26 (3), 2025, 1428-1444

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

https://jpmipa.fkip.unila.ac.id/index.php/jpmipa

The Effectiveness of Probing Prompting Models for Critical Thinking Development in Indonesian Science Education: A Systematic Literature Review

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Abstract: This study aims to systematically examine the trends, focus areas, and effectiveness of the Probing Prompting learning model in improving students' critical thinking skills within Indonesian science education. Using the Systematic Literature Review (SLR) method based on the PRISMA protocol, 20 peer-reviewed articles published between 2020 and 2024 were selected from Scopus, SINTA, and Google Scholar databases. The inclusion criteria focused on empirical studies applying the Probing Prompting model in science learning contexts with clear outcomes related to critical thinking skills development. To enhance the analytical depth, bibliometric mapping was conducted using VOSviewer to visualize keyword patterns, thematic clusters, and the centrality of research topics in the field. The results show that the Probing Prompting model is most effectively implemented at the junior high school level, aligning with students' cognitive development at the formal operational stage. Key strategies include structured sequential questioning and the use of students' worksheets that guide students through reasoning and reflection. Dominant indicators of critical thinking skills developed through this model are analysis, evaluation, and inference. Visualizations reveal that "critical thinking" and "probing prompting" are among the most frequently occurring and central keywords, emphasizing their strong association in recent literature. This review also identifies emerging clusters related to digital integration, local wisdom, and artificial intelligence, suggesting future directions for contextualized and technology-supported applications of the model. It concludes that the Probing Prompting model has strong potential to be further developed as a critical thinking skills-oriented strategy, particularly in science education. The study recommends future research to conduct quantitative meta-analyses, explore long-term impacts through longitudinal studies, and integrate the model with project-based and digital learning frameworks to enhance effectiveness and sustainability.

Keywords: probing prompting, critical thinking skills, science learning, SLR, VOSviewer.

▪ INTRODUCTION

In facing the challenges of the 21st century, education today is directing its efforts toward achieving competence (Rahmawati et al., 2021). Critical thinking skills are one of the key competencies that students must possess (Hidayati & Julianto, 2025). These skills enable students to not only receive information but also to analyze, evaluate, and integrate information logically in decision-making (Muhtarom et al., 2024). In the context of science education, critical thinking is an important foundation in the scientific process, hypothesis testing, and problem solving (Parisu et al., 2025). However, various studies show that Indonesian students' critical thinking skills are still at an alarming level (Rizqa et al., 2025; Maulina et al., 2024), so that innovative learning approaches are needed to overcome this problem (Syaiful, 2024).

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DOI: http://dx.doi.org/10.23960/jpmipa.v26i3.pp1428-1444
Received: 13 June 2025
Accepted: 30 July 2025
Published: 11 August 2025

However, the critical thinking skills of Indonesian students, especially at the elementary and junior high school levels, are still relatively low. This low level of critical thinking skills is caused by various factors, including the dominance of lecture methods with minimal interaction, a lack of active student involvement in the learning process, and limited strategies used by teachers in designing activities that stimulate higher-level thinking (Hulu et al., 2024). In addition, assessments that still focus on memorization and final results prevent students from becoming accustomed to analytical and reflective thinking challenges (Sari & Kurniawati, 2024; Jariatin et al., 2024).

One of the learning models that is relevant to the development of critical thinking skills is the Probing Prompting model (Sitepu et al., 2024). This model is a learning approach that emphasizes gradual and targeted questioning techniques, starting with simple questions and moving on to more complex ones. The aim is to explore students' understanding in depth, encourage them to think logically, and connect the concepts they have learned reflectively (Rusnawati, 2023; Akmal et al., 2025). Through this process, students are required not only to answer questions but also to explain their reasoning, develop arguments, and critically evaluate ideas. Probing Prompting also positions teachers as active facilitators who provide scaffolding through questions tailored to students' cognitive development levels. Therefore, this model is highly suitable for science education, which requires analytical skills, data interpretation, and evidence-based conclusion-drawing (Khomariah et al., 2024).

Theoretically, the Probing Prompting model is grounded in constructivist learning theory, which emphasizes that knowledge is actively constructed by learners through experiences and reflection. This model also reflects the principles of Socratic questioning, where sequential and open-ended questions are used to guide learners toward self-discovery and deeper reasoning. Vygotsky's social constructivism supports this approach through the concept of scaffolding, where teachers provide guided interaction to help students reach higher cognitive levels. Thus, Probing Prompting is considered an effective pedagogical method for developing higher-order thinking, particularly in science learning.

Empirical studies conducted in Indonesia have consistently supported the effectiveness of this model. Muchsin, Zakiah, and Maqfirah (2023) found an improvement in critical thinking skills in physics and biology learning through targeted questions that stimulate in-depth analysis. Intan et.al. (2021) added that the use of probing prompting-based worksheets also strengthens the critical abilities of science students. Additionally, Intan et.al. (2021) and Oxman et al. (2025) emphasize that this approach effectively encourages cognitive engagement and reflective thinking in science. Research by Zahra et al. (2021) and Auliyah et al. (2023) also reinforces this finding with evidence in the context of mathematics and thematic learning that enhances students' critical thinking from an early age.

Despite its increasing adoption, there remains a lack of systematic reviews that comprehensively synthesize research on the use of the Probing Prompting model in Indonesian science education. Most existing studies are fragmented and limited in scope. Therefore, this study aims to fill that gap by conducting a Systematic Literature Review (SLR) of research published between 2021 and 2024 (Milah et al., 2023). Specifically, this review will (1) identify trends in the application of Probing Prompting in science learning, (2) explore its effectiveness across different educational levels, and (3) examine

which critical thinking indicators are most commonly targeted. The review also includes a bibliometric analysis using VOSviewer to visualize research focus and emerging themes. The findings are expected to provide insights for educators, researchers, and policymakers in designing science instruction that is more reflective, contextual, and critical thinking-oriented.

▪ METHOD

Research Design

This study employed a Systematic Literature Review (SLR) method (Akmal et al., 2025) to examine the use of the Probing Prompting learning model in science education to improve students' critical thinking skills. The review design was based on the Kitchenham protocol, which allows researchers to comprehensively map, analyze, and synthesize research trends within a specific theme (Daud, 2024). SLR was selected due to its structured and replicable process in identifying, evaluating, and synthesizing relevant research evidence.

This study adopted a qualitative approach combining bibliometric analysis and qualitative synthesis of research content. The review followed three main stages: identification, screening, and eligibility, as outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram to ensure transparency and rigor in literature selection and data reporting (Mubarrok et al., 2025).

Search Strategy

Relevant articles were retrieved from Google Scholar, Scopus, and SINTA databases. The keywords used in both English and Indonesian were: "probing prompting," "critical thinking skills," "science learning," and "model pembelajaran probing prompting". Boolean operators such as AND and OR were applied during the search process. The publication date range was limited to articles published from January 1, 2020, to December 31, 2024, in order to ensure the currency and consistency of reviewed studies across sources.

Inclusion and Exclusion Criteria

The following inclusion criteria were applied: (1) Articles published between 2020 and 2024; (2) Research explicitly using the Probing Prompting learning model; (3) Studies within the field of Natural Sciences (IPA); (4) Articles published in English or Indonesian; (5) Peer-reviewed journal articles. Exclusion criteria included: (1) Articles that did not explicitly discuss critical thinking skills; (2) Articles that lacked precise data or research results; (3) Non-journal publications; (4) Review papers not containing original data; (5) Duplicates from the same source.

Data Analysis

Selected articles were analyzed using VOSviewer to perform bibliometric mapping, including network visualization, overlay visualization, and density visualization of keywords. In addition, a qualitative content analysis was conducted to examine the research focus, implementation strategies, and identified outcomes from each article. Articles that passed all stages were further classified in a summary table and analyzed descriptively to synthesize their contributions to the development of students' critical thinking skills using the Probing Prompting model.

The stages of a systematic literature review consist of three main processes, namely: identification, screening, and eligibility (Mubarrok et al., 2025). Furthermore, this study used the PRISMA (preferred reporting items for systematic reviews and meta-analyses) approach as shown in Figure 1.

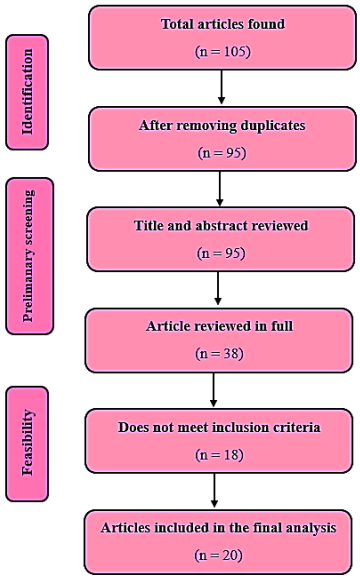


Figure 1. PRISMA flow chart

Figure 1 shows the article selection process flow in a Systematic Literature Review (SLR) study. The process began with the identification stage. Stage 1 (identification) involved searching for literature using the keywords “probing prompting” and “critical thinking skills” through the Google Scholar, Scopus, and Sinta databases, resulting in a total of 105 articles. After the duplication removal process, the number of articles remaining was 95. Stage 2 (screening) involved reviewing the titles and abstracts of all articles. As a result, 38 articles were selected for full review. However, after an in-depth review, 18 articles did not meet the established inclusion criteria.

Stage 3 (feasibility) Finally, 20 articles met the criteria and were included in the final analysis. The articles analyzed consisted of twelve articles obtained through Google Scholar, five articles from the Scopus database, and three articles from the Sinta database. This process ensures that only relevant and high-quality articles are used in this literature review. The article selection process is carried out in stages, starting with an initial search using relevant keywords, screening of titles and abstracts, and a full review of the article content (Putri et al., 2024).

Articles that meet the criteria are included in the analysis table for further analysis based on author name & year, keywords, research results, and their contribution to the development of students' critical thinking skills through the probing prompting model (Puspitasari et al., 2025). The data obtained was then analyzed using VOSviewer software, which builds and visualizes bibliometric networks. This study qualitatively analyzes and describes the results of network visualization, overlay visualization, and density visualization.

▪ RESULT AND DISSCUSSION

The results of bibliometric analysis using VOSviewer show that the Probing Prompting learning model occupies a central position in the development of critical thinking skills in science learning. One of the main clusters that emerged is the green cluster, which links probing prompting with discovery learning, creativity, and sustainability. This finding is reinforced by the results of qualitative synthesis, where at least 6 of the 20 reviewed articles combine probing prompting with discovery-based learning strategies or creative approaches. For example, studies by Megasari et al. (2021) and Muchsin et.al. (2023) emphasize how the use of creative worksheets and structured questions encourages active exploration and discovery of concepts by students.

From the visualization results as shown in Figure 2, the words "critical thinking", "critical thinking skills," and "probing prompting" appear to be larger than the other items. This shows that these topics are the primary focus of recent research, especially that conducted between 2021 and 2023, as can also be seen in the overlay visualization with yellow-green colors indicating more recent publication years. Each color in the network visualization represents a cluster, each with a different thematic focus, as summarized in Table 1.

Table 1. Elements represented by each cluster

Cluster (color)	Element	Cluster Description
Blue	Critical thinking, critical thinking skills, distance learning	This cluster represents the main focus of research related to the development of critical thinking skills, both in the context of offline and online learning (distance learning). The emergence of the term distance learning indicates that the studies in this cluster are relevant to post-pandemic learning issues and educational technology. Research in this cluster emphasizes the urgency of critical thinking as a core competency in science education and various approaches to developing it.
Green	Probing prompting, discovery learning, students, creativity, sustainability	This cluster includes studies that explore the application of innovative learning models such as Probing Prompting and Discovery Learning to foster student creativity and sustainability in the learning process. The research in this cluster primarily focuses on how pedagogical strategies promote student engagement and active knowledge construction and effectively develop critical thinking skills in science education. The emphasis is on structured questioning, reflection, and inquiry-based learning environments that encourage students to think analytically and independently.
Red	Artificial intelligence, theory, copyright, assessment, case study, Indonesia	Studies in this cluster concentrate on the integration of technology in education, particularly the use of Artificial Intelligence (AI), along with discussions on educational theory, copyright, and assessment practices. The presence of "Indonesia" and "case

Cluster (color)	Element	Cluster Description
		study" suggests a strong contextual and qualitative focus in the literature. Notably, this cluster offers a promising direction for future research, the potential integration of AI-based tools into pedagogical models such as Probing Prompting. For example, AI could be employed to generate adaptive, personalized probing questions or to analyze student response patterns in real time. This synergy could enhance the model's effectiveness in developing critical thinking by allowing for more targeted, data-driven instructional feedback. The co-occurrence of terms in both clusters highlights the opportunity to bridge pedagogical innovation with technological advancement, particularly in the context of 21st-century science learning.
Purple	Prompting, pedagogy, prompt programming, few-shot learning, fake news	This cluster focuses on contemporary pedagogical approaches, particularly those related to the use of prompting and prompt programming techniques in learning. The existence of terms such as few-shot learning and fake news reflects the relevance of learning to the challenges of information literacy in the digital age, where students are required to critically sort through information and build evidence-based reasoning.
Orange	Generative AI, training	This cluster contains studies related to the use of generative Artificial Intelligence (AI) in training and education processes. The main focus is on how Generative AI can support content development, data-based training, and assessment automation, which has the potential to improve the quality of learning, including students' critical thinking skills.
Brown	Reasoning	The main focus of this cluster is on developing reasoning skills as an integral part of critical thinking skills. Research in this cluster tends to examine cognitive indicators related to logical thinking, the ability to make inferences, and the ability to construct arguments systematically.
Light pink/light purple	Critical thinking skills, local wisdom	This cluster emphasizes the integration of critical thinking development with local wisdom as a contextual learning resource. Combining the Probing Prompting model with local cultural values allows questioning strategies to be grounded in students' real-life experiences. This integration not only fosters deeper critical thinking but also strengthens students' cultural identity, making science learning more relevant and meaningful in local contexts.

The overlay visualization depicts the temporal development of terms in the literature. Keywords such as probing prompting and critical thinking skills tend to appear in recent studies (shown in bright yellow). In contrast, terms such as theory, learning, and artificial intelligence have a broader temporal distribution or tend to appear earlier (shown in blue to green).

Meanwhile, in the density visualization, the red areas indicate the highest concentration of frequently occurring terms, such as critical thinking, which is at the center of the network. The green and blue areas indicate lower density, for example, terms such as autism spectrum disorder or reasoning, which appear less frequently and are more scattered.

Thus, this analysis confirms that critical thinking and probing prompting are two key concepts that are highly relevant and interrelated in the current literature. These findings reinforce the urgency of integrating critical thinking skills into student learning.

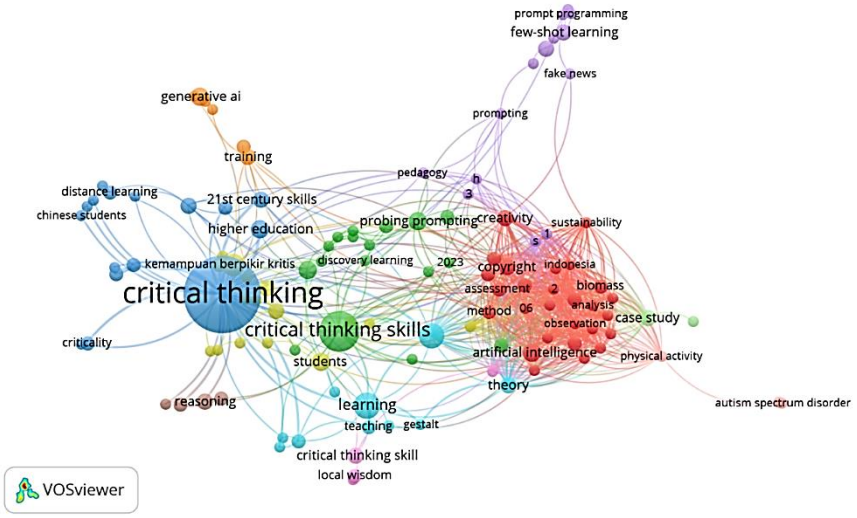
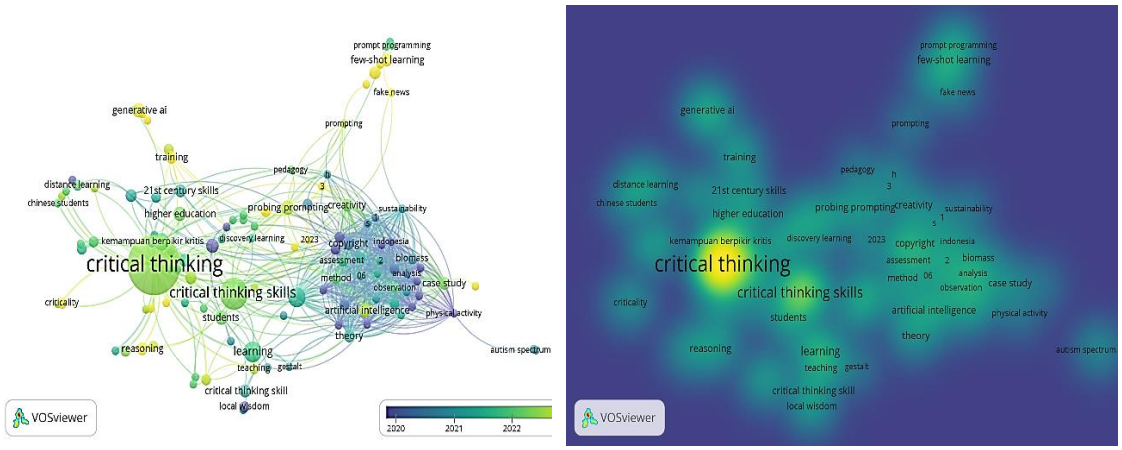


Figure 2. Network visualization results

Based on the results of bibliometric visualization using VOSviewer in Figure 2, it shows that critical thinking skills occupy a central position in the keyword network, indicating that this topic is the main focus of various scientific publications. This term is closely related to other keywords such as critical thinking, learning, teaching, students, and discovery learning, reflecting that critical thinking skills are often studied in the context of active, student-centered learning. One of the learning approaches that emerged in this network was probing prompting. Although the size of the probing prompting circle is smaller than other main keywords, its position is directly linked to critical thinking skills, pedagogy, and creativity, and students show that this approach has significant potential in developing students' critical thinking skills.

The probing prompting learning model generally belongs to the same group as constructivist approaches, such as discovery learning and creativity, which emphasize the active role of students in the learning process. This relationship indicates that probing prompting is used as a learning strategy that encourages students to think more deeply through questions that require analysis, reasoning, and reflection. Thus, it can be concluded that the probing prompting model contributes positively to strengthening

critical thinking skills, especially when applied in an interactive, reflective, and student-centered learning context.



(a) (b)

Figure 3. (a) Overlay visualization results, (b) Density visualization results

Based on Figure 3, the results of bibliometric visualization using VOSviewer show that critical thinking is the most dominant and central topic in literature studies in recent years. This can be seen from the large size of the node and its position in the center of the map, indicating its high frequency of occurrence and its relevance to various other terms such as critical thinking skills, learning, and 21st-century skills. The green color on this node indicates that the topic of critical thinking has been a stable focus of research from 2021 to 2023.

Meanwhile, the term probing prompting has emerged as a relatively new topic, with a yellow-green color indicating intensified attention over the past 2 to 3 years. Although its node size is still smaller than critical thinking, its connection to concepts such as creativity, pedagogy, prompting, and discovery learning shows that the probing prompting approach is beginning to be recognized as a relevant learning strategy for encouraging critical thinking skills in students (Muchsin et.al., 2023). Its proximity to the critical thinking node reinforces the assumption that this model has the potential to directly contribute to the development of higher-order thinking skills.

The density visualization results reinforce this finding. The term critical thinking is located in the bright yellow area, indicating that this concept is one of the most frequently appearing in publications. In contrast, probing prompting is in the medium density range, but still shows increasing intensity. This indicates a growing trend in literature, where the probing prompting approach is beginning to be used as an innovative pedagogical method in learning, particularly in the context of improving critical thinking skills.

Theme 1 - Comparison of the Effectiveness of Probing Prompting Models Based on Educational Level

Based on an analysis of a number of scientific articles examining the Probing Prompting learning model, several important findings were obtained regarding the effectiveness of its implementation at different educational levels, the types of probing activities used, and the dominant critical thinking indicators developed. To assess how

effectively the probing prompting model performs across various education levels, the studies involving elementary, middle, and high school students are compared and summarized as shown in Table 2.

Table 2. Comparison of the effectiveness of the probing prompting model based on education level

Level	Effectiveness	Student Characteristics	Supporting Strategies
Elementary school	Moderate	Need for concrete guidance and visual media	E-worksheets, videos, and picture questions
Junior high school	High	Able to think logically and abstractly	Step-by-step questions, discussions, context-based worksheets
Senior high school	High	Able to evaluate and construct complex arguments	Data-driven probing, scientific reflection

In terms of educational level, the Probing Prompting model is most effective at the junior high school level, demonstrated by a notable improvement in students' critical thinking skills across various integrated science topics. This finding is due to junior high school students being at the formal operational stage of cognitive development, according to Piaget's theory that students at this level begin to be able to think abstractly and logically. At this stage, students also demonstrate improved ability in responding to step-by-step questions and engaging in reflection, making them highly receptive to scaffolding strategies such as probing prompting.

At the elementary school level, this model remains effective. However, its success is highly relies on the use of contextual and visual learning media, such as electronic worksheets and educational videos. Elementary school students, who are still in the concrete operational stage, tend to be more emotionally and cognitively responsive when guided through visual stimuli and contexts that are close to their experiences. Emotional engagement is an important factor in maintaining motivation and concentration when answering prompt questions.

Meanwhile, at the high school level, the effectiveness of this model remains high, especially in subjects such as physics and chemistry. The focus of learning at this level is more on developing higher-order thinking skills such as evaluation, synthesis, and argumentation based on experimental data. However, the complexity of the material and instructions can raise cognitive load, so the question design and its presentation must be adjusted to avoid overwhelming students. Although high school students are generally more independent, they still benefit from probing strategies that activate prior knowledge and challenge assumptions in a supportive learning environment.

This difference highlights the importance of considering students' social-emotional factors and cognitive readiness when applying the Probing Prompting model at various levels of education.

Theme 2 - Types of Probing Prompting Activities and Their Effectiveness in Developing Critical Thinking

The success of implementing the probing prompting model is greatly influenced by the type of activities used in learning. Various activities have been identified and

categorized based on their descriptions and levels of effectiveness, as presented in Table 3.

Table 3. Types of probing prompting activities and their effectiveness in developing critical thinking

Type of Activity Probing Prompting	Brief Description	Effectiveness
Structured Sequential Questions	Teachers provide a series of questions ranging from low to high levels to explore and guide students' understanding progressively.	Highly Effective
Reflective Prompting	Teachers encourage thinking skills by asking follow-up questions that prompt students to clarify, refine, or deepen their answers.	Effective
Problem-Based Guided Discussion	Students discuss solving real-world problems with guidance from probing questions and prompts that guide their thinking process.	Effective
Worksheets or e-Worksheets Based on Probing Prompting	The worksheet includes probing and prompting questions in sequence to guide concept exploration and reflection.	Highly Effective
Visual Stimulus with Probing Prompting	Teachers present images, videos, or scientific phenomena for students to use as the basis for probing and prompting questions.	Quite Effective
Prompting in Science Practicum	Teachers ask follow-up questions while students conduct and observe the experiments to guide them toward understanding the concepts.	Effective

The most effective activities, such as structured step-by-step questions and Probing Prompting-based worksheets, have been proven to systematically guide students from basic understanding to analytical thinking skills. The effectiveness of this approach can be explained by Vygotsky's scaffolding theory, in which teachers act as facilitators who provide gradual support in accordance with the students' Zone of Proximal Development (ZPD). Through tiered questions and guided discussions, students are encouraged to think independently while still receiving the necessary cognitive support until they are able to complete tasks independently.

In addition, the effectiveness of structured worksheets is also in line with Cognitive Load Theory, which emphasizes the importance of managing students' cognitive load so that it does not become excessive. By presenting information and questions gradually, Probing Prompting activities help reduce intrinsic cognitive load and avoid unnecessary extrinsic load. This allows students to focus on critical thinking processes, such as analysis, evaluation, and inference, without feeling overwhelmed by the complexity of the information presented all at once.

Therefore, the success of the Probing Prompting model in developing students' critical thinking skills does not only stem from the content of the material taught, but also from the learning activities that are designed in accordance with pedagogical principles based on strong learning theories.

Theme 3 - Dominant Critical Thinking Skills Indicators

In addition to reviewing the effectiveness and form of activities, the analysis also focused on critical thinking skill indicators that are most often developed in probing prompting-based learning. Table 4 below shows the frequency of occurrence of each indicator in the reviewed articles:

Table 3. Dominant critical thinking skills indicators

Indicator	Description	Frequency of Occurrence (in articles)
Analysis	Analyzing information and comparing	18
Evaluation	Evaluating arguments or ideas	14
Inference	Drawing conclusions based on data/facts	13
Explanation	Stating and clarifying ideas	11
Self-regulation	Recognizing and organizing thought processes	9

Although the most dominant critical thinking skill indicators in primary studies are analysis, evaluation, and inference, it is necessary to consider the possibility of bias in measurements that could affect the validity of the findings. One potential bias stems from the nature of the probing prompting model itself, which tends to emphasize concept exploration through gradual questioning. This model naturally guides students toward analytical skills as an initial stage, making analytical indicators more easily observable and measurable compared to other critical thinking indicators, such as explanation or self-regulation.

In addition, bias can also arise from the diversity of instruments used in primary studies. Many measurement instruments only test some of the indicators of critical thinking skills (for example, only three of the six indicators in Facione's framework), which could potentially result in an incomplete picture of students' critical thinking skills as a whole. In other words, the limited number of indicators measured could lead to an overestimation of the development of certain skills and an underestimation of others.

Therefore, in interpreting the research results, it is important to consider these methodological aspects to avoid excessive generalization. Further studies are recommended to use more comprehensive instruments and consider the proportional distribution of indicators to obtain a more accurate picture of the impact of the probing prompting model on the entire spectrum of critical thinking skills.

Theme 4 - Implementation of the Probing Prompting Model to Improve Critical Thinking Skills in Science Learning

Critical thinking skills are essential competencies in science learning, which include biology, physics, chemistry, and integrated science. These skills enable students to analyze, evaluate, and draw conclusions from information logically, thereby providing a foundation for understanding scientific phenomena. Students' critical thinking skills are developed and improved to produce high-quality, competent, and competitive human resources (Suciati, 2022). Based on the results of the literature selection using the PRISMA method, 20 articles were selected for further analysis. These articles were published between 2021 and 2024 and sourced from Google Scholar, Scopus, and Sinta journals. All articles examined the application of the Probing Prompting model in science

education, and the Probing Prompting learning model was consistently effective in improving students' critical thinking skills in science learning at various levels of education. This model encourages students to think actively and logically, evaluate arguments, and construct scientific explanations reflectively. The use of tiered questions, which is a hallmark of this model, has proven effective in stimulating deep cognitive engagement.

Several studies indicate that the application of Probing Prompting in contextual settings, such as in Social Science Issue (SSI)-based learning, can significantly improve critical thinking indicators such as interpretation and evaluation (Hadiansah & Yuliawati, 2024). This is supported by Zai & Dwikristanto (2023), who found in their literature review that Probing Prompting, as part of an innovative model, can enhance elementary students' critical thinking skills in science subjects. On the other hand, Muchsin et.al. (2023) emphasize that students become more active and logical in their thinking, while teachers act as facilitators in the learning process.

The application of probing prompting has also been proven to improve conceptual understanding and learning interest. Nufus et al. (2022) reported that junior high school students experienced an increase in critical thinking in environmental pollution material through probing prompting. Khumairok et al. (2021) showed that the Prompting Question technique is effective in revealing variations in students' critical thinking abilities in vibration and sound material. Additionally, the use of learning media such as e-worksheets (Sari & Kurniawati, 2024) and interactive multimedia (Oktaviyanti et al., 2021) based on Probing Prompting also enhances understanding and learning outcomes.

Other studies expand the scope of this model's effectiveness. Nurliana et al. (2021) state that integrated science learning using this model can improve students' ability to draw conclusions and design scientific strategies. Jariatin et al. (2024) found that national research trends show an increasing focus on innovative learning models that support higher-order thinking. Pereira et al. (2023) integrated Probing Prompting into the Problem-Based Learning (PBL) framework and found a significant impact on middle school students' critical thinking skills.

Studies by Sudyana et al. (2023) and Rompegading et al. (2023) show that the Probing Prompting approach, whether directly or through digital media such as Mentimeter, can create reflective and enjoyable learning. The use of technology is also discussed by Mahdian et al. (2021) through the integration of Virtual Reality, which enhances learning experiences and students' critical thinking skills.

In the context of primary and secondary education, the study of Ismatulloh et al. (2021), Kamilah et al. (2021), and Anisah & Carlian (2021) reinforce that Probing Prompting is highly relevant in physics, chemistry, and science education at Madrasah Ibtidaiyah. This model not only improves learning outcomes but also fosters argumentative skills and logical reasoning. Megasari et al. (2021) even show that members of the Youth Scientific Group (KIR) demonstrate better critical thinking skills after using this model.

Finally, the results from Siskayanti et al. (2022) and Sumiati et al. (2022) show that the development of Probing Prompting-based learning tools, whether in the form of PBI modules or physics learning videos, yields high effectiveness in enhancing students' critical thinking skills and learning outcomes. Thus, all the studies analyzed show that the probing prompting model makes a significant contribution to science learning,

particularly in strengthening the critical thinking skills of Indonesian students at various levels of education.

The flexible Probing Prompting model is often combined with other approaches such as Problem-Based Learning, Problem-Based Instruction, and Guided Inquiry. In addition, the effectiveness of Probing Prompting increases when supported by interactive learning media such as videos, multimedia, virtual reality, and digital worksheets (Yuniati et al., 2024). These studies show that critical thinking skills are the main objective of applying this model at various levels of education, especially elementary and junior high schools (Sholeh, 2024). The trend of using the Probing Prompting model in research began to increase in 2021 and peaked in 2023, indicating that the probing prompting model has become one of the most relevant and sought-after approaches in the development of 21st-century learning.

▪ CONCLUSION

A systematic review of 20 articles revealed that the Probing Prompting learning model is consistently effective in enhancing students' critical thinking skills within science education. This model is most impactful at the junior high school level, where learning activities such as step-by-step questioning and the use of probing-based worksheets are frequently applied. The critical thinking indicators most commonly developed using this model are analysis, evaluation, and inference. Bibliometric analysis further confirms that research linking Probing Prompting and critical thinking has shown a steady and growing presence in science education literature over the past five years, indicating its relevance and significance in the field of 21st-century learning.

These findings have important implications for science education, particularly in promoting inquiry-based, student-centered learning. The study highlights the pedagogical potential of Probing Prompting to foster deeper reasoning and reflective thinking when implemented through structured questioning. However, this research has limitations. The study is based solely on secondary data, and the analysis is restricted to articles published in select databases between 2019 and 2023. In addition, variations in research design and context among the reviewed studies may affect the generalizability of the conclusions. Future research is encouraged to integrate Probing Prompting with digital tools or local wisdom contexts to explore its broader applicability and impact.

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