

The Influence of the Guided Inquiry Learning Model in Supporting Chemistry Learning: A Systematic Literature Review

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Abstract: This study systematically examines the implementation of guided inquiry-based learning in chemistry learning. The study covers guided inquiry implementation, applicable chemical materials, measured variables, research media, and gaps. The research was conducted through a systematic literature review by following the PRISMA framework based on identification, screening, feasibility, and inclusion to ensure rigorous and transparent article selection. The selected articles published between 2016 and 2025 were retrieved using the ScienceDirect, Scopus, ERIC, and Google Scholar databases, resulting in 24 articles. The articles were then analyzed using a thematic synthesis approach, following Braun & Clarke's steps, to answer the research questions. This review aims to provide teachers and researchers in chemistry education with information on the influence and application of the guided inquiry learning model. The review shows that the guided inquiry learning model has been integrated with various learning approaches and models, such as green chemistry, STEM, SETS, scientific, experimental, contextual, simulation, and other learning models. Chemical equilibrium is the most researched material, while reaction rate is still relatively understudied. The most commonly measured aspect was learning outcomes, followed by critical thinking, high-level thinking skills (HOTS), and science process skills. In terms of learning tools, students' worksheets (LKPD) are the most widely used because they can systematically facilitate guided inquiry. The analysis also shows that research is still dominated by a quantitative approach focused on learning outcomes. At the same time, research that measures cognitive and affective aspects, such as comprehension and self-efficacy, remains limited. The use of other media is still limited. Guided inquiry learning using electronic modules is a promising research opportunity because it can support all stages of inquiry in a structured way and integrate digital features that increase student engagement and help visualize abstract chemistry concepts.

Keywords: guided inquiry learning, chemistry, high school.

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■ INTRODUCTION

Education plays an important role in improving quality of life through high-quality human resources (Rahimi & Oh, 2024). 21st-century global development is marked by rapid advances in information technology across various fields, including education (Deepika, 2024; Kalyani, 2021). These technological developments have spurred the information era, making knowledge creation and access to information much easier (Saravanakumar et al., 2023; Surendran et al., 2024). In the 21st century,

education faces complex challenges from technological developments, globalization, and socio-cultural changes that demand transformation of the education system (Alimova & Raimova, 2025; Jafarov, 2024). This condition is in line with the rapid development of science and technology in the Industrial Revolution 4.0, which requires education to play an important role in equipping students with critical thinking skills (Moraes et al., 2023) and creative, collaborative, and communicative skills to face global competition (Thornhill-Miller et al., 2023).

Education must keep pace with these dynamics to remain relevant and avoid being left behind (Talvio et al., 2023).

In response to the need for national education transformation, the Indonesian government established an independent curriculum to be implemented in 2022-2023 to address 21st-century challenges (Muhammad & Wati, 2025) and emphasize student-centered learning (Bremner et al., 2022). This curriculum encourages the development of 4C competencies, including creativity, collaboration, communication, and critical thinking, in solving problems (Abdukamalovna & Bakhtiyar, 2026; Hanifa et al., 2024) and is flexible and balances cognitive, affective, and psychomotor aspects (Das, 2024). The learning outcomes of the independent curriculum in phase F for chemistry subjects include two main elements, namely understanding chemistry and process skills, as stated in BSKAP number 033/H/KR/2022 (Wulan & Yusemaita, 2023). This demand directly requires implementing an active learning model that trains students to construct knowledge independently, not just receive information from teachers (Darling-Hammond et al., 2024). This is reflected in PISA 2018 results, which placed Indonesia at 396, ranking 71 out of 79 countries; in PISA 2022, the science literacy score dropped again to 383. However, the ranking increased to 67 out of 81 countries. This shows that Indonesian students' science literacy is still far below the OECD average of 485 (OECD, 2023). This pattern reflects a learning gap: not all students can understand the subject matter well (Thoms et al., 2026), as shown by low learning and academic outcomes (Pane et al., 2025). Although the independent curriculum has simplified the material and provided learning flexibility, understanding is not evenly distributed across subjects; students still struggle with abstract and complex chemistry material (Kings, 2025).

In chemistry learning, students face interrelated concepts (Moju et al., 2025), such

as abstract concepts, mathematical skills, and experimentation, so they need to understand the relationships between concepts to master the material as a whole (Qian et al., 2023; Thoms et al., 2026). However, classroom implementation is not fully optimal because teachers often focus on delivering content without paying attention to students' understanding (Adu-Gyamfi & Asaki, 2023). Even in ideal learning approaches such as Student-Centered Learning, the teacher acts as a facilitator who helps students understand and apply chemistry concepts in real life through practicums, discussions, and projects (Dong, 2023; Leying et al., 2024; Salo et al., 2024). In Indonesia, where conventional methods such as lectures and memorization still dominate, this approach has proven ineffective at building meaningful conceptual understanding. Many complex, difficult-to-explain chemistry concepts leave students confused, passive, and discouraged (Rocha et al., 2026). This situation is worsened by obstacles to teachers' competence in designing learning, a lack of facilities and infrastructure, resistance to change, and limited implementation time (Boonmoh & Sanmuang, 2024; Rosero-Cardenas et al., 2024). Overall, these problems call for revitalizing chemistry learning by renewing creative, innovative, and technology-based strategies so students can develop their potential through practical learning activities (Iyamuremye et al., 2024; Kings, 2025).

As a solution, the guided inquiry learning model is a constructivist approach highly relevant to chemistry learning (Potier, 2023). Guided inquiry involves students discovering concepts through active exploration with teacher guidance (Orosz et al., 2023), aligning with the principles of student-centered learning in the independent curriculum. This model invites students to think critically, plan experiments, and draw conclusions based on their own findings in a scientific investigation (Orosz et al., 2023), so that it can meet the theoretical and practical aspects, with

the main advantages in the form of increasing active student involvement, scientific thinking, and science process skills (Antonio & Prudente, 2023). This aligns with Nababan & Dalimunthe (2025): the model involves students in an active learning process, giving them the freedom to explore and discover concepts independently in a learning discussion group while still being guided by the teacher. This is supported by the analysis results: Zhong et al. (2025) show that the group discussion method effectively increases student involvement in cognitive, affective, and psychomotor aspects (Alafnan, 2025). These findings are relevant and applicable to chemistry learning, especially at the high school level.

Researchers have developed variations of the guided inquiry model by integrating it into various approaches, models, media, and learning tools to optimize student learning outcomes in chemistry (Alberto et al., 2024; Antonio & Prudente, 2023; Zou et al., 2025). Research by Yanti & Suyanta (2025) shows that the guided inquiry model combined with STES (Science, Technology, Environment, and Society) effectively improves critical thinking skills and self-efficacy in buffer solution materials. Widyaningrum & Andromeda (2023) also reported that the guided inquiry learning model combined with the LSLC system (Lesson Study for Learning Community) in basic law material in chemistry significantly improved student learning outcomes. In addition, Novita (2024) shows that the e-students' worksheet (e-LKPD) is based on guided inquiry using Liveworksheet. The material on chemical equilibrium can improve students' science process skills. Thus, previous research consistently shows that guided inquiry can be integrated with various learning innovations that positively impact student learning outcomes (Nguyen et al., 2024).

Based on the description above, although various studies have shown the effectiveness of the guided inquiry model in high school chemistry learning, studies that comprehensively synthesize

and evaluate the overall empirical evidence remain limited, especially those that examine the variety of approaches and learning tools combined with the model. Therefore, this study aims to conduct a Systematic Literature Review of articles published from 2016 to 2025 regarding the influence of the guided inquiry learning model in chemistry learning. This review's findings are expected to make theoretical and practical contributions to educators, curriculum developers, and researchers committed to improving the quality of chemistry learning. This systematic review is guided by the following four main research questions:

RQ1: What are the implementation variations used in guided inquiry-based learning studies in chemistry learning?

RQ2: What are the most studied chemistry topics in the context of the application of the guided inquiry learning model?

RQ3: How is the guided inquiry learning model affecting student learning outcomes in chemistry subjects?

RQ4: How effective is the use of learning tools in guided inquiry learning?

RQ5: What are the research gaps, and in which direction is further research needed?

■ METHOD

Research Design

This research used a Systematic Literature Review (SLR) design, following the PRISMA 2020 guidelines developed by Page et al. (2021). The SLR approach was chosen because it synthesizes research findings systematically, transparently, and reproducibly for future research. The review process is carried out in stages, including formulating research questions, determining inclusion and exclusion criteria, systematically searching the literature, selecting studies based on the criteria, extracting data from selected articles, and analyzing and synthesizing findings to answer the questions.

Search Strategy

The literature search was conducted in four leading scientific databases: Scopus, ScienceDirect, ERIC, and Google Scholar. These four databases were selected because they cover a wide range of publications in science education and chemistry education. The literature search is limited to English and Indonesian articles published from 2016 to 2025 to ensure the relevance and novelty of the information obtained. The search strategy uses Boolean operators (AND, OR) to combine keywords from three main conceptual domains: learning models, chemistry learning, and school level. By using the Science Direct database on the Elsevier Science Direct platform for the strings “(“guided inquiry” OR “guided inquiry learning”) AND (“chemistry education” OR “chemistry learning” OR “chemistry teaching” OR chemistry)”; Scopus database on the Elsevier platform for the strings

“TITLE-ABS-KEY (“guided inquiry” OR “guided inquiry learning”) AND TITLE-ABS-KEY (“chemistry education” OR “chemistry learning” OR “chemistry teaching”)”; The ERIC database on the ProQuest ERIC platform for the strings “(“guided inquiry” OR “guided inquiry learning”) AND (“chemistry education” OR “chemistry learning” OR “chemistry teaching” OR chemistry)” and the Google Scholar database of the Google Scholar platform for the strings “guided inquiry” AND “chemistry” AND “high school”. The term “high school” is included in Google Scholar searches only because Google Scholar Indexes publications across various disciplines and educational levels. This additional keyword narrows the search results.

The article selection process followed the PRISMA 2020 flow, which includes four stages: identification, screening, eligibility, and inclusion.

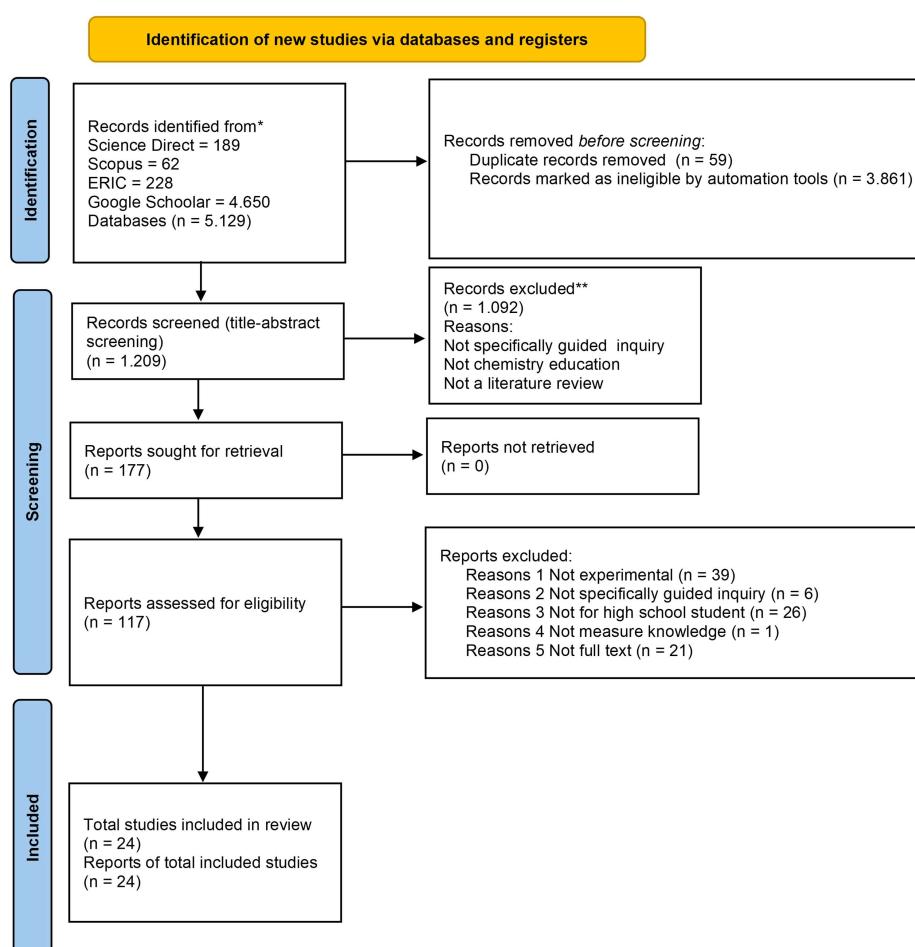


Figure 1. Data selection at PRISMA 2020

The article identification stage of all articles was obtained a total of 5.129 articles were obtained from the four databases. In the initial screening stage, we removed articles based on title, year, and duplicates, resulting in 1.209 articles from ScienceDirect, Scopus, ERIC, and Google Scholar. In the screening stage, we excluded 1,092 articles based on title and abstract because they were irrelevant or not specific to guided inquiry, chemistry learning, or empirical research (literature review, bibliometrics, and SLR). The eligibility stage involved full-text review of 117 articles, and 93 were excluded because they did not meet the inclusion criteria. Finally, 24 articles were included for final analysis. The PRISMA 2020 flowchart showing the number of articles at each selection stage is presented in the Results section.

Inclusion and Exclusion Criteria

The inclusion criteria in this study include: (a) the article is empirical research (not a review of literature, literature, bibliometrics, or other SLR); b) articles focus on the application of guided inquiry; c) articles contain the context of chemistry learning in high school; d) articles published in the period 2015-2025; and (e) the article is available in English or Indonesian. Meanwhile, the exclusion criteria include: (a) articles that are not specific to chemistry learning; b) the learning context used is not fully guided inquiry; c) studies that use research designs other than experimental or quasi-experimental designs; d) the research subject used is not a high school student.

These articles met the criteria for further analysis focusing on the guided inquiry learning model in supporting chemistry learning. Relevant data from each study were extracted. Each article includes details such as the title, author, year, research objectives, integration of the guided inquiry model with other learning strategies, chemistry materials, measured variables, learning

tools, and main findings. This data extraction was carried out by the first author. Every step was done to ensure data consistency and minimize the occurrence of bias. Article quality assessment used key criteria such as the relevance of titles and keywords, the suitability of the research focus, the suitability of the discipline, and full-text availability. In particular, 1,209 articles were excluded because they were not specifically related to guided inquiry learning, as the term inquiry in the literature has a very wide scope and does not always refer to the guided inquiry used in this study. Articles that do not explicitly address chemistry subjects, are too general, or fall outside the educational discipline, such as studies of pure chemistry or chemical engineering, are excluded because these researchers are specifically concerned with the pedagogical context of high school chemistry learning. Some articles were excluded because they were literature reviews, bibliometric studies, or SLRs, as this study synthesizes only findings from primary empirical research that can be verified directly.

A total of 117 additional articles were excluded because they lacked an empirical basis or reported on studies other than experimental and quasi-experimental studies. This was necessary to provide direct evidence of the guided inquiry model's effectiveness on student learning outcomes. Articles that do not specifically apply the guided inquiry model are excluded because they include various inquiries, each with different characteristics, procedures, and learning outcomes, so they cannot be generalized as a construct equivalent to guided inquiry. Articles not intended for high school students are excluded because cognitive development, material complexity, and curriculum demands at the high school level differ from other levels. The article does not directly measure aspects of student learning because it is not relevant to research questions that focus on the impact of guided inquiry on student learning outcomes. The article

is also not available in full text, which makes it impossible to extract accurate data, and is based only on a review of abstracts.

To ensure methodological accuracy and minimize bias, the 24 articles that met the eligibility criteria were manually assessed for quality. The assessment was conducted using five predefined criteria: (1) clarity of research objectives and research questions; (2) appropriateness of the study design relative to the study objectives; (3) accuracy of the selection and description of the study subjects; (4) validity and reliability of the instruments used; and (5) completeness of the

reporting of results. Each criterion was assigned a score of “met” (1) or “not met” (0), resulting in a maximum score of 5 per article. Articles with a score of ≥ 3 (60%) met the quality threshold and were retained in the final synthesis. This internal quality screening ensured that only credible, peer-reviewed studies aligned with the theme were included in the final analysis. Through this careful and transparent selection process, 24 empirical journal articles were identified as suitable for further analysis and data synthesis. The results of the quality assessment for all studies are presented in Table 1.

Table 1. Quality assessment results of 24 included articles

Article Code	Author (Year)	C1	C2	C3	C4	C5	Total Score	Status
A1	Nababan & Dalimunthe (2025)	1	1	1	0	1	4	Included
A2	Thayban et al. (2025)	1	1	1	0	1	4	Included
A3	Kurniawan et al. (2025)	1	1	1	1	1	5	Included
A4	Yanti & Suyanta (2025)	1	1	1	1	1	5	Included
A5	Andu et al. (2025)	1	1	0	1	1	4	Included
A6	Rosanna & Harahap (2025)	1	1	1	0	1	4	Included
A7	Drastisianti et al. (2024)	1	1	1	1	1	5	Included
A8	Harahap et al. (2024)	1	1	1	1	1	5	Included
A9	Paembonan & Ikhsan (2021)	1	1	1	1	1	5	Included
A10	Said et al. (2021)	1	1	1	1	1	5	Included
A11	Juniar et al. (2020)	1	1	1	1	1	5	Included
A12	Marwadi et al. (2020)	1	1	1	1	1	5	Included
A13	Tengker & Sulistyaningsih (2020)	1	1	1	1	1	5	Included
A14	Risna et al. (2020)	1	1	1	1	1	5	Included
A15	Dewi & Wardani (2020)	1	1	1	1	1	5	Included
A16	Yani et al. (2019)	1	1	1	1	1	5	Included
A17	Lungan & Laksono (2019)	1	1	0	0	1	3	Included
A18	Mahmud et al. (2019)	1	1	1	1	1	5	Included
A19	Stieff (2019)	1	1	0	1	1	4	Included
A20	Jainal et al. (2019)	1	1	1	1	1	5	Included
A21	Andromeda et al. (2019)	1	1	1	1	1	5	Included
A22	Rusiani et al. (2019)	1	1	1	1	1	5	Included
A23	Wardani & Anggraeni (2019)	1	1	1	0	1	4	Included
A24	Muna et al. (2016)	1	1	1	1	1	5	Included
Total		24	24	21	19	24	112	100%

Note: C1 = Clarity of research objectives and questions; C2 = Suitability of research design with study objectives; C3 = Accuracy of subject selection and description; C4 = Validity and reliability of instruments used; C5 = Completeness of reporting of results.

Data Analysis

Data analysis from 24 research articles was carried out using thematic synthesis to answer the four research questions (RQ1-RQ4). Data extraction was carried out systematically using a synthesis matrix that included the subject, year, research design, chemical material, device used, variables measured, and the main findings of each article. This approach follows a thematic analysis framework of six steps Braun & Clarke, (2006): (1) familiarization that involves reading articles repeatedly to understand the content; (2) perform initial coding to provide meaningful labels on key data; (3) search for themes for grouping related codes; (4) the review of the theme on the coherence and relevance of each theme; (5) the definition and naming of themes to clarify the scope and meaning of each theme; (6) coherent narrative synthesis in integrating findings to highlight research patterns and gaps.

RESULT AND DISCUSSION

This study addresses the problem formulation by reviewing several articles on the guided inquiry learning model in high school chemistry. To support data analysis and presentation, this study assigned codes A1 to A24 to the analyzed articles. A total of 24 articles that met the selection criteria were then analyzed in depth. For each article, we presented the discussion systematically by Research Question (RQ), accompanied by data visualizations to make patterns and findings easier to understand. Before answering each RQ, we first present an overview of publication characteristics, including publication trends and the distribution of authors' countries of origin, in Figure 2.

Based on the analysis of publication trends, the number of studies on the topics studied fluctuated between 2016 and 2025. The first peak occurred in 2016, with 1 article (100%) from

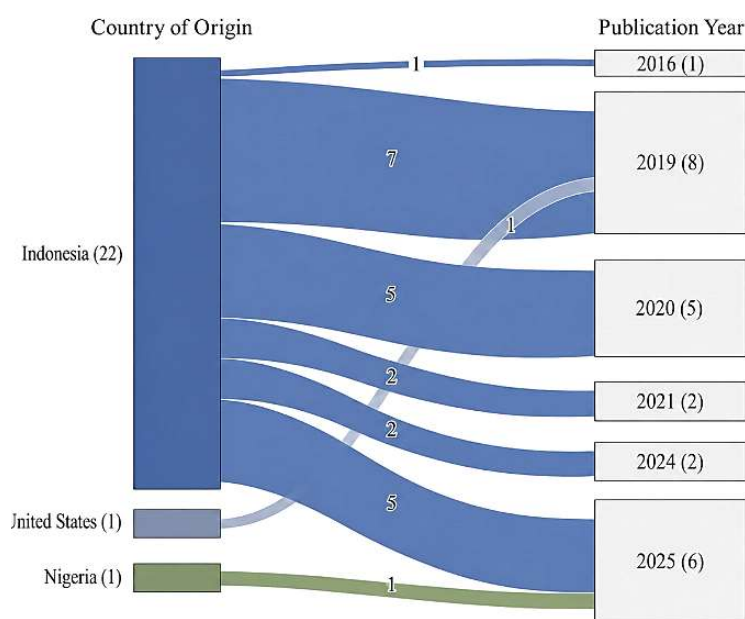


Figure 2. Distribution of articles by country of origin and publication year (2016-2025)

Indonesia, followed by a break in 2017 and 2018 with no publications. The second peak occurred in 2019 with 8 articles (87.5% Indonesia, 12.50% United States). This increase aligns with

growing global attention to inquiry-based learning in response to the demands of 21st-century skills. In the post-pandemic period, science education researchers began to emphasize the importance

of learning strategies, and many tested the effectiveness of guided inquiry by implementing a curriculum that demanded student-centered learning (Antonio & Prudente, 2023). After 2019, there was a gradual decline in 2020 (5 articles) and 2021 (2 articles), followed by a complete gap in 2022 and 2023 with no publications. This decline pattern is inseparable from the impact of the COVID-19 pandemic, which has affected the world since early 2020. The data show that 2020 (n=5 articles) and 2021 (n=2 articles) were followed by a total gap in publications. This decline reflects COVID-19 pressures that significantly hampered research and educational productivity in various countries, disrupted learning through exam cancellations, and created significant knowledge gaps among students. The revival in 2025 (n=6 articles) marks a renewed interest in guided inquiry. After the pandemic, attention has increased to evidence-based learning strategies that can adapt to 21st-century needs, especially in developing students' higher-order thinking skills (Morris, 2025). Overall, Indonesia has the most publications, with 22 articles (91.66%) of the 24 analyzed. Meanwhile, the United States and Nigeria each contributed 1 article (4.16%) published. These findings show that research on this topic is still dominated by authors from Indonesia, so the study remains largely national. However, contributions from the United States and Nigeria suggest that this research topic is beginning to attract international attention, although the number remains very limited.

For each research question, a synthesis matrix presents an overview of the characteristics of the included studies. The resulting themes were mapped into four main research questions and classified based on patterns that appeared consistently throughout the article. A synthesis matrix summarizes the characteristics of the selected studies included in this systematic literature review. The matrix contains key information from each article, including year of

publication, authors, study title, country, research design, educational level, integration of guided inquiry-based learning, learning media, chemistry topics, aspects measured, and main findings. Given the volume of information presented in the synthesis matrix, the complete matrix is provided in the [Supplementary File](#). The synthesis matrix provides an overview of the variations in the implementation of guided inquiry-based learning and the aspects measured in each study. These characteristics serve as the basis for further analysis in accordance with the formulated research questions (RQs). The following sections present a detailed discussion of implementation patterns, integration approaches, measured learning outcomes, and research gaps.

Implementation of Guided Inquiry in The Integration of Chemistry Learning (RQ1)

Based on the analysis of 24 scientific articles, the implementation of guided inquiry in chemistry learning can be grouped into 8 main themes. The analysis showed that most studies applied guided inquiry independently or integrated it with certain approaches, with the pure guided inquiry group dominating with 16 articles (66.67%). In this approach, chemistry learning is carried out purely using guided inquiry syntax without being integrated with other approaches or models, so that the focus is entirely on the process of guiding students to find concepts independently through the orientation stages, formulating problems, proposing hypotheses, collecting data, testing hypotheses, and drawing conclusions (Sanjaya, 2006).

The 16 studies examined diverse aspects, including learning outcomes, learning achievement, critical thinking skills (HOTS), learning activities, conceptual understanding, and communication skills. In practice, teachers act as facilitators who guide without giving direct answers, while students actively engage in scientific inquiry. Collaborative interaction among students is an

important part, as discussions and scientific findings encourage a deeper understanding of concepts (Kuhlthau et al., 2007). The teacher's role as a facilitator and students' collaborative interaction distinguish pure guided inquiry from conventional teacher-centered learning. In addition, the predominance of pure guided inquiry may be related to its structured, straightforward syntax, which can be implemented without cross-disciplinary preparation. In contrast, an integrated approach incorporates additional components

into the learning process. STEM studies integrate perspectives from science, technology, engineering, and mathematics into the study of reaction rates (Thayban et al., 2025), while SETS studies incorporate dimensions of science, the environment, technology, and society into the study of buffer solutions (Yanti & Suyanta, 2025). Similarly, two studies integrated guided inquiry learning with green chemistry principles in different chemistry learning contexts (Kurniawan et al., 2025; Risna et al., 2020).

Table 2. Grouping guided inquiry integrations

Implementation	Grade	Article Code	Frequency	Percentage %
STEM Integrated	XI	A2	1	4.17%
Integrated Green Chemistry	XI	A3, A14	2	8.33%
SETS Integrated	XI	A4	1	4.17%
Scientifically Integrated	X	A10	1	4.17%
Integrated Simulation	Unspecified	A19	1	4.17%
Integrated Experiments	XI	A21	1	4.17%
Contextual Integrated	X	A23	1	4.17%
Pure Guided Inquiry	X	A1, A5, A6, A7, A8, A9, A11, A12, A13, A15, A16, A17, A18, A20, A22, A24	16	66.67%
Total			24	100%

A total of 2 articles (8.33%) integrated guided inquiry with the green chemistry approach. Research by Kurniawan et al. (2025) and Risna et al. (2020) reports that students are guided not only to discover chemical concepts through the inquiry stage, but also to analyze and evaluate the environmental impact of the chemical processes they investigate. The investigation process uses safe, environmentally friendly materials so each stage of the inquiry introduces

students to the principles of green chemistry. Thus, this integration enriches guided inquiry by adding an environmental sustainability perspective to every concept-discovery process.

Furthermore, STEM integration amounted to 1 article (4.17%); research by Thayban et al. (2025) reports that guided inquiry is used as the main framework in the investigation process, while STEM provides context for cross-disciplinary problems. Students are guided

through the inquiry stage to investigate problems that involve not only science concepts but also require thinking from the perspectives of technology, engineering, and mathematics simultaneously. The learning process is designed so students can identify real problems, design data-based solutions, and draw conclusions by considering cross-disciplinary aspects. The integration of SETS (Science, Environment, Technology, and Society) amounted to 1 article (4.17%), and research conducted by Yanti & Suyanta (2025) reports the stages of guided inquiry enriched with the dimensions of SETS, where each investigation process is explicitly associated with the context of the environment, technology, and social life. Students are not only guided to discover chemical concepts through the inquiry process. They are also invited to reflect on the implications of the concepts for the environment and society. The learning process directs students to analyze relevant social and environmental issues through guided inquiry in a broader context than just in the laboratory. Integrating a scientific approach amounting to 1 article (4.17%), the research conducted by Said et al. (2021) shows that each implementation of the stages of guided inquiry is designed explicitly to contain structured scientific activities where students observe chemical phenomena, formulate questions, conduct LKPD-assisted experiments, analyze data, and communicate their findings.

In the integration of computer simulations amounting to 1 degree (4.17%) in the learning, students are guided to investigate chemical

phenomena that are difficult to observe directly, such as at the submicroscopic level where the interaction between particles such as atoms, molecules, ions, and forces between particles cannot be observed directly with the naked eye or microscope, so that the simulation in the Connected Chemistry Curriculum (CCC) allows students to visualize what regulates the behavior of particles individually. This integration of simulations allows guided inquiry to be applied to abstract chemistry concepts that cannot be presented in real life in the classroom (Stieff, 2019). Regarding the integration of experiments, 1 article (4.17%) places laboratory activities at the core of concept discovery. This hands-on laboratory experience deepens students' science process skills (Andromeda et al., 2019). In integrating guided inquiry with contextual learning, 1 article (4.17%) described how the orientation and problem-formulation process began with real phenomena close to students' experiences, making learning more meaningful and relevant. This context does not change the syntax of guided inquiry; rather, it enriches the starting and ending points of the inquiry process with reality (Wardani & Anggraeni, 2019).

Mapping of Emerging Chemical Materials (RQ2)

In addition to implementation, this study also analyzes the dominant dependent variables of students most studied in the application of guided inquiry across cognitive, affective, and psychomotor aspects.

Table 3. Mapping of chemical materials

Chemical materials	Article Code	Frequency	Percentage %
Electrolyte and Non-Electrolyte	A1, A8, A23,	3	12.5%
Reaction Rate	A2, A7	2	8.33%
Green Chemistry	A3,	1	4.17%
Buffer Solution	A4, A14, A16	3	12.5%
Organic Chemistry (Esterification)	A5	1	4.17%

Chemical Equilibrium	A6, A20,A21	3	12.5%
Acid-Base	A9, A12, A22,	3	12.5%
Basic Laws of Chemistry	A10	1	4.17%
Colligative Properties of Solutions	A11, A18	2	8.33%
Chemical Bonds	A13	1	4.17%
Redox	A15	1	4.17%
Particle Properties, Chemical Reactivity, and Chemical Equilibrium	A19	1	4.17%
Solubility and solubility product constant (Ksp)	A24	1	4.17%
Not Specific	A17	1	4.17%
Total		24	100%

Based on the analysis of the 24 reviewed articles, 24 chemistry topics were identified across 14 topic categories. Notably, article A19 (Stieff, 2019) covers three topics simultaneously: particle properties, chemical reactivity, and chemical equilibrium within a single integrated simulation-based study and is therefore presented as one entry in Table 3. Overall, 14 chemistry topics were investigated in the context of guided inquiry implementation. The distribution of these topics indicates that researchers tend to select particular chemistry topics as contexts for implementing guided inquiry in senior high school chemistry learning. The four most frequently studied materials in 3 articles (12.5%) are electrolytes and non-electrolytes, buffer solutions, acid-base solutions, and chemical equilibrium. These four materials are conceptually related to real phenomena in daily life, so they are relevant to study through guided inquiry. Reaction rate material, in particular, includes complex subtopics such as the definition of reaction rate, collision theory, factors that affect reaction rate, and activation energy, making it a rich topic for inquiry.

Article A19 categorizes three materials at once: reaction rate, atomic structure, and chemical equilibrium. This is because research by Stieff (2019) using a Connected Chemistry Curriculum (CCC) simulation, designed to

visualize chemical phenomena at the submicroscopic level, shows that chemical processes that cannot be directly observed can be presented as particle interactions. In the reaction rate material in phase F (class XI), the study focuses on several main sub-materials: the definition of reaction rate, collision theory, and factors that affect reaction rate. In the Connected Chemistry Curriculum (CCC) simulation, the chemical reactivity material focuses on collisions between particles with the right energy and orientation, presenting collision theory as the core of the reaction rate material. Meanwhile, the particle material is also related to the atomic structure material in phase E (class X), which includes the development of atomic models, atomic symbols, isotopes, isobars, and isotons, quantum numbers, electron configurations, and groups and periods. This linkage is based on the principle that the properties and behavior of matter are determined by the structure and behavior of particles at the microscopic level. Therefore, CCC simulations help visualize abstract concepts, making them easier for students to understand.

Furthermore, material on the colligative properties of solutions appeared in 2 articles (8.33%). This material involves quantitative calculations that are complex enough that guided

inquiry is relevant for helping students build knowledge gradually through investigation. Meanwhile, nine other materials each have only 1 article (4.17%), including green chemistry, organic chemistry, basic laws of chemistry, chemical bonds, redox, particle properties/chemical reactivity/chemical equilibrium (A19),

and solubility and solubility product constant (K_{sp}). The low frequency of research on these materials does not mean guided inquiry is less relevant. However, it may indicate that research still focuses on materials commonly taught through practicum activities in the laboratory as the main context for applying the guided inquiry model.

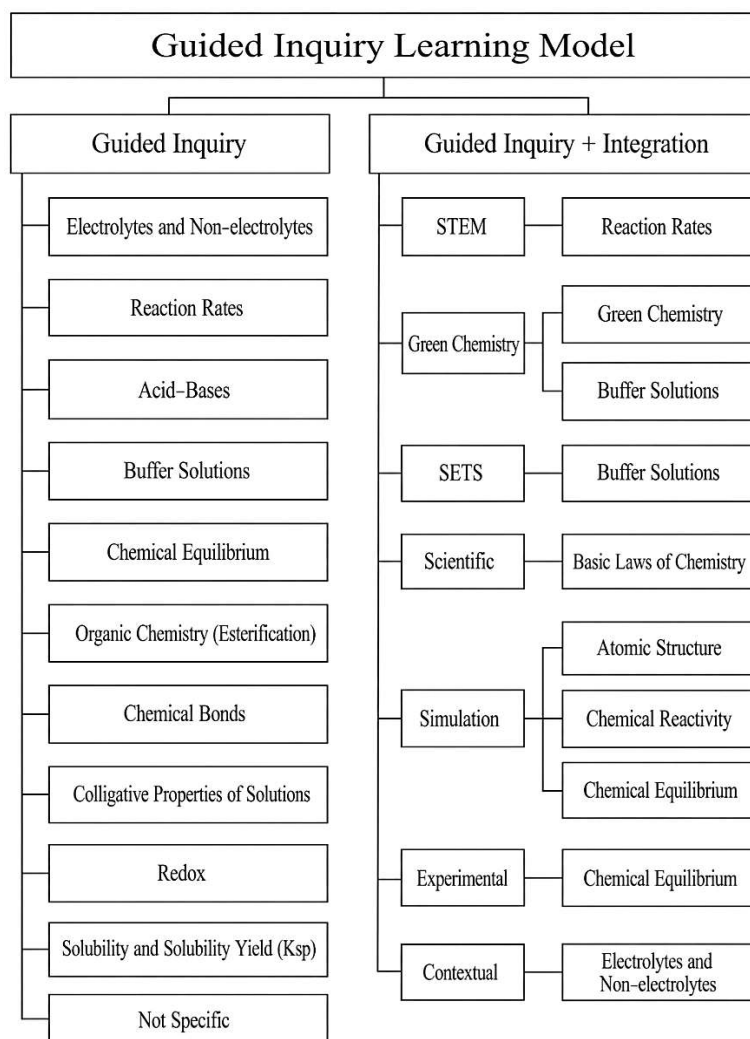


Figure 3. Thematic map research clusters of guided inquiry implementation types and chemistry topics in included studies

Figure 3 presents a thematic map illustrating the relationship between guided inquiry application types and the chemical topics studied in the field. The map shows that guided inquiry is mostly applied as a self-paced learning model on

a variety of chemical topics, including electrolyte and non-electrolyte solutions, reaction rate, acid-base, buffer solution, chemical equilibrium, organic chemistry (esterification), chemical bonds, solution colligative properties, redox, and

solubility and solubility product (K_{sp}). In contrast, research that integrates guided inquiry with other learning approaches is relatively limited and tends to focus on specific chemistry topics. For example, STEM integration is identified only in the rate of reaction because this topic involves concepts across science, technology, engineering, and mathematics simultaneously (Thayban et al., 2025). Green chemistry integration is applied to green chemical materials and buffer solutions relevant to environmental sustainability principles (Kurniawan et al., 2025; Risna et al., 2020). The integration of SETS is also applied to buffer solution materials as a contextual foundation because it can connect science, environment, technology, and society (Yanti & Suyanta, 2025). Applying scientific integration to the basic laws of chemistry is necessary for structured scientific activities such as observation, experimentation, and data analysis (Said et al., 2021). This simulation-based integration applies to atomic structure, chemical reactivity, and chemical equilibrium because these topics involve submicroscopic processes that students cannot directly observe in the classroom (Stieff, 2019). In addition, experimental integration was applied to chemical equilibrium by using laboratory activities as the core of conceptual discovery (Andromeda et al., 2019). Contextual integration, meanwhile, is applied to the topics of electrolytes and nonelectrolytes by incorporating real-life phenomena closely related to students' daily experiences, thereby providing a meaningful starting point for the inquiry process (Wardani & Anggraeni, 2019). These findings indicate that although guided inquiry has been applied to various chemistry topics, its integration with other learning approaches remains limited to only a few chemistry topics. This pattern suggests opportunities to expand the implementation of guided inquiry integrated with chemistry content in the future.

Guided Inquiry on Learning Outcomes Measured in Chemistry Learning (RQ3)

This study also examines the effectiveness of learning tools in supporting the implementation of guided inquiry. Based on the results of the analysis in Table 4, 14 dependent variables were measured in studies on the application of guided inquiry in chemistry learning. The high frequency of measuring learning outcomes in 9 articles (28.1%) shows that research still uses learning outcomes as the main benchmark of learning success, since learning outcomes are the easiest indicators to measure quantitatively through test instruments (Putra et al., 2024). In addition, the high frequency of critical thinking measurement in 5 articles (15.6%) shows that guided inquiry is seen as a suitable model for training students to think analytically and evaluatively in chemistry learning. Critical thinking includes the ability to identify problems, build arguments, draw conclusions, evaluate information, and set problem-solving strategies (Sharma et al., 2022).

Furthermore, 3 articles (9.37%) measured high-level thinking skills (HOTS) and science process skills. HOTS measurement in guided inquiry learning is particularly relevant because this model inherently requires students to analyze data, evaluate hypotheses, and independently infer findings involving analysis (C4), evaluation (C5), and creation (C6) based on the revised Bloom Taxonomy. Likewise, science process skills that involve students in chemical investigations include observing, classifying, measuring, predicting, interpreting data, and communicating observation results. In addition to the three aspects that are often measured, there are several variables that each measure only 1-2 articles, namely metacognitive (6.25%), learning achievement (6.25%), learning motivation, practicum activities, self-efficacy, concept understanding, learning activities, student activities, communication skills, and chemical literacy, which

each appeared at 3.12%. The range of dependent variables measured indicates that researchers are beginning to explore the impact of guided inquiry

more broadly, not only in cognitive achievement but also in affective and psychomotor dimensions.

Table 4. Aspect distribution of measured dependent variables

Dependent variable aspects	Article Code	Frequency	Percentage (%)	Direction of Effect	Evidence Summary
Metacognitive	A1, A24	2	6.25%	Positive	Guided inquiry-based learning significantly improves students' metacognitive skills, with a positive correlation to learning outcomes (A1). Collaborative interactions and teacher support facilitate this improvement (A24).
Learning Outcomes	A1,A3, A6, A10, A13, A18, A19, A21, A22	9	28.1%	Positive	The nine studies reported greater improvements than with conventional learning (A6); short- and long-term improvements with visualization (A19); and effectiveness with the integration of experiments (A21).
Critical thinking	A2, A4, A7, A15, A20,	5	15.6%	Positive	STEM integration enhances critical thinking skills (A2); PhET simulations significantly enhance critical thinking skills regarding reaction rates (A7); Edmodo support enhances critical thinking skills regarding redox reactions (A15).
Learning Motivation	A3	1	3.12%	Positive	Green chemistry-based guided inquiry lab sessions effectively enhance learning motivation (A3).
Practicum Activities	A3	1	3.12%	Positive	Green chemistry-based guided inquiry practicum effectively improved practicum activities (A3).
Self Efficacy	A4	1	3.12%	Positive	Guided inquiry-based learning integrated with SETS effectively enhanced self-efficacy in the topic of buffer solutions (A4).
Concept Understanding	A7	1	3.12%	Positive	Guided inquiry-based learning using PhET significantly improved conceptual understanding of reaction rates (A7).
Learning Achievement	A5, A8	2	6.25%	Positive	Guided inquiry is more effective than the lecture method in teaching organic chemistry (esterification) (A5); it significantly affects achievement in the topic of electrolytes (A8).
Science Process Skills	A9, A11, A21	3	9.37%	Positive	Augmented reality media is effective and has a significant impact (A9); students demonstrate excellent skills in using tools and collaborating in a group (A11); module-based guided inquiry is effectively used in learning (A21).
Learning Activities	A11	1	3.12%	Positive	Students are highly proficient in using tools, actively express their opinions, and draw conclusions (A11).
Higher Level Thinking (HOTS)	A12, A14, A16	3	9.37%	Positive	Student worksheets are useful for enhancing higher-order thinking skills (HOTS) as a 21st-century outcome (A12); enhancing HOTS with a focus on green chemistry (A14); and improving higher-order thinking skills (A16).
Student Activities	A17	1	3.12%	Positive	Guided inquiry learning positively impacts students' learning activities (A17).
Communication Skills	A17	1	3.12%	Positive	Guided inquiry-based learning positively impacts students' communication skills (A17).
Chemical Literacy	A23	1	3.12%	Positive	Contextual guided inquiry learning significantly improves chemistry literacy (A23).
Total		32	100%	Positive	All 24 of these studies consistently reported positive effects of guided inquiry learning on the measured dependent variables.

Effectiveness of Tools Used in Guided Inquiry Learning (RQ4)

This study also examines the effectiveness of learning tools in supporting the implementation of guided inquiry. Based on the analysis in Figure 4, 20 articles explicitly use specific learning tools or media, while the other 4 apply guided inquiry without mentioning any specific tools. The most dominant learning tool is LKPD, with 10 articles covering buffer solution material, basic laws of chemistry, colligative properties of solutions, acids and bases, chemical bonds, and solubility and solubility products (K_{sp}). The frequent use of LKPD shows that this device is widely chosen because it aligns with the characteristics of guided inquiry learning. In practice, guided inquiry

requires systematic learning stages, from problem identification and hypothesis formulation to data collection and conclusion drawing. These materials generally require students to analyze concepts and solve problems; this LKPD serves as a guide that helps students carry out the investigation process in a directed manner. These findings indicate that LKPDs are often chosen because their format is aligned with the procedural characteristics of guided inquiry and can be tailored to a wide range of chemistry topics that require structured investigation and concept construction.

In addition, experimental materials such as green chemistry and esterification that use practicum guides show that guided inquiry is well

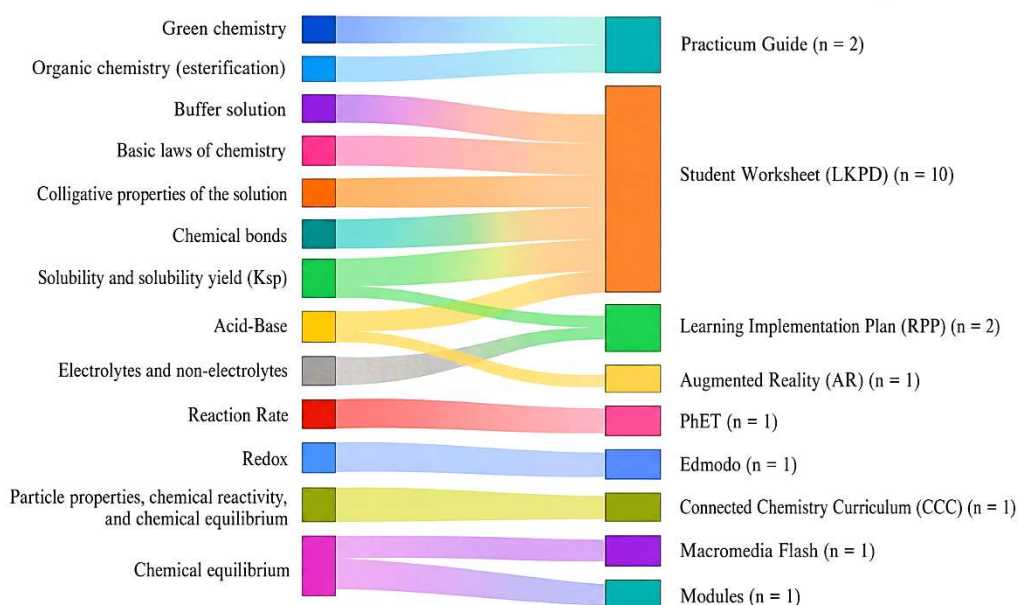


Figure 4. Distribution of learning media by chemistry topic in guided inquiry studies

suited to materials that allow students to conduct direct investigations through laboratory activities. Through practicum guides, students can design observations, collect data, and draw conclusions from experimental results, so the knowledge-construction process can be carried out through real experience. In addition to research activity-based devices, several studies use visual media

and simulations to help students understand abstract concepts, such as reaction rate material using PhET simulations, particle properties material, chemical reactivity, and chemical equilibrium using the Connected Chemistry Curriculum (CCC). Using simulations in these media allows students to visualize particle-level processes that cannot be directly observed. Acid-

base materials use Augmented Reality (AR) to present three-dimensional visualizations that help students understand the properties and behavior of ions in solutions that cannot be seen with the naked eye, and chemical equilibrium materials use Macromedia Flash to visualize dynamic equilibrium processes that take place at the molecular level. This visual media shows that guided inquiry is more effective when supported by technology that bridges the levels of representation: macroscopic, microscopic, and symbolic. In addition to learning media such as simulations to deliver abstract material, other tools, such as lesson plans, help teachers design learning stages according to the guided inquiry syntax. Edmodo media supports interaction and digital-based learning on redox materials, and modules provide more independent learning guides on balance materials.

What are The Research Gaps For Further Research (RQ5)

To map research gaps comprehensively, the synthesis results of 24 articles are mapped into a concept map that connects four main aspects with identified research gaps, as shown in Figure 5. Based on the analysis of the 24 research articles mapped in Figure 5, several chemistry topics remain underrepresented in studies implementing the guided inquiry learning model. These include green chemistry, organic chemistry (esterification), fundamental principles of chemistry, chemical bonding, redox reactions, properties of particles, chemical reactivity and chemical equilibrium, solubility and solubility product (K_{sp}), and non-specific chemistry topics, each represented by only one article (4.17%). In addition, reaction rates and colligative properties of solutions were each studied in only two articles (8.33%), indicating that these topics received relatively limited attention compared to electrolyte and non-electrolyte solutions, buffer solutions, chemical equilibrium, and acid-base chemistry, each of

which was represented by three articles (12.50%). As a result, studies that examine reaction rates in depth are far less common than those numbers suggest. In fact, reaction rate is an important chemistry concept that is often difficult for students to understand because it is abstract and complex, and it can lead to misconceptions that negatively impact learning outcomes (Afriyuni et al., 2025). This complexity makes reaction rates challenging yet rich material to study through guided inquiry, as it requires observation, investigation, data collection, and drawing conclusions based on observed phenomena. In addition, concepts learned in reaction rates such as impact theory, reaction rate factors (surface area, temperature, concentration, and catalysts), and activation energy require analytical thinking and problem-solving processes that are in line with the syntax of guided inquiry, because, in its implementation, guided inquiry provides a space for students to be actively involved through discussion and investigation activities (Wafiroh & Budijastuti, 2020), who are guided by teachers in finding information, analyzing data, and integrating their knowledge (Widiya & Radia, 2023).

In line with the limitations of the study on reaction rate material, it shows that there are eight dependent variables, each of which is only measured in 1 article (3.13%), including learning motivation, practicum activities, self-efficacy, concept understanding, teaching activities, student activities, communication skills, and chemical literacy. Among these variables, concept understanding and self-efficacy most clearly represent research gaps that need to be addressed immediately. Concept understanding is crucial because it is the foundation on which students build chemical knowledge meaningfully. Without a strong conceptual understanding, students may memorize procedures without grasping the cause-and-effect relationships between variables in reaction rates, making them prone to

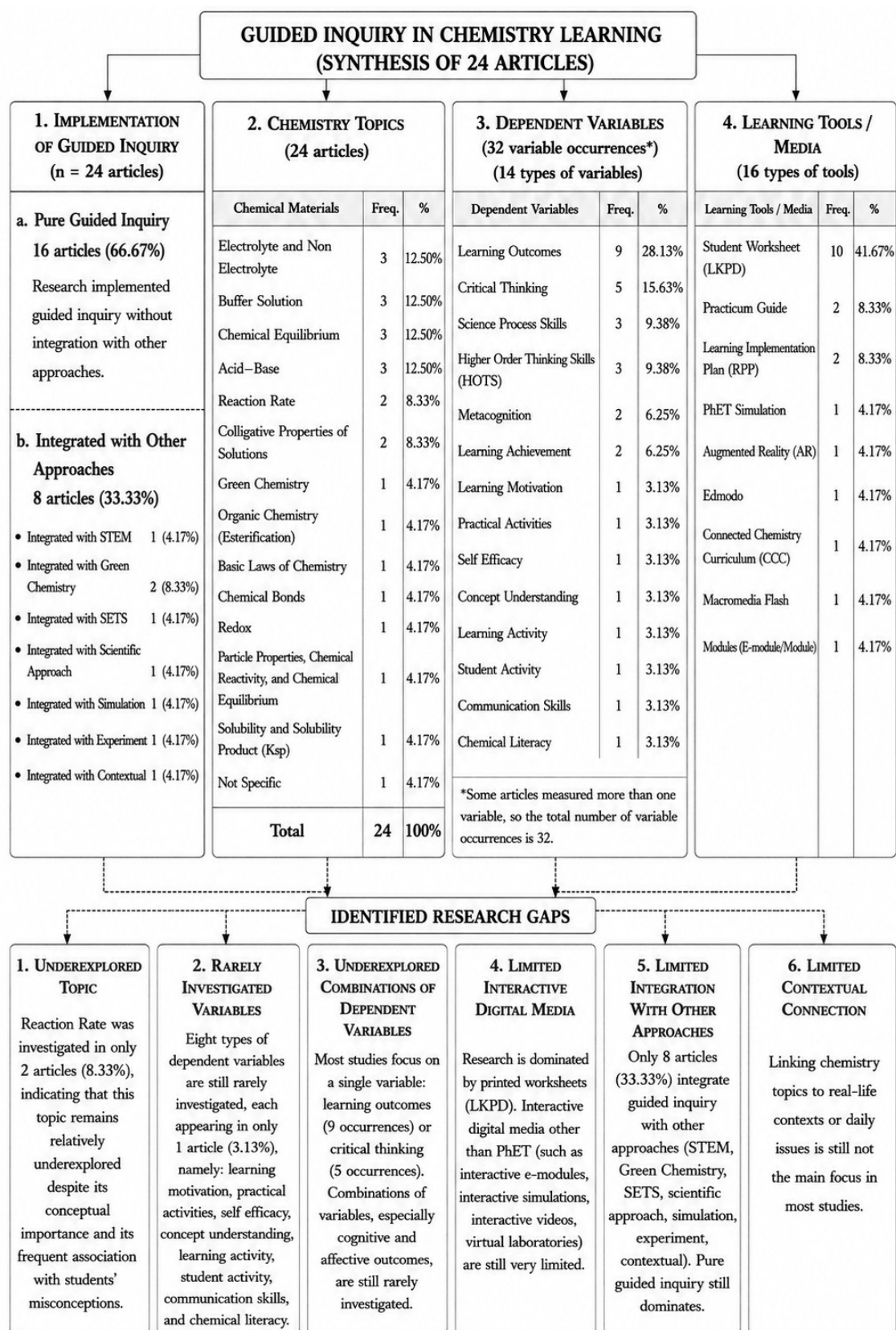


Figure 5. Concept map of synthesis of guided inquiry research in chemistry learning and identified research gaps

misconceptions that hinder mastery of more complex chemical material. On the other hand, chemistry learning cannot focus only on the cognitive aspect; it must also address students' psychological dimension, including self-efficacy. Self-efficacy plays an important role because it determines how confident students feel in their ability to complete analytical tasks that require diligence. On the other hand, low self-efficacy can cause students to give up easily when faced with difficult material, even if their cognitive abilities are adequate. Thus, studying concept understanding and self-efficacy together is important because both affect each other. Strong conceptual understanding can foster students' self-confidence, while strong self-confidence also encourages students to be more persistent in building their conceptual understanding. Unfortunately, no study has measured both simultaneously, especially in reaction rate material. Therefore, the next research is expected to examine the application of guided inquiry specifically to reaction rate material by measuring the combination of self-efficacy and in-depth conceptual understanding, to obtain a more comprehensive picture of the impact of learning models on students' cognitive and affective performance.

Based on the analysis of learning devices, previous research used PhET simulations as one digital medium for reaction rate. In contrast, the use of other, more interactive digital devices remains very limited. Limitations in presenting interactive media often make reaction-rate material feel less relevant, so students do not see its connection to real life. In fact, reaction rates involve macroscopic, microscopic, and submicroscopic processes, as well as particle-collision dynamics, that require visualization so students can understand the relationship between observed phenomena and the processes that occur. Reaction rate simulations are also widely encountered in real life, such as using floor

cleaners, fermenting bread, and using ice cubes, so students are more interested and enthusiastic about learning (Minarni et al., 2025; Yaayin et al., 2024). However, the approach taken has not integrated learning with daily life. In addition, the characteristics of guided inquiry that require students to follow the stages of systematic inquiry require learning tools that can integrate each learning syntax in one unit, which is a need that has not been fully met by the printed LKPD, which dominates the use of learning tools but is static. The module device has been used in previous research, but it remains in print form without interactive digital features. Therefore, guided inquiry-based e-modules are a promising research opportunity because they can facilitate all stages of inquiry in a structured manner and integrate various digital features to increase student engagement and help visualize abstract chemistry concepts.

Thus, further research is suggested to apply guided inquiry learning to reaction rate materials that can be associated with students' lives, supported by interactive digital devices, and measure aspects of understanding and self-efficacy at the same time, so that this approach is expected to make a new contribution in developing chemistry learning that is more meaningful, interactive, and in accordance with the demands of the 21st century.

■ CONCLUSION

This study shows that guided inquiry has been widely applied in various chemical learning contexts, mostly characterized by a quantitative approach, especially in quasi-experimental designs. The variable that is often measured is learning outcomes, while the combined measurement of cognitive and affective aspects is still limited. Guided inquiry has also been shown to improve understanding and self-efficacy separately. However, studies have examined the two in different articles, and no empirical evidence

shows its impact on both aspects simultaneously. These findings contribute to chemistry education by identifying research gaps that need immediate investigation, especially regarding the integration of cognitive and affective dimensions in learning abstract chemistry material. In addition, effective strategies include interactive digital media such as simulations, but their use remains limited to certain abstract materials. In addition, guided inquiry requires students to follow the stages of investigation systematically, so learning tools must integrate each learning syntax into a single unit. Therefore, guided inquiry-based e-modules are a promising research opportunity because they can not only support all stages of inquiry in a structured manner, but also integrate various digital features that increase student engagement and help visualize abstract chemistry concepts.

The implications of this research for the learning process, especially for developing future chemistry learning strategies, include encouraging the use of interactive digital learning tools such as guided inquiry-based e-modules that integrate all stages of inquiry in a structured manner while visualizing abstract chemistry concepts through simulations or other digital media. Although this review has limitations, namely the geographical concentration of the study, which is dominated by articles from Indonesia, and the quality assessment process that is carried out manually without standard instruments such as MMAT, this review opens up a meaningful direction for future research, especially in exploring how interventions that integrate cognitive and affective dimensions can shape students' understanding and self-efficacy of chemistry sustainably. Ultimately, strengthening guided inquiry in abstract chemistry materials is not only about improving academic achievement, but also about forming a generation of students who view chemistry as a discipline that can be understood, interpreted, and connected to their real lives.

■ CONCLUSION

While writing this manuscript, the authors used Grammarly to refine the language and check spelling. The authors have reviewed the entire manuscript and take full responsibility for the final content of the published article.

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