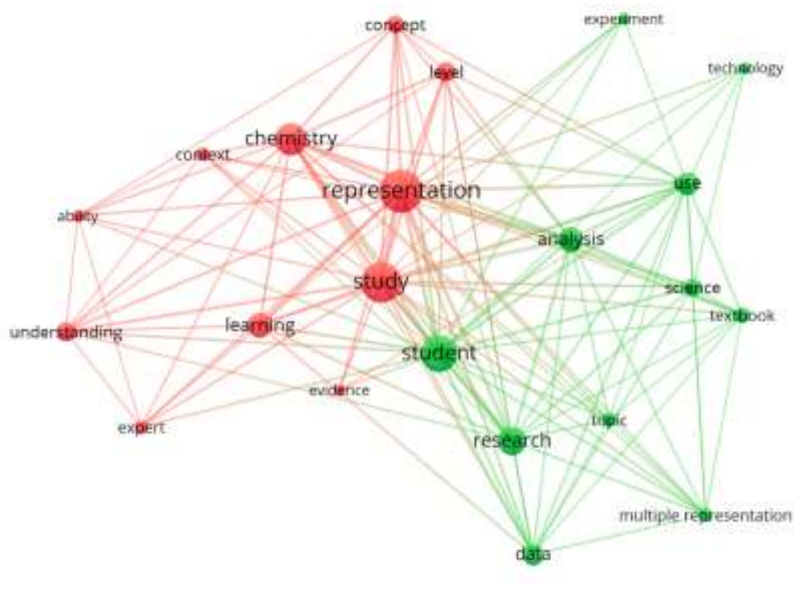

Figure 3
Article keyword mapping was obtained

The distribution of the research publications obtained each year can be seen in Figure 4 via the graph.

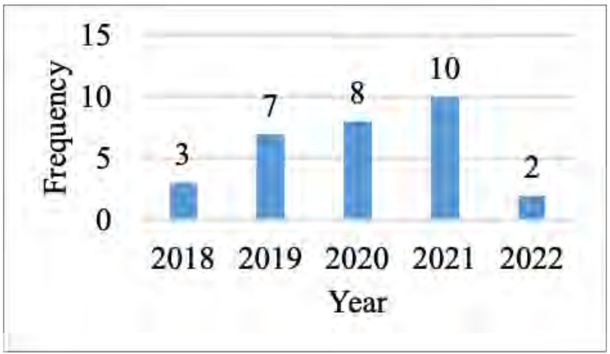

Figure 4
Distribution of article every year

Based on figure 4, the most of frequency publish article in 2021 and 2022 the article about chemistry and representation are significantly decrease. Because in these years, the Covid-19 pandemic turned everything into online learning and blended learning strategies used during the pandemic compared to previous years (Akhunzada, 2016). The bar chart in Figure 4 can be used to display the number of citations to the articles that were obtained.

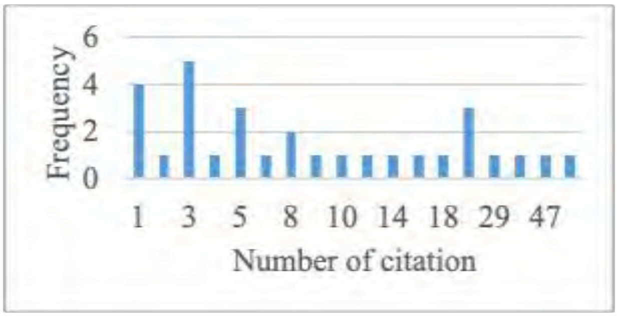

Figure 5
Number of article citations obtained

Citations are very useful for researcher to locate relevant information on a topic (Liang & Lee, 2023). According to Figure 5, the most cited article has 62 citations at a frequency of 1 article with title 'Learning material of chemistry in high school using multiple representations'. It is indicated that many researchers cite this article, and the trend about representation is still high. The distribution of journal publication sources gathered can be seen in the Figure 6.

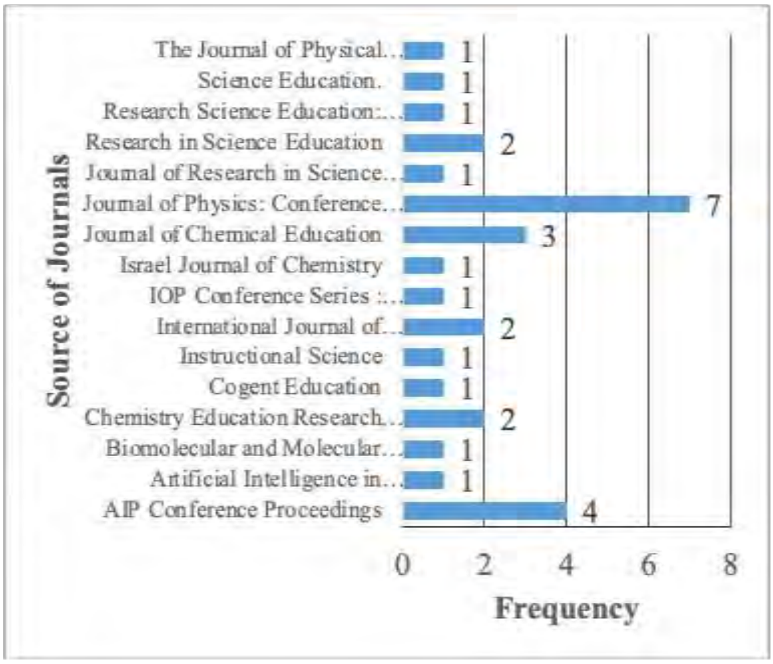

Figure 6
Distribution of sources article

Figure 6 displays the distribution of article sources acquired primarily from Journal of Physics: Conference Series sources, which included up to 7 articles. The plot in Figure 7 depicts the distribution of the obtained article publications.

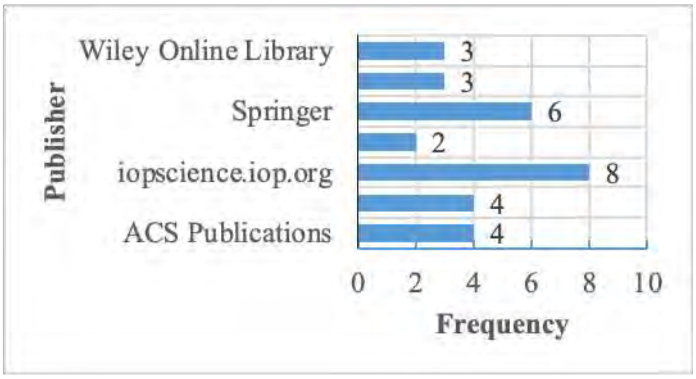

Figure 7
Number of article publisher

According to Figure 7, the most widely received distribution of article publishing was as much as 8 articles from iopscience.iop.org. As a result, it is possible to conclude that the characteristics of the articles retrieved through screening primarily included the keywords Chemistry Education and Multiple Representation, with the year distribution of the articles primarily in 2021. The maximum number of citations was 62, while the most articles with three citations were five. The majority of the journal sources for these papers came from the Journal of Physics: Conference Series, which has the most publications, particularly iopscience.iop.org.

Research designs related to representation in chemistry learning from 2018 to 2022 are divided into 4 codes shown in table 1. Representative research with various designs is mostly in qualitative and second is quantitative designs, this is because many studies want to see the effect of representation on chemistry learning or analyse factors that can develop students' representative abilities.

Table 1
Frequency of research design of articles

Design	Frequency
Qualitative	15
Quantitative	10
Mix Method	2
Research and Design	3
Total	30

Result of sample in Articles shown in table 2. It shows the variation of the samples studied. In contrast to the results of the literature review research on representational abilities, the research samples were more students and teachers (Santos & Arroio, 2016). This is because the trend of representative research in chemistry is still in great demand. There are still many things that can be developed considering the many things that can be influenced by the ability of representation and the benefits of its application in the classroom**.**

Table 2
Frequency of sample of articles

Sample	Frequency
Textbook	6
Students	9
University Students	6
Preservice Teacher	4
Teacher	5
NA	2
Total	32

The number of samples exceeds the number of articles because there are 2 articles which have 2 samples in their research. There are 2 journals that do not explain the research sample. Because first article is to representation prediction of molecular properties with software, and second article is about development of learning material based on representation.

The samples of articles also in many aspect with the most frequency is students, following with teachers. There are a lot of good reasons for implementing multiple representations in general for teaching, such as the ability to take advantage of the learners' particular characteristics and preferences (Dreher et al., 2016). However, the teacher's lack of understanding regarding chemical representations (Mindayula & Sutrisno, 2021). Teachers have applied levels of chemical representation in learning, but in terms of multiple representations, teachers still do not understand the term multiple representations and in practice teachers more often use macroscopic representations and symbolic, for submicroscopic representation teacher rarely use it.

Additionally, textbooks serve as the primary source of instruction for both teachers and students at the school (Nyachwaya & Gillaspie, 2016). Because the characteristics of chemical concepts necessitate external representation through various modes, such as descriptive representation (verbal, graphs, tables), experimental, mathematical, figurative, and visual representation, multiple representation is very important as a reference for developing teaching materials (Gilbert, 2013**).**

Table 3
Frequency of course in articles

Course	Frequency
General Chemistry	11
Organic Chemistry	3
Biochemistry	3
Inorganic Chemistry	4
Physical Chemistry	9
Total	30

Frequency of course codes are presented in Table 3. It shown all of aspect in chemistry were studied in research. The most frequency in course is general chemistry like in topic state of matter. This is because the state of matter material is the fundamental material in developing the properties of compounds found in nature, so before moving on to more complex material, the teacher wants to review the fundamental concepts in the state of matter material (Yaseen & Aubusson, 2020). In addition, the particulate nature of matter is also part of the state of matter and is related to particle models, symbolic representations, and macroscopic phenomena (Taskin & Bernholt, 2014).The codes for cognitive as variable in the articles are shown in table 4

Table 4
Frequency of cognitive of articles

Code	Frequency
Identifying Representational	4
Conceptual Understanding	6
Perception of Multiple Representational	1
Critical Thinking	3
Learning Achievement	2
Practice of Multiple Representation	4
Development of Multiple Representation	1
Chemistry Concept	7
Conceptual Change	1
Analyzing Representaion	2
Design Content Representation	1
Understanding Phenomena	1
Total	33

Many cognitive related about teaching use representation and this is due to many research on the ability of teachers or prospective teachers in using multiple representations and chemical representations in the classroom (Adadan, 2020; Wiyarsi et al., 2019; Yaman, 2020). The most researched cognitive level is about the chemistry concept, which is related to the representation of chemical which plays an important role in helping learners to understand chemical learning. (Lansangan et al., 2018). Understanding of chemistry depends on understanding of the invisible and untouchable, until chemical representation serves as a tool that can stone learners to understand models of representation of the sub-microscopic level of invisibility (Johnstone, 2000; Santos & Arroio, 2016).

Understanding chemical representations is a necessity to learn chemistry, but at the same time chemical representations are a major challenge for learners to understand chemical concepts (Taskin et al., 2015). Furthermore, research related to conceptual understanding is the second most researched. In research by Holme et al.,(2015) students who demonstrate conceptual understanding can transfer, deepen, predict, solve problems, and translate across scale and representation. That is why conceptual understanding is closely related to representation.

Ferreira and Lawrie (2019) stated that the most common representation used by teachers in the learning process is symbolic representation including symbol, formulas and chemistry equation. At the level of sub microscopic representation is very rarely used in learning, therefore, the student has difficulty in linking the degree of macroscope representation with the microscopical level (Gilbert, 2013). Comprehensive conceptual understanding is especially crucial for teacher candidates in their field of expertise, as they are going to be responsible to assist their future students in developing their conceptual understanding (Puk & Stibbards, 2011). Nevertheless, the teacher's involvement in learning is the most important factor in grasping the concept of chemistry (Mindayula & Sutrisno, 2021). Aside from using multimedia or methods to promote chemistry comprehension at all levels of representation, instructors are also critical for student understanding (Pavlin et al., 2019). This is supported by Sausan et al research which states that technology-based multimedia through podcasts and chemistry technoecopreneurship worksheets makes it easier for teachers to introduce chemical concepts and increase students' curiosity so that it has an impact on understanding concepts and scientific literacy (Sausan et al, 2021; Hidayah et al, 2021). Chemistry learning strategies and methods also need to be better developed to achieve conceptual understanding of chemistry, because traditional methods only teach problem solving but ignore conceptual understanding of representation (Salame & Casino, 2021). As a result, teachers must be familiar with numerous representations and be able to implement them into their classroom. For future studies will be relevant to the environment. Green chemistry is so closely linked to environment and sustainability (Sharma et al., 2013) that requires a representative skill that can describe the relationship of chemical reactions occurring in the atmosphere.

CONCLUSION

Based on the results of systematic literature review research related to research trends on representation in chemistry learning, it can be concluded (1) research related to representation in chemistry education is still popular in various types of research, but the type of research that is often carried out is qualitative research followed by quantitative research. (2) The research samples that are often used in representation research trends are students and teachers, although there are several studies using samples from students or pre-service teachers. (3) The chemistry learning material that is often discussed in representation research is general chemistry in material form. (4) Most of the research on representation in chemistry learning discusses the impact of cognitive abilities which include understanding concepts, identification of representations, critical thinking, analysis of representations, and multiple representations. (5) The use of technology-based multimedia and the choice of learning method strategies often appear in research trends in chemistry learning representations to overcome the problem of representational abilities in chemical concepts.

The implication for further research is that it is hoped that in the future the trend of representation research in chemistry learning can be developed more broadly and deeply in terms of year coverage or in terms of the types of representation discussed. This is because research trends are always ongoing, while the ability of representation in chemistry learning is something that needs to be considered by both teachers and researchers. Apart from that, in the future research on representation trends will not only focus on the characteristics of the articles being studied, but there needs to be an in-depth discussion regarding the content of the articles to review the influencing factors, obstacles that often arise and problem solutions offered in representation problems.

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