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Analysis of Research Trends on Chemistry: Diagnosis of Chemistry Misconceptions at The Senior High School Level

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Abstract

Misconceptions represent a fundamental challenge in chemistry learning at the senior high school level, as they are closely associated with students' failure to construct accurate conceptual understanding. This study aims to analyze research trends on chemistry misconceptions in Indonesia during the 2023–2025 period. The study employed a systematic literature review (SLR) method using a descriptive qualitative approach. Data were analyzed based on the frequency distribution of publications across 18 major chemistry topics. The results indicate a concentration of studies on specific topics, including atomic structure, redox reactions, thermochemistry, acid–base concepts, stoichiometry, and chemical equilibrium, all of which showed a significant increase in 2025. In contrast, topics such as the periodic table, hydrocarbons, colloids, and molecular polarity remain relatively underexplored. These findings suggest an imbalance in research focus that may impact the development of misconception-based instructional strategies. Furthermore, the study reveals that most existing research is still oriented toward identifying misconceptions, while intervention-based studies remain limited. Therefore, more comprehensive and balanced research is needed to support the improvement of chemistry education quality in Indonesia.

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Introduction

Chemistry education at the senior high school level plays a crucial role in developing students' scientific thinking skills, logical reasoning, and scientific literacy. Chemistry involves not only the study of facts, concepts, and scientific laws but also the explanation of various natural phenomena through interconnected macroscopic, submicroscopic, and symbolic representations. These characteristics render many chemistries concepts abstract, thereby demanding a high level of conceptual ability. When students fail to integrate these three representations, their conceptual understanding remains incomplete, potentially leading to misconceptions (Taber, 2019). Consequently, the success of chemistry instruction is measured not merely by students' ability to solve problems, but also by the accuracy of their conceptual understanding.

Misconceptions represent a major challenge in chemistry education, as students construct understandings that conflict with scientific concepts and tend to persist in these views despite receiving formal instruction. In contrast to errors caused by lack of knowledge, misconceptions are persistent because they have become integrated into the students' cognitive structures. This situation hinders the construction of new knowledge, rendering the learning process less meaningful. Research indicates that misconceptions are influenced by a variety of internal and external factors. Internal factors include prior knowledge, abstract thinking skills, and the ability to connect chemical representations, while external factors encompass instructional strategies, learning media, textbook quality, assessment instruments, and the teacher's ability to explain concepts (Pacaci et al., 2024). Furthermore, rote-learning-oriented instruction and inconsistent conceptual representations also contribute to the emergence of misconceptions.

Over the past decade, research on chemistry misconceptions has expanded rapidly. Various studies report that topics such as atomic structure and electron configuration, chemical bonding, redox reactions, stoichiometry, thermochemistry, chemical equilibrium, and acids and bases are the most frequent sources of misconceptions; this is due to their high level of abstraction and the simultaneous requirement for visualization skills, mathematical reasoning, and a mastery of chemical representations (Shiddiqi et al., 2024; Widarti et al., 2024). Conversely, topics such as the periodic table, hydrocarbons, compound polarity, buffer solutions, colloidal systems, salt hydrolysis, colligative properties, polymers, petroleum, and the chemistry of elements have received relatively little attention, even though these concepts also have the potential to give rise to misconceptions. This situation indicates that research on chemistry misconceptions remains concentrated on specific topics, highlighting the need for a more comprehensive mapping of research distribution based on the subject matter studied.

In tandem with advancements in educational technology, research on misconceptions has shifted focus beyond merely identifying conceptual errors to developing more effective remediation strategies. Various diagnostic instruments, such as two-tier, three-tier, and four-tier diagnostic tests are widely employed to identify misconceptions with greater accuracy. Meanwhile, the conceptual change approach is highly recommended, as it enables learners to reconstruct erroneous initial concepts through cognitive conflict, reflection, and the reinforcement of scientific concepts. This approach can be implemented through inquiry-based learning, virtual simulations, digital laboratories, or conceptual change texts—methods proven more effective than conventional instruction in enhancing students' conceptual understanding (Pacaci et al., 2024; Suparman et al., 2024). Recent research also indicates that integrating technology into chemistry instruction can enhance conceptual understanding while significantly reducing student misconceptions by presenting concept representations in a more interactive and contextual manner (Suyono et al., 2022). One emerging innovation involves the use of

digital chemistry laboratory applications, which facilitate more effective practical work and assist students in grasping abstract concepts. Research by Ramadhani et al. (2025) demonstrates that the use of chemistry laboratory applications provides a more interactive learning experience, thereby offering the potential to improve students' understanding of chemistry concepts.

In Indonesia, research on chemistry misconceptions has shown an upward trend alongside the implementation of the *"Kurikulum Merdeka",* whichh emphasizes the strengthening of competencies, critical thinking, problem-solving, and learning grounded in conceptual understanding (Ministry of Education, Culture, Research, and Technology [Kemendikbudristek] 2022). Nevertheless, the majority of studies remain focused on identifying misconceptions within specific subject areas or developing diagnostic instruments, while comprehensive analyses mapping publication trends, the distribution of research topics, and the overall research landscape remain relatively limited. Consequently, there is a lack of comprehensive information regarding the trajectory of chemistry misconception research in Indonesia and the specific topics that require further attention.

One approach suitable for mapping the evolution of a research field is the Systematic Literature Review (SLR). This method enables researchers to identify, evaluate, and synthesize scientific evidence in a systematic, transparent, and replicable manner, thereby providing insights into research trends, topic distribution, and existing research gaps. By synthesizing findings from various studies, an SLR can serve as a foundation for formulating future research agendas and offer recommendations for developing evidence-based learning innovations.

Given this context, this study employs a Systematic Literature Review (SLR) to analyze research trends on chemistry misconceptions at the high school level during the 2023–2025 period, identify the distribution of research topics related to these misconceptions, and examine existing research gaps and their implications for chemistry instruction. The findings are expected to provide a comprehensive overview of publication trends and research topic distribution, while identifying opportunities for further investigation. Furthermore, this study is expected to serve as a foundation for future research and support the development of more effective chemistry teaching innovations aimed at identifying, addressing, and minimizing student misconceptions.

Methods

This study employs the Systematic Literature Review (SLR) method to analyze research trends regarding chemistry misconceptions at the senior high school level in Indonesia during the 2023–2025 period. The SLR method was selected for its ability to identify, evaluate, and synthesize research findings in a systematic, transparent, and replicable manner, making it suitable for mapping the development of a research field (Snyder, 2019). Furthermore, this approach is widely used in educational research to identify research trends, research gaps, and directions for future study (Donthu et al., 2021). The research stages adhere to the Systematic Literature Review procedure comprising identification, screening, eligibility assessment, and article inclusion as recommended by the "*PRISM 2020*" guidelines (Page et al., 2021). The identification process involved searching for scholarly articles via the Google Scholar database using keywords such as "*miskonsepsi kimia", "chemistry misconception", "chemical misconceptions", "high school chemistry", and "conceptual understanding"*. The search was limited to articles published between 2023 and 2025.

Article selection was conducted based on established inclusion and exclusion criteria. Inclusion criteria included: (1) research articles addressing misconceptions in chemistry learning; (2) research conducted at the senior high school level or equivalent; (3) publication between 2023 and 2025; (4) availability as full-text articles; and (5) publication in scholarly journals. Conversely, articles that did

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not align with the research focus, such as conference proceedings or opinion pieces, or those lacking empirical data, were excluded from the analysis. The entire selection process was carried out systematically to ensure the inclusion of relevant, high-quality articles that met the study's objectives.

Articles meeting the criteria were subsequently processed using a data extraction form capturing information on the publication year, chemistry topic, research objectives, research methods, misconception identification instruments, and key findings. The articles were then classified according to high school chemistry topics based on the "*Kurikulum Merdeka*" learning outcomes, resulting in 18 main topics: atomic structure and electron configuration, redox reactions, thermochemistry, physical and chemical changes, chemical bonding, the mole concept, acids and bases, chemical equations, reaction rates, chemical equilibrium, stoichiometry, solutions and particle properties, ionic bonding, the periodic table, buffer solutions, compound polarity, hydrocarbons, and colloidal systems (Kemendikbudristek, 2022).

The data were analyzed using a quantitative descriptive approach and content analysis. Descriptive analysis was employed to calculate the frequency and percentage of articles for each topic and publication year, while content analysis was used to identify research trends and topics that remain under-researched. The analysis results are presented via tables, graphs, and descriptive narratives to provide an overview of topic distribution and trends in chemistry misconception research in Indonesia during the study period. To enhance the credibility of the findings, each stage of article selection and classification was conducted consistently based on established criteria and documented in accordance with PRISMA 2020 guidelines. This approach aims to produce a literature synthesis that is objective, transparent, and scientifically rigorous (Page et al., 2021; Snyder, 2019).

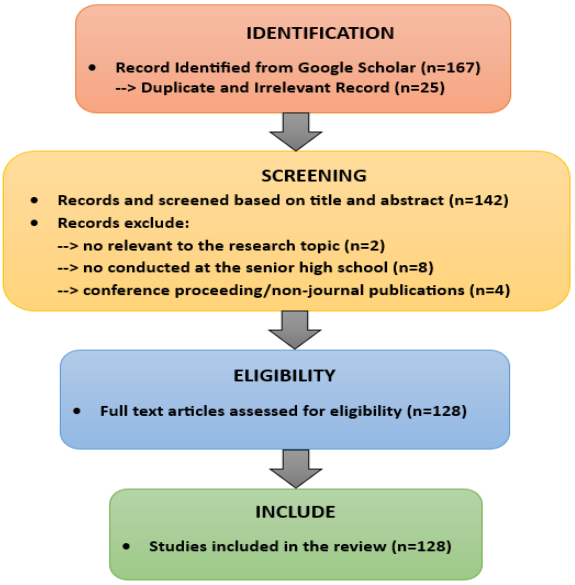


Figure 1. Article selection flowchart based on the PRISM 2020 guidelines

Results and Discussions

1. Trends in the Number of Articles on Misconceptions (2023–2025)

Based on the analysis of several articles published between 2023 and 2025 regarding misconceptions in chemistry, the following results were obtained:

Table 1. Number of Articles on Misconceptions (2023–2025)

Year	Quantity	Percentage
2023	50	39%
2024	18	14%
2025	60	47%

Based on the graph, it is evident that the number of journals discussing misconceptions in chemistry education varies from year to year. The highest number of articles appeared in 2025, accounting for 47% (60 articles). This was followed by 2023, with 50 articles (39%). The lowest number was recorded in 2024, with 18 articles (14%). The number of articles discussing misconceptions in high school chemistry is presented in the following diagram:

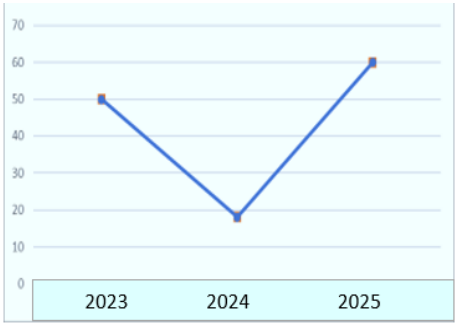


Figure 2. Number of journals on misconceptions in 2023–2025.

The figure 2 reveals that the number of journals addressing misconceptions in chemistry education varies from year to year. A drastic decline occurred in 2024, whereas 2025 saw a surge that surpassed the number of articles published in 2023. The drop in publications in 2024 can be understood as a transitional phase within the education and research systems. Literature indicates that fluctuations in scientific productivity are often linked to policy changes, adaptation to new curricula, and shifts in research priorities (Snyder, 2019; Donthu et al., 2021). The decline in publications in 2024 should not be interpreted as a waning interest among researchers in the study of chemistry misconceptions. Instead, this phenomenon is best understood as the result of a combination of factors, including the transition period for the implementation of the "*Kurikulum Merdeka*", a shift in educational research focus toward other strategic issues, the relatively long cycles associated with journal publication, and limitations on conducting field research. Furthermore, the number of articles identified in this study was influenced by the literature search strategy and selection criteria applied during the Systematic Literature Review process. Therefore, the fluctuation in publication numbers in 2024 requires careful interpretation and cannot serve as a sole indicator to conclude that research activity regarding chemistry misconceptions in Indonesia is declining.

2. Identifying Trends in Misconception Topics Over the Years

Based on the analysis of the articles, several topics prone to misconceptions were identified. These include a mix of recurring and new topics from year to year. The trends in misconception topics for the 2023–2025 period are as follows:

Table 2. Trends in Journal Topics Regarding High School Chemistry Misconceptions (2023–2025)

No.	Topic	Quantity		
		2023	2024	2025
1	Atomic structure and electron configuration	5	1	6
2	Redox Reactions	5	1	6
3	Thermochemistry	5	1	6
4	Physical and Chemical Changes	5	1	6
5	Chemical Bonding	-	1	-
6	Mole concept	-	1	-
7	Acid & Base	5	1	6
8	Chemical Reaction Equation	5	1	6
9	Reaction Rate	-	1	-
10	Chemical Equilibrium	5	2	6
11	Stoichiometry	5	1	6
12	Solutions and Particle Properties	5	1	6
13	Ionic Bond	5	1	6
14	Periodic Table of Elements	-	1	-
15	Buffer Solution	-	1	-
16	Polarity of Compounds	-	1	-
17	Hydrocarbons	-	1	-
18	Colloidal System	-	1	-

Analysis results indicate that research on chemistry misconceptions at the high school level during the 2023–2025 period remains concentrated on several key topics: atomic structure and electron configuration, redox reactions, thermochemistry, acids and bases, stoichiometry, chemical equilibrium, and chemical equations. The dominance of these topics suggests that researchers tend to prioritize material characterized by high levels of abstraction material consistently reported to pose significant conceptual difficulties for students. These findings align with the study by Shiddiqi et al. (2024), which notes that the majority of research on chemistry misconceptions focuses on fundamental concepts, as these serve as prerequisites for understanding advanced chemistry topics.

The nature of this material requires students to simultaneously connect various forms of chemical representation, ranging from directly observable phenomena to processes occurring at the particulate level and chemical symbolic notation. An inability to link these representations leads students to construct alternative concepts that differ from scientific ones, thereby giving rise to misconceptions (Taber, 2024). Widarti et al. (2024) reported that atomic structure and chemical bonding are the two topics most frequently associated with conceptual errors, as students struggle to grasp the relationships between atomic models, electron configuration, and the chemical properties of elements. These findings reinforce the results of the current study, confirming that atomic structure remains one of the most dominant research topics.

In addition to atomic structure, redox reactions, stoichiometry, thermochemistry, and chemical equilibrium are also primary research focuses because they demand simultaneous conceptual and quantitative reasoning skills. Regarding stoichiometry, for instance, students are required not only to understand the mole concept but also to relate quantitative connections between substances via chemical equations. Meanwhile, in the context of chemical equilibrium, students often mistakenly believe that the reaction ceases upon reaching an equilibrium state (Mayasari et al., 2023; Permatasi et

al., 2022; Amin et al., 2024), whereas, scientifically, the reaction continues to proceed dynamically. Various systematic studies indicate that misconceptions regarding these topics are consistently found across different countries, making them a primary focus of research in chemistry education (Suparman et al., 2024; Shiddiqi et al., 2024).

Regarding the topic of acids and bases, a common misconception is that pH measures only acidic solutions (Fitria et al., 2023), whereas it can actually measure acidic, basic, and neutral pH levels. One potential solution is the use of effective practical experiment applications (Ramadhani et al., 2025). Conversely, the results of this study indicate that certain topics associated with misconceptions, such as chemical bonding, the periodic table of elements, buffer solutions, compound polarity, hydrocarbons, colloidal systems, and reaction rates were investigated only once during the 2024 period and not in 2023 or 2025. In fact, based on the literature search, certain topics such as salt hydrolysis, the colligative properties of solutions, polymers, and others have not been identified as research foci in the articles that met this study's inclusion criteria. These findings indicate that the distribution of research on chemical misconceptions in Indonesia remains uneven.

3. Identifying Research Gaps

Based on the analysis of the selected articles, several research gaps were identified in studies on chemistry misconceptions at the senior high school level. First, many chemistry topics have not yet been adequately investigated in relation to student misconceptions. Second, although numerous studies on chemistry misconceptions were published in 2023 and 2025, the range of topics examined in these two years remained relatively similar. In contrast, studies published in 2024 covered a wider variety of chemistry topics. Furthermore, the distribution of research across grade levels was uneven, with most studies focusing on Grades 10 and 11, while research involving Grade 12 students remained limited. Geographical coverage was also concentrated in Java, with relatively few studies conducted in Eastern Indonesia. In addition, several chemistry topics commonly taught at the senior high school level were not represented in the reviewed articles, including the fundamental laws of chemistry, salt hydrolysis, solubility and solubility product, colligative properties, functional groups of carbon compounds, and macromolecules. These gaps highlight the need for more diverse and geographically inclusive research that covers underexplored chemistry topics and grade levels to provide a more comprehensive understanding of student misconceptions and inform the development of effective chemistry teaching strategies.

The scarcity of research regarding point 6 does not necessarily imply an absence of student misconceptions in that specific subject matter. Instead, this situation highlights an existing research gap. Shiddiqi et al. (2024) emphasize that research on chemistry misconceptions remains dominated by specific topics, while many other chemical concepts have yet to be explored in depth. Similarly, Suparman et al. (2024) conclude that research on chemistry misconceptions is still concentrated on identifying misconceptions within core topics, whereas studies on other subject matter, as well as the development of remediation strategies, remain relatively limited. This uneven distribution of topics also reflects a tendency among researchers to focus on material long known for its high level of difficulty, thereby limiting research opportunities regarding other topics. Yet, the implementation of the *Kurikulum Merdeka* underscores the importance of comprehensive conceptual understanding across all chemistry learning outcomes; consequently, any topic carries an equal risk of misconceptions arising if the learning process fails to connect concepts with students' learning experiences (Kemendikbudristek, 2022). Therefore, future research should be directed toward less

frequently studied topics to obtain a more comprehensive picture of student misconception profiles across the entire high school chemistry curriculum.

Overall, the findings indicate that research on chemical misconceptions in Indonesia remains dominated by abstract, fundamental topics, while other areas have not received adequate attention. This situation presents an opportunity for future researchers to broaden the scope of study, not only by identifying misconceptions in under-researched topics but also by developing instructional models, digital media, and diagnostic instruments capable of more effectively mitigating misconceptions. Consequently, future research in this field is expected to not only increase the volume of publications but also diversify the topics addressed and contribute more significantly to enhancing the quality of chemistry education in Indonesia.

Conclusion

Based on a systematic literature review of scholarly articles concerning chemical misconceptions at the high school level in Indonesia between 2023 and 2025, it can be concluded that research trends exhibit a dynamic yet uneven pattern. In terms of quantity, there is a significant fluctuation: a relatively high number of publications in 2023, a sharp decline in 2024, and a subsequent steep increase in 2025. This pattern suggests that the evolution of research in chemistry education is influenced by external factors, such as educational policies and curriculum adaptations. Regarding the distribution of topics, research on chemical misconceptions remains dominated by core, abstract, and complex subjects, such as atomic structure, redox reactions, thermochemistry, acids and bases, stoichiometry, and chemical equilibrium. This concentration indicates that researchers tend to focus on topics long identified as primary sources of misconceptions. Conversely, there is a clear imbalance, as other topics, such as the periodic table, hydrocarbons, colloidal systems, molecular polarity, and buffer solutions, remain relatively under-explored, despite their potential to foster significant misconceptions.

Methodologically, most studies remain focused on identifying and mapping misconceptions through descriptive approaches using diagnostic instruments. While such approaches are essential for establishing a foundational understanding, research directed toward the development and testing of instructional interventions remains limited. This suggests that research on chemical misconceptions in Indonesia is still in an exploratory phase and has yet to fully transition toward more applied and innovative directions. Overall, this research confirms that the study of chemical misconceptions in Indonesia has evolved and garnered increasing attention, particularly by 2025. However, future challenges include the need for a more balanced distribution of research focus across various topics, improvements in the quality and diversity of research methodologies, and the development of evidence-based instructional strategies capable of effectively addressing misconceptions. Consequently, more systematic and sustained efforts are required to steer research, moving beyond the mere identification of problems toward the development of innovative solutions that can enhance the quality of chemistry education at the high school level.

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