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THE IMPACT OF INQUIRY-BASED LEARNING ON K-12 STUDENTS' MOTIVATION AND SCIENCE LITERACY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

This systematic literature review (SLR) explores the impact of inquiry-based learning (IBL) on K–12 students' learning motivation and science literacy. A total of 20 empirical studies published between 2018 until 2025 were selected using PRISMA 2020 guidelines from Scopus, SpringerLink, and Elsevier databases. The studies employed various inquiry-based learning models (guided, open, and socio-scientific), educational levels, and instructional media. The findings show that inquiry-based learning consistently enhances students' intrinsic motivation by fostering autonomy, engagement, and contextual learning. Simultaneously, inquiry-based learning improves science literacy through inquiry cycles involving observation, hypothesis testing, experimentation, and reasoning. Guided inquiry appears to be the most effective form, particularly at primary and lower secondary levels, while hybrid models like SSIBL and IB-NOSA enhance students' argumentation and scientific thinking. However, the effectiveness of inquiry-based learning is influenced by teacher readiness, duration of intervention, and technological support. This review reinforces the pedagogical relevance of inquiry-based learning in promoting 21st-century competencies and suggests its integration into curriculum design, teacher training, and science education policies.

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INTRODUCTION

Science education plays a strategic role in preparing the younger generation to face the complex challenges of the 21st century. In line with rapid technological advancements and escalating global social challenges, students are expected not only to understand scientific concepts, but also to develop high levels of scientific literacy and learning motivation (OECD, 2015). Scientific literacy reflects the ability to go beyond rote memorization of theories—it encompasses understanding and applying scientific knowledge in daily life, making evidence-based decisions, and actively engaging in issues related to science and technology (Bybee, 2010). On the other hand, learning motivation is a critical psychological factor that directly influences students' academic achievement and engagement in learning activities (Ryan & Deci, 2000).

However, international assessments such as the Programme for International Student Assessment (PISA) indicate that Indonesian students still perform poorly in scientific literacy, and many of them lack interest or intrinsic motivation to learn science (OECD, 2019). This condition necessitates innovation in instructional models—approaches that not only guide students toward achieving learning goals but also foster curiosity and active participation. In this context, inquiry-based learning emerges as a promising pedagogical model aligned with 21st-century learning demands, emphasizing exploration and investigation.
Inquiry-based learning positions students at the center of the learning process, encouraging them to formulate questions, design experiments, explore data, and draw conclusions through scientific reasoning (Hmelo-Silver et al., 2007). Numerous studies have shown that inquiry-based learning enhances learner autonomy, critical thinking, and scientific literacy (Furtak et al., 2012; Maison et al., 2021). Furthermore, this approach has been found effective in increasing students' learning motivation by providing opportunities for meaningful and active engagement (Song et al., 2012). Similar concerns have also been raised internationally, as several studies have reported inconsistencies in the effectiveness of IBL across different educational levels, cultural contexts, and classroom implementations. However, the extent to which IBL consistently improves learning motivation and scientific literacy remains unclear due to variations in instructional design, levels of scaffolding, and assessment approaches used across studies.

Although a considerable body of research has explored the application of inquiry-based learning in science education, existing studies remain fragmented in terms of research design, educational contexts, levels of schooling, and target variables. While some have examined the impact of inquiry-based learning on learning outcomes (Ernawati et al., 2023), there is still limited research that explicitly investigates the relationship between inquiry-based learning, learning motivation, and scientific literacy simultaneously, particularly within the K–12 student population. Moreover, there appears to be a lack of systematic reviews that comprehensively synthesize empirical findings on this topic. These variations underline the need for a comprehensive synthesis that not only evaluates the overall impact of IBL but also examines how contextual and methodological differences shape learning outcomes.

This article conducts a systematic literature review (SLR) of scholarly publications that investigate the influence of inquiry-based learning (IBL) in K–12 science education, with a specific focus on two key outcome variables: students' learning motivation and scientific literacy. The review identifies emerging trends in the implementation of IBL, examines how different forms of IBL influence motivational and literacy outcomes, and synthesizes methodological approaches, instructional strategies, and contextual factors across studies to reveal overarching patterns of effectiveness, variations in learning outcomes, and the mechanisms that may explain those variations. The findings of this review are intended to support the design of evidence-based, student-centered instructional practices that align with the demands of 21st-century science education and to guide future research agendas on IBL in school science contexts.

METHOD

This study employed a Systematic Literature Review (SLR) approach to identify, evaluate, and synthesize empirical findings regarding the implementation of inquiry-based learning models in enhancing students' learning motivation and scientific literacy at the K–12 level. The review was conducted in accordance with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which are designed to ensure transparency, replicability, and reporting quality in systematic reviews (Page et al., 2021).

The SLR approach was chosen as it offers a comprehensive overview of existing research, helping to uncover prevailing patterns, trends, and research gaps. Moreover, it provides a stronger foundation for evidence-based decision-making compared to traditional narrative reviews.

Research Question and PICo Framework. The research question of this review is to examine how inquiry-based learning influences K–12 students' learning motivation and scientific literacy in science education.

The focus of this review was structured using the PICo framework (Population, Interest, Context) as follows:

Table 1. PICo framework

PICo Element	Description in This Study
Population	K–12 students (primary and secondary education)
Interest	Implementation of inquiry-based learning in science education
Context	Formal science education settings (Biology, Physics, Chemistry, or Integrated Science)

The use of the PICo framework enables precise definition of the study's scope and facilitates the formulation of specific research questions regarding the effectiveness of inquiry-based learning within formal K–12 science learning environments.

The article search was conducted electronically through three reputable international databases: Scopus, SpringerLink, and Elsevier. These databases were selected based on their broad multidisciplinary coverage and high indexing quality in the fields of education and science.

The search strategy was designed using Boolean operators with the following keyword combinations:

("inquiry-based learning" OR "inquiry learning" OR "guided inquiry")
AND ("learning motivation" OR "science motivation" OR "scientific literacy")
AND ("students" OR "K–12" OR "elementary school" OR "secondary school")

The search was conducted in June 2025, focusing on article titles, abstracts, and keywords, and limited to the publication period between 2018 and 2025. This range was selected to reflect the most recent developments in inquiry-based learning research, particularly in light of the post-COVID-19 transformation in educational practices.

Table 2. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Empirical studies (quantitative, qualitative, or mixed-methods)	Non-empirical or conceptual papers
Focus on inquiry-based learning as the primary instructional approach	Study participants are not students (e.g., teachers, university students)
Measures learning motivation and/or scientific literacy	Focuses on non-science subject areas
Population includes K–12 students (elementary to secondary level)	Full text is not available
Published between 2018 and 2025	Not relevant to the variables under investigation
Published in languages accessible to the reviewers (English, Indonesian, or others)	

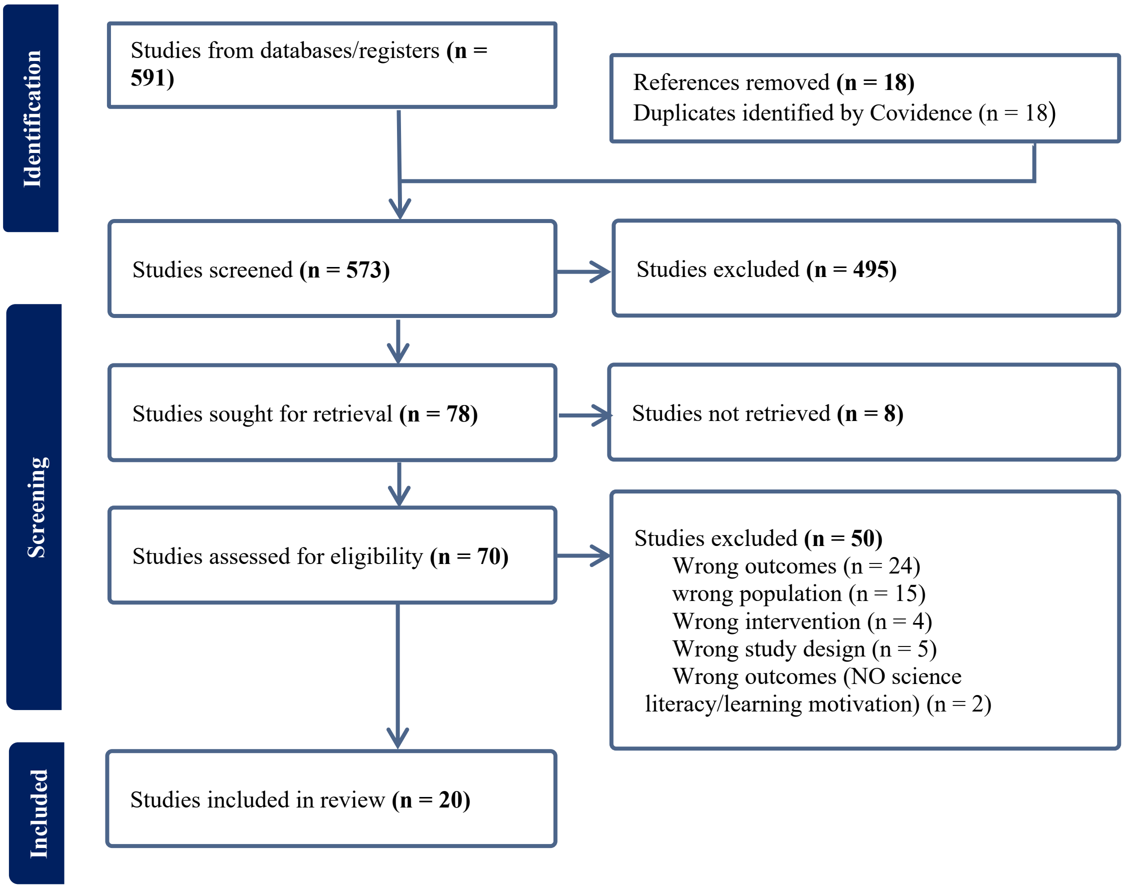


Figure 1. PRISMA Flow Diagram

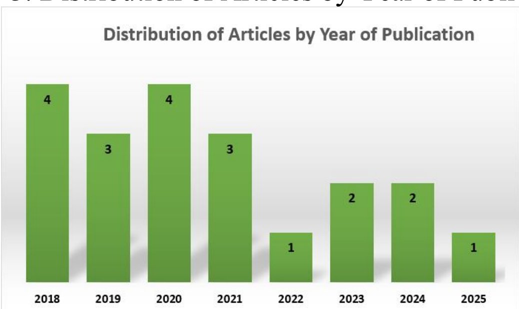
This systematic review was designed and carried out through three main phases: planning, conducting, and reporting, to ensure process transparency and methodological consistency.The planning phase began with the identification of the main issue to be reviewed, namely the effectiveness of inquiry-based learning in improving K–12 students' learning motivation and scientific literacy. During this stage, the researchers formulated the research problem and objectives of the review, defined the PICo framework to clarify the focus of article selection, developed a search protocol including relevant keywords and databases, and established detailed inclusion and exclusion criteria. A review protocol document was prepared beforehand to ensure that the article selection process could be replicated and remained free from bias.

The conducting phase involved the implementation of literature searching, article selection, and quality assessment. The researchers conducted a systematic search of the literature across three major databases: Scopus, SpringerLink, and ScienceDirect (Elsevier). The initial screening was performed based on titles and abstracts, followed by full-text review to ensure the articles met the predetermined inclusion criteria. Methodological quality of the selected articles was assessed using the Mixed Methods Appraisal Tool (MMAT) 2018. The MMAT was used as a methodological quality appraisal tool without calculating an overall numerical score. All included studies met the minimum MMAT criteria relevant to their study design. The appraisal results were used to describe the methodological quality of the included studies rather than as an exclusion criterion. Subsequently, relevant data from the eligible articles were extracted for further analysis. All these steps were carried out by two independent reviewers, and any discrepancies were resolved through discussion to reach consensus.

RESULT AND DISCUSSION

Based on the PRISMA flow diagram (see Figure 1), a total of 20 articles met the inclusion criteria. As shown in Figure 2, these articles were published between 2018 until 2025, with the lowest frequency of publication in 2022 (1 article), and the highest in 2018 and 2020, with four articles. The distribution of publication years is summarized in Table 3 below.

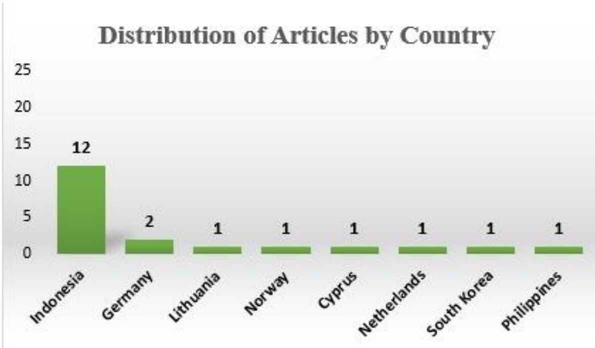
Table 3. Distribution of Articles by Year of Publication



The data in Table 3 indicates that the research on inquiry-based learning in science education has been relatively consistent over the last eight years, reflecting a sustained scholarly interest in this instructional model. In terms of geographical distribution, the included studies originated from several countries.

The reporting phase adhered to the PRISMA 2020 guidelines. The article selection process was presented in a PRISMA flow diagram, accompanied by detailed explanations regarding the number of articles at each selection stage, the methodological characteristics and contextual information of the included studies, the thematic synthesis of the key findings, and the presentation of results in both narrative and tabular forms. The report was written systematically and transparently to allow readers to understand the entire review process and assess the quality and scope of the study.

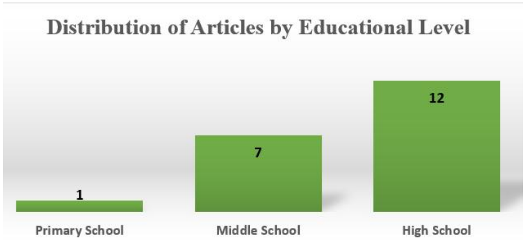
Table 4. Distribution of publication years of articles



As presented in Figure 3, Indonesia contributed the largest number of articles (12 out of 20), followed by Germany (2 article) and several other countries, each contributing one article. This suggests that Indonesia has shown considerable research attention toward the implementation of inquiry-based learning in K–12 science education.

The educational level distribution of the studies is displayed in table 5.

Table 5. school level distribution



Most studies were conducted at the high school level (12 articles), followed by the middle school level (7 articles). This trend indicates that inquiry-based learning is widely applied and considered suitable for secondary education, where students are generally more prepared for open-ended exploration and scientific reasoning.

In summary, this review analyzed 20 empirical studies related to the implementation of inquiry-based learning in K–12 science education. The studies were published between 2018 and 2025 and originated from various countries, including Indonesia, Germany, Lithuania, Norway, South Korea, and others. Collectively, the articles featured various inquiry-based learning approaches (guided, structured, and open inquiry), covered multiple educational levels (primary, middle, and high school), and employed diverse intervention formats, such as learning modules, worksheets, digital media, ethnoscience integration, and socio-scientific inquiry-based learning (SSIBL) models.

Table 6. Summary of Selected Article

No	Author (Year)	Research Title	Key Findings
1	(Heindl, 2020)	An Extended Short Scale for Measuring Intrinsic Motivation When Engaged in Inquiry-Based Learning	The EKIM scale is valid and reliable for measuring the intrinsic motivation of elementary school students after inquiry-based learning
2	(Pečiuliauskienė & Belakoz, 2019)	School Students' Motivation for Learning Sciences: How is it Influenced by Self-confidence in Science and Inquiry-based Teaching Approach?	inquiry-based learning improves students' self-regulation and learning motivation in a sustainable manner.

3	(Pedersen & Haavold, 2023)	Students' Mathematical Beliefs and Motivation in the Context of Inquiry-Based Mathematics Teaching	inquiry-based learning has a positive effect on motivation, although self-confidence is more dominant
4	(Hufri et al., 2019)	Validation Analysis of Physics Teaching Materials Based on Contextual Through Inquiry to Increase Student's Science Literacy	inquiry-based learning encourages a positive outlook and high motivation towards mathematics.
5	(Kahar et al., 2022)	The Effectiveness of the Integrated Inquiry Guided Model STEM on Students'Scientific Literacy Abilities	Inquiry-based teaching materials are very valid for improving scientific literacy.
6	(Parno et al., 2020)	The Impact of STEM-based Guided Inquiry Learning on Students' Scientific Literacy in the Topic of Fluid Statics	inquiry-based learning-STEM is effective in improving science literacy, especially the epistemic aspect.
7	(Georgiou & Kyza, 2023)	Fostering Chemistry Students' Scientific Literacy for Responsible Citizenship through Socio-Scientific Inquiry-Based Learning (SSIBL)	inquiry-based learning-STEM is superior to conventional methods in improving science literacy
8	(Meulenbroeks et al., 2024)	Fostering Secondary School Science Students' Intrinsic Motivation by Inquiry-based Learning	SSIBL enhances students' understanding of science and sustainability values
9	(Conradty & Bogner, 2019)	From STEM to STEAM: Cracking the Code? How Creativity & Motivation Interacts with Inquiry-Based Learning	G-IBL with video is more effective than direct instruction in increasing intrinsic motivation
10	(Sutiani, 2021)	Implementation of an Inquiry Learning Model with Science Literacy to Improve Student Critical Thinking Skills	STEAM increases motivation, but not significantly on creativity without ongoing training
11	(Kang, 2020)	Interrelationship Between Inquiry-Based Learning and Instructional Quality in Predicting Science Literacy	Improving literacy, critical thinking, and awareness of the social impact of science
12	(Rizki et al., 2025)	Ethnoscience-Enhanced Physics Virtual Simulation and Augmented Reality with Inquiry Learning: Impact on Students' Creativity and Motivation	Guided inquiry is positive, open inquiry is negative; teaching quality reinforces positive effects
13	(Indana et al., 2020)	Effectiveness of Learning Material by ICT-Based Guided Inquiry Model to Train Critical Thinking Skill and Science Literacy	ESIL effectively increases motivation through contextual and enjoyable learning.
14	(Widowati et al., 2018)	Applying innovative approach "Nature of Science (NoS) within inquiry" for developing scientific literacy in the student worksheet	Effectively improving scientific literacy through scientific exploration and reasoning
15	(Yuliati et al., 2018)	Building Scientific Literacy and Concept Achievement of Physics through Inquiry-Based Learning for STEM Education	Effectively improve the understanding of scientific concepts and scientific thinking of junior high school students
16	(Yuliati et al., 2021)	Concept Acquisition and Scientific Literacy of Physics within Inquiry-Based Learning for STEM Education	inquiry-based learning-STEM improves students' conceptual understanding and science literacy
17	(Batong & Wilujeng, 2018)	Developing Web-Students' Worksheet Based on Inquiry Training for Increase Science Literacy	inquiry-based learning-STEM strengthens the content, context, and competency aspects of scientific literacy.

18	(Mufida et al., 2021)	Development of digital learning media based on android games with joyful inquiry model to increase science literacy skills for second year students of junior high school in subject matter of vibration	Inquiry-based learning media with a fun approach has been proven to be effective in improving students' scientific literacy skills in identifying scientific problems and explaining phenomena.
19	(Lestari et al., 2024)	Effect of the Inquiry-Based Nature of Science Argumentation Instructional Model in Scientific Literacy Skills	IB-NOSA is more effective than GIBL and discovery, especially in scientific thinking and argumentation.
20	(Aulia et al., 2018)	The Effectiveness of Guided Inquiry-based Learning Material on Students' Science Literacy Skills	Guided inquiry-based learning effectively improves students' scientific literacy in all aspects: context, attitude, and knowledge.

Overall, this synthesis reaffirms the effectiveness of inquiry-based learning in supporting two key dimensions of 21st-century science education: learning motivation and scientific literacy. The findings from the reviewed studies reinforce constructivist theory, which emphasizes the importance of active participation and experiential learning (Hmelo-Silver et al., 2007). Furthermore, the motivation that emerges from authentic learning experiences aligns with the principles of Self-Determination Theory (Ryan & Deci, 2000). However, the successful implementation of inquiry-based learning is not automatic. Several factors, such as the duration of the intervention, the clarity of teacher roles, availability of instructional media, and student readiness, play a critical role in determining outcomes. For instance, studies by Kang (2020) and Georgiou & Kyza (2023) demonstrate that unguided inquiry approaches may lead to student confusion and declining learning outcomes when not adequately supported or facilitated.

Most of the reviewed studies indicated that inquiry-based learning positively contributes to enhancing students' learning motivation, particularly intrinsic motivation. Heindl (2020) developed the EKIM scale to measure students' intrinsic motivation during inquiry-based learning and found that this approach fostered deep curiosity and sustained interest in science learning. Similar findings were reported by Meulenbroeks et al. (2024), in which students participating in guided inquiry experiments supported by instructional videos showed significantly higher levels of intrinsic motivation compared to those engaged in direct instruction. A longitudinal study by Moote (2017) demonstrated that participation in the CREST-based inquiry-based learning program had long-term effects on students' self-regulation and internal motivation. This aligns with the findings of Rizki et al. (2025), who implemented the ethnoscience-based inquiry learning (ESIL) model. Their results showed that the integration of virtual simulations and augmented reality provided contextualized learning experiences, fostering enthusiasm and enhancing students' motivation.

However, Pečiuliauskienė & Belakoz (2019) highlighted that while inquiry-based learning can improve motivation, students' self-confidence in science remains a stronger predictor. This suggests that the effectiveness of inquiry-based learning can be maximized when combined with interventions that strengthen students' self-efficacy. The use of innovative media such as robotics, augmented reality (Rizki et al., 2025), STEAM (Conradty & Bogner, 2019), and web-based student worksheets (Batong & Wilujeng, 2018) has consistently been associated with increased student motivation. However, Conradty & Bogner (2019) also observed that while motivation improved, creativity did not significantly develop without consistent training, indicating that motivation alone is not sufficient for broader skill development.

Inquiry-based learning has also been shown to be highly effective in improving students' scientific literacy, including content understanding, scientific process skills, and contextual application. Yuliati et al. (2018) reported that inquiry-based learning-STEM improved students' conceptual understanding of physics and their overall scientific literacy. Similarly, (Indana et al., 2020) implemented ICT-based guided inquiry materials and found improvements in students' comprehension of scientific concepts, inquiry processes, and application of science in real-life contexts. Previous studies demonstrated that inquiry approaches focusing on the Nature of Science (NoS) and socio-scientific issues helped students understand science as a human endeavor deeply embedded in societal decision-making processes (Widowati et al., 2018; Sutiani, 2021).

Several articles emphasized the role of digital media in enhancing student engagement and comprehension. For example, Mufida et al. (2021) developed Android-based game media using a joyful inquiry model and found significant improvements in students' ability to identify scientific problems and explain phenomena. Similarly, Batong & Wilujeng (2018) used web-based worksheets integrated with PhET simulations, resulting in comparable learning gains. Kang (2020) found that guided inquiry had a positive impact on scientific literacy, while open inquiry resulted in negative outcomes. This variation was attributed to classroom management and the quality of teacher-student interactions, reinforcing the notion that inquiry-based learning should be adapted to the readiness of learners. Lestari et al. (2024) also found that the IB-NOSA model (inquiry-based Nature of Science Argumentation) outperformed traditional guided inquiry, particularly in fostering students' ability to explain phenomena, think scientifically, and construct evidence-based arguments.

Several contextual factors were found to influence the successful implementation of inquiry-based learning, including teacher quality, duration of intervention, and instructional design. According to Pedersen & Haavold (2023), students' beliefs and motivation improve when teachers are able to consistently structure and facilitate inquiry-based instruction effectively. Studies such as those by Aulia et al. (2018) and Parno et al. (2020) demonstrate that significant improvements in scientific literacy occur when inquiry-based learning interventions are implemented systematically and repeatedly rather than as one-off activities. Hufri et al. (2019) further emphasized the importance of validating inquiry-based teaching materials, as well-developed materials serve as a solid foundation for improving students' scientific understanding consistently.

The types of inquiry-based learning applied in the analyzed studies were quite varied. Of the 20 articles, 13 implemented guided inquiry, which emphasizes structured guidance throughout the investigative process, and these studies consistently reported significant improvements in both scientific literacy and students' learning motivation. In contrast, open inquiry, which allows students greater autonomy to formulate questions and design experiments independently, yielded more varied results. Kang (2020) found that open inquiry does not always lead to improved scientific literacy, particularly when not supported by sufficient teacher facilitation and when students are not cognitively prepared. This highlights that the effectiveness of inquiry-based learning is highly contextual and dependent on student readiness and scaffolding strategies. Meanwhile, socio-scientific inquiry-based learning (SSIBL), as implemented in studies by Georgiou and Georgiou & Kyza (2023) and Sutiani (2021), proved to be highly effective in increasing students' awareness of the role of science in social and sustainability issues. SSIBL also strengthens scientific literacy as a tool for evidence-based decision-making in everyday life.

Therefore, guided inquiry appears to be the most generally effective form of inquiry-based learning for K–12 science education, especially at the elementary and secondary levels. However, hybrid approaches—such as IB-NOSA Lestari et al. (2024), which combine explicit-reflective inquiry with scientific argumentation—also show strong potential for fostering deeper and more contextual scientific literacy. Based on the synthesis of 20 articles, five key themes can be identified, encompassing the relationship between motivation, literacy, digital media integration, inquiry type, and contextual readiness, all of which collectively demonstrate the pedagogical strength of inquiry-based learning in modern science education.

Table 7. Summary of Findings

Theme	Findings
Motivation to learn increases with an active approach	inquiry-based learning creates a learning environment that stimulates student engagement and curiosity (Heindl, 2020); (Meulenbroeks et al., 2024).
Scientific literacy increases when students engage in the full scientific process.	inquiry-based learning helps students understand science concepts through observation, hypothesis, experimentation, and reflection activities (Yuliati et al., 2021); (Lestari et al., 2024b)
Digital media strengthens inquiry-based learning effectiveness	Simulations, AR, and interactive modules support student understanding and engagement (Rizki et al., 2025); (Mufida et al., 2021)
Guided inquiry produces more stable results than open inquiry	Guided approaches show more consistent results on scientific literacy (Kang, 2020)
The effectiveness of contextual inquiry-based learning on student level and readiness	inquiry-based learning is more effective in junior and senior high schools than in elementary schools, depending on student readiness and teacher mentoring strategies (Parno et al., 2020); (Pedersen & Haavold, 2023)

Thus, the findings from these 20 studies confirm that Inquiry-based learning is a consistently effective approach for enhancing K–12 students' learning motivation and scientific literacy. Across the reviewed studies, most reported moderate to high improvements in students' motivation and engagement; however, the magnitude of these gains varied across contexts. Studies implemented in well-resourced classrooms with strong teacher facilitation tended to demonstrate more robust outcomes, whereas those conducted in less supportive instructional environments reported more modest effects. These findings suggest that the effectiveness of inquiry-based learning is not solely determined by the instructional approach itself, but is also strongly influenced by contextual factors such as teacher support and the instructional media employed.

CONCLUSION

Based on a systematic review of 20 selected studies, this study concludes that inquiry-based learning is an effective instructional approach for enhancing students' learning motivation and scientific literacy at the K–12 level across various science learning contexts. Inquiry-based learning promotes students' intrinsic motivation through exploratory activities, problem-solving, and meaningful learning experiences, while also strengthening their ability to understand scientific concepts, conduct investigations, and apply scientific reasoning.

However, the effectiveness of inquiry-based learning is influenced by contextual factors such as the type of inquiry implemented, teacher readiness, instructional support, and the availability of learning media. In addition, this review has several limitations. The number of included studies was limited to 20 articles that met the inclusion criteria, which may restrict the generalizability of the findings. Variations in research design, educational contexts, and outcome measures across studies also limited the possibility of conducting a strong quantitative synthesis.

Future research is therefore recommended to include a larger number of studies, broader geographical coverage, and more standardized quantitative data to provide stronger empirical evidence. Despite these limitations, the findings indicate that inquiry-based learning holds strong potential for supporting the development of essential 21st-century skills, including critical thinking, problem-solving, and scientific reasoning, particularly when implemented under supportive instructional conditions.

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AUTHOR CONTRIBUTIONS

The First Author: Conceptualization, methodology, writing – original draft, and visualization.
The Second Author: Investigation, data curation, formal analysis, and writing – review & editing.
The Third Author: Validation, supervision, and project administration.

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