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A Decade of Science Education Research in Indonesia: Trends, Learning Models, and Student Outcomes

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ABSTRACT

Purpose – This study aims to identify the most frequently examined learning models in science education research in Indonesia, map the most commonly studied learning outcomes, and analyze the patterns of relationships between the two.

Methodology – This study employs an SLR design following the PRISMA 2020 guidelines. Data retrieval was conducted via the Scopus database using the Publish or Perish application, covering the timeframe 2016–2025. Of the total 509 identified articles, 57 empirical studies were selected based on strict inclusion criteria. Data were analyzed using thematic synthesis to map the frequencies of models and outcomes, and to identify emerging patterns of relationships.

Findings –The results indicate that IBL is the most frequently studied model (28 studies), followed by PBL and PjBL. The most commonly examined outcomes are critical thinking skills (21%), science process skills (17.5%), and academic learning outcomes. Relationship patterns fall into three configurations: one-to-many, many-to-one, and exclusive. Trends for 2024–2025 indicate a shift toward more holistic outcomes such as computational thinking, teachers' pedagogical competencies, and reflective skills. This shift can be linked to the dynamics of the Merdeka Curriculum, the strengthening of project-based learning, and the demands of 21st-century competencies.

Contribution – The dominance of the IBL model and the focus on critical thinking skills as learning outcomes reflect methodological convenience and alignment with curriculum policy rather than pedagogical superiority alone, with significant gaps remaining in non-dominant models (Cooperative Learning, Discovery Learning, ADDIE, Susan Loucks-Horsley) and non-cognitive learning outcomes. This study contributes theoretically through a relational model–outcome mapping framework that reveals one-to-many, many-to-one, and exclusive patterns, and practically by providing a basis for educators to select learning models and a roadmap for future research agendas.

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INTRODUCTION

Educational developments in the 21st century call for science education that goes beyond a focus on conceptual mastery (Gervacio, 2025; Tijani & Adeduyigbe, 2026a). Science education must also develop critical thinking, creativity, collaboration, communication, digital literacy, and problem-solving skills (Hasan Harahap et al., 2025; Sholihath & Abidin, 2025; Sumadi, 2025). This need is growing stronger with technological advancements, the demands of Society 5.0, and changes in the competencies required of students in both academic and social life (Siti Karimah et al., 2024; Susanto & Dwi Putri Hartiningsari, 2025).

Instructional models play a crucial role in helping students achieve various learning outcomes in science education (Nisa Pangsuma et al., 2024). Models such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry-Based Learning (IBL) are widely used because they position students as active participants in the learning process (Nghiem et al., 2025; Prihatin et al., 2024; TANJUNG et al., 2025). These models encourage students to observe, ask questions, investigate, analyze, and draw conclusions based on evidence (Sari et al., 2025). Several studies also indicate that integrating technology, such as augmented reality, can enhance students' higher-order thinking skills and science literacy (Auralia & Juliani, 2024; Rusmansyah et al., 2025; Sudarma, 2025).

Science education research in Indonesia has continued to evolve over the past decade. The focus of studies has begun to shift from academic learning outcomes toward more diverse outcomes, such as science process skills, critical thinking, science literacy, creative thinking skills, and teacher competencies (Kurniahtunnisa et al., 2024; Muchson et al., 2024). Recent trends also indicate growing attention to technology-based learning, STEM/STEAM approaches, and project-based learning aligned with 21st-century competency needs (Hasibuan et al., 2024; Tijani & Adeduyigbe, 2026b; Zaman et al., 2025).

Efforts to map educational research on science learning are not new. Several systematic reviews have been conducted, but their scope remains limited either to single models, such as IBL (Stefvannof et al., 2025) and PjBL (Sholihath & Abidin, 2025), or to single outcomes, such as multi-representation skills (Stefvannof et al., 2025). The available bibliometric reviews also tend to focus on general curriculum policy issues (Yusmadi et al., 2024), rather than on the relationship between specific learning models and outcomes. Consequently, there is currently no mapping that places all learning models and all outcomes within a single relational framework, making it impossible to comprehensively identify patterns of dominance, convergence, and under-researched areas. It is this gap that this study aims to fill.

The selection of the 2016–2025 timeframe in this study is based on conceptual, policy, and methodological considerations. This period represents a full decade since the rise of discourse on 21st-century competencies and global education agendas such as SDG 4, which have helped shift the orientation of science education research toward the mastery of higher-order thinking skills, scientific literacy, collaboration, creativity, and students' adaptive abilities. From a policy perspective, 2016 can be viewed as a critical phase in the widespread implementation and revision of the 2013 Curriculum in Indonesia, which brought about a paradigm shift from teacher-centered learning to a more student-centered approach (Rahmah et al., 2024). This period also encompasses the disruptive phase of the COVID-19 pandemic, which drastically upended pedagogical practices, as well as the transition to the Merdeka Curriculum beginning in 2022, which emphasizes the Pancasila Student Profile and flexibility in learning (Alwanda & Saputra, 2025). Thus, the 2016–2025 period not only presents a decade's worth of data but also documents a relatively complete cycle of curriculum transformation, from the consolidation of the 2013 Curriculum through a period of learning crisis to the emergence of a new direction with the Merdeka Curriculum. From a methodological perspective, a decade-long span is considered sufficient to identify medium-term patterns, ensuring that the resulting analysis goes beyond a snapshot that is easily distorted by annual fluctuations.

Another gap has emerged in teaching and learning activities. Teachers still face challenges in selecting instructional models that align with learning objectives, student characteristics, and desired outcomes (Akhmadeeva et al., 2013; Wang, 2024). Several important outcomes, such as multi-representation skills, collaborative skills, attitudes toward science, student engagement, and other affective-social outcomes, have been relatively under-researched compared to cognitive outcomes such as critical thinking, learning outcomes, and science literacy (Diani et al., 2024; Pattipeilohy et al., 2022; Sudarma et al., 2026). This situation highlights the need for studies that not only examine learning models in isolation but also analyze their relationship with learning outcomes.

Based on this gap, the novelty of this study lies in three aspects. First, unlike previous reviews that focused on a single model or a single outcome, this study maps the relationships between models and outcomes relationally through Sankey diagrams, thereby enabling the simultaneous identification of one-to-many, many-to-one, and exclusive patterns. This approach has not yet been employed in the context of science education research in Indonesia. Second, this study compares the periods before and after the transition to the Merdeka Curriculum (2016–2020 vs. 2021–2025), allowing shifts in trends to be directly linked to the dynamics of national curriculum policy. Third, this study explicitly identifies models and outcomes that have been under-researched as a basis for recommendations for future research agendas, rather than merely reporting the frequency of dominant models and outcomes. Based on the above discussion, this study aims to map trends in science education research in Indonesia during the 2016–2025 period. The primary focus of this study is learning models, student outcomes, the patterns of relationships between models and outcomes, and research gaps that remain to be addressed. Specifically, this study is designed to answer the following research questions:

1. Which learning models have been most frequently studied in science education research during the 2016–2025 period, and what factors underlie their dominance?
2. Which learning *outcomes* were most frequently examined in science education research, and why is there a concentration on specific *outcomes*?
3. What is the pattern of the relationship between learning models and the resulting *outcomes*, and what are the pedagogical implications?
4. What trends in learning models and outcomes emerged during the 2024–2025 period, and what factors likely drove these shifts?
5. Which learning models and *outcomes* remain under-researched, and why is it important to address this gap?

METHODOLOGY

Research Design

This study employs a Systematic Literature Review (SLR) approach to comprehensively examine trends in learning models and their implications for student learning outcomes over the 2016–2025 period. The study was conducted in accordance with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which encompass four main stages: identification, screening, eligibility assessment, and inclusion (Kuncoro et al., n.d.; Psicología & Educación, 2022).

Literature Search Strategy

The literature search was conducted using the Publish or Perish (PoP) application, which is integrated with the Scopus database as the primary source of research data. The publication range was limited to 2016–2025 to capture the latest developments in educational research, particularly those related to learning models and student outcomes in science education. The search strategy employed a combination of English keywords with Boolean operators (AND, OR), specifically: (“Science education”) AND (“Indonesia”). This query was used to obtain a broad initial scope of science education research in Indonesia. Subsequently, the screening and eligibility process focused on empirical articles that explicitly discussed science learning models and learning outcomes.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were established to ensure that the articles analyzed are relevant to the research objectives and have adequate methodological quality. Included articles are Scopus-indexed empirical studies (quantitative, qualitative, or mixed-methods) that explicitly discuss learning models and learning outcomes, were published between 2016 and 2025, and are available in full text. Conversely, articles irrelevant to the research topic, duplicates, and non-journal publications such as conference proceedings, books, and reports were excluded from the analysis. Articles lacking clear research data were also excluded. Specifically, articles that only discussed learning approaches, methods, or strategies without identifying a learning model were excluded. Additionally, articles that did not measure learning outcomes and non-empirical articles—such as theoretical, conceptual, or opinion-based studies—including systematic literature reviews (SLRs), bibliometric studies, meta-analyses, and literature reviews—were excluded from the analysis.

Table 1. Inclusion-Exclusion Criteria

Aspect	Inclusion	Exclusion
Database	Scopus	Non-Scopus
Year	2016–2025	Before 2016
Publication type	Empirical journal articles	SLR, meta-analysis, bibliometrics, opinion, book, report
Focus	Science learning models and outcomes	Does not discuss models or outcomes
Context	Science education in Indonesia	Outside the context of science or Indonesia
Access	Full text available	Full text not available

Quality Assessment

Article quality assessment is conducted to ensure methodological validity and minimize the risk of bias. The assessment is performed using a checklist that covers article relevance, methodological clarity, source credibility, and data completeness. Low-quality articles are excluded from the analysis to ensure that the research results are more accurate and reliable. Each article is evaluated using ten criteria as shown in Table 2.

Table 2. Article Quality Assessment Criteria

Code	Assessment Criteria	Score 0	Score 1	Score 2
QA1	Relevance of the article to science education in Indonesia	Not relevant	Partially relevant	Very relevant
QA2	Clarity of the learning model under review	Not mentioned	Mentioned but unclear	Clearly explained
QA3	Clarity of learning outcomes	Not measured	Mentioned but unclear	Measurable and clearly explained
QA4	Appropriateness of research design	Unclear/inappropriate	Fairly appropriate	Highly appropriate
QA5	Clarity of research subject/sample	Not explained	Partially explained	Fully explained
QA6	Clarity of research instruments	Not mentioned	Mentioned but limited	Fully described
QA7	Clarity of model implementation procedures	Not explained	Explained in general terms	Explained systematically
QA8	Clarity of data analysis techniques	Not explained	Briefly mentioned	Explained clearly and appropriately
QA9	Evidence of the relationship between the learning model and outcomes	No evidence	Descriptive evidence	Clear empirical evidence
QA10	Credibility of sources and completeness of article information	Incomplete/not credible	Fairly complete	Complete and credible

Each criterion is scored from 0 to 2, so the maximum score for each article is 20. Articles with a score of 16–20 are categorized as high quality, 11–15 as moderate quality, and 0–10 as low quality. Articles in the low category are excluded from the final synthesis, while moderate- and high-quality articles are included in the analysis if they align with the research focus.

Article Selection Procedure (PRISMA)

The article selection process was conducted systematically following the PRISMA 2020 flowchart. During the identification stage, 509 articles were retrieved from the Scopus database. After removing 112 duplicate articles, 397 articles remained for screening. During the screening stage, articles were selected based on their titles and abstracts, resulting in the elimination of 160 articles because they were irrelevant to the research topic, did not fall within the context of science education, did not discuss learning models and outcomes, or only addressed learning approaches, methods, and strategies. After this stage, 237 articles remained. Next, during the eligibility assessment stage, 237 full-text articles were analyzed further. At this stage, 180 articles were eliminated for failing to meet criteria, such as not discussing learning models, not measuring learning outcomes, not being empirical studies, not being within the context of science education, not being journal articles, falling under the SLR or meta-analysis categories, or not being available in full-text format. Following the eligibility phase, articles meeting the initial criteria were evaluated using a quality assessment. Articles with low scores were excluded from the final analysis. Consequently, 57 articles that met all criteria were selected and used in the thematic synthesis.

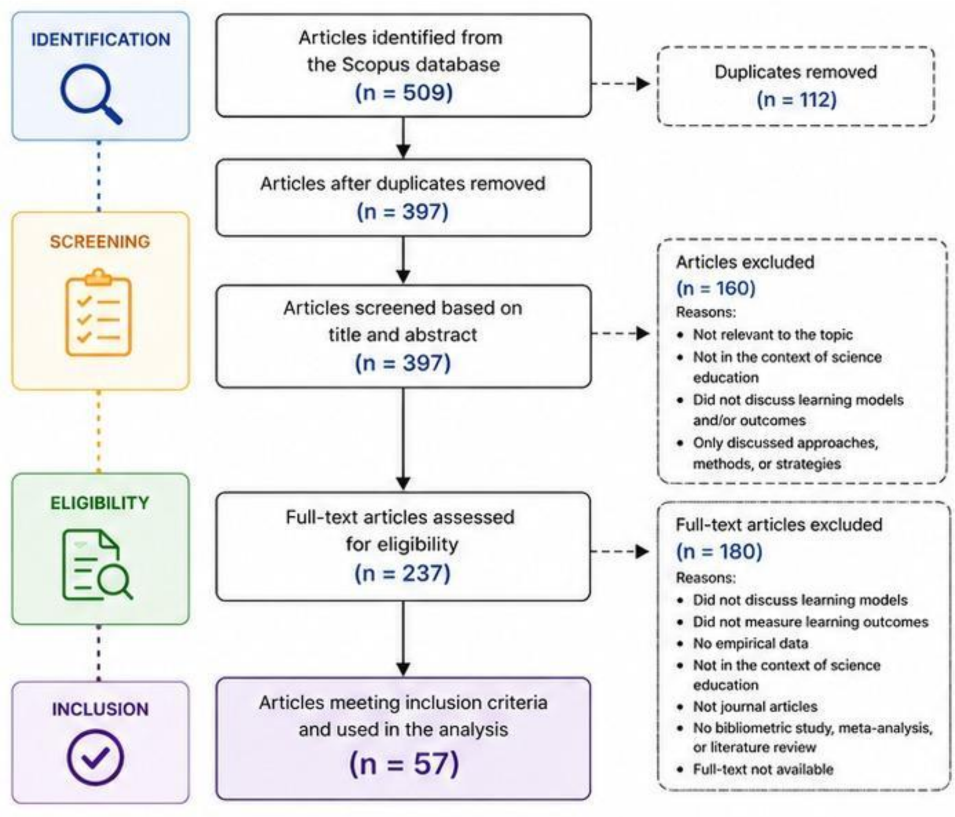

Figure 1. PRISMA Diagram

Data Extraction

Data from the selected articles were systematically extracted using Microsoft Excel to ensure structured organization of the information. The information collected included article identifiers, research methods, learning models, research subjects, research instruments, learning outcomes, and key findings. This process was conducted meticulously to ensure data accuracy and completeness.

Data Analysis

Data analysis employed thematic synthesis to identify patterns and relationships between learning models and learning outcomes. The analysis process includes data coding, theme grouping, pattern synthesis, and interpretation of results within an educational context. Through this process, a mapping of the relationship between learning models and learning outcomes was developed from the 57 analyzed articles, thereby providing a comprehensive overview of research trends in science education. A more detailed description of the article selection procedure using the PRISMA method is presented in Figure 1.

FINDINGS

This section summarizes the results of a systematic review of 57 research articles on science education from 2016 to 2025, using thematic synthesis to identify patterns in instructional models and outcomes, their relationships, trends, and research gaps. The findings indicate the dominance of certain learning models with outcomes focused on higher-order cognitive skills and science literacy, in line with global policy directions such as UNESCO's Education 2030 framework (Romli et al., 2024; Yanto et al., 2025). The results of the analysis are presented in tables, visualizations, and narrative descriptions, supported by research findings, as shown in Table 3 and Table 4.

Table 3. Distribution of Learning Models and Outcomes in Indonesian Science Education Research (2016–2025)

Learning Model	Learning *Outcome*	Year of Emergence	Number	% of Total	Model Frequency
ADDIE Model (Analysis, Design, Development, Implementation, Evaluation)	PCK / Teacher Competencies	2025	1	1.75%	1
Cooperative Learning	Learning Outcomes / Achievement	2018, 2019, 2021, 2024	4	7%	5
	Conceptual understanding	2019	1	1.75%	
Discovery Learning	Critical thinking skills	2025	1	1.75%	2
	Conceptual understanding	2020	1	1.75%	
Inquiry-Based Learning (IBL)	Critical thinking skills	2019(3), 2020(2), 2021	6	10.5%	28
	Science literacy	2020, 2023, 2024(2)	4	7	
	Learning Outcomes / Achievement	2019, 2022, 2024	3	5.2	
	Science process skills	2017, 2019, 2020(3), 2022, 2023, 2024	8	14	
	PCK / Teacher Competencies	2025(2)	2	3.5%	
	Conceptual understanding	2018, 2019, 2021	3	5.2%	
	Computational thinking	2019	1	1.75%	
	Creative thinking skills	2017	1	1.75%	
Problem-Based Learning (PBL)	Critical thinking skills	2020, 2021, 2025(2)	4	7%	11
	Science literacy	2016, 2020, 2025	3	5.2	
	Learning Outcomes / Achievement	2022, 2025	2	3.5%	

Learning Model	Learning *Outcome*	Year of Emergence	Number	% of Total	Model Frequency
Project-Based Learning (PBL)	Student engagement	2020(2)	2	3.5%	9
	Science process skills	2019, 2024	2	3.5%	
	Creative thinking skills	2021	1	1.75%	
	Teachers' reflective thinking skills	2025	1	1.75	
	Critical thinking skills	2025	1	1.75%	
	Science literacy	2020	1	1.75%	
	Conceptual understanding	2025	1	1.75%	
	Academic and Professional Identity Development	2022	1	1.75%	
	Curriculum integration	2025	1	1.75%	
Susan Loucks-Horsley Model	Conceptual understanding	2016	1	1.75%	1

Table 3 above displays the distribution of 57 articles comprising seven main learning models with a total of 12 identified learning outcome variants. From the overall data, IBL was the most-studied model, with 28 studies, followed by PBL with 11 and PjBL with 9. Meanwhile, models such as ADDIE and the Susan Loucks-Horsley Model appeared only once, indicating a gap in exploration of these models. In addition to mapping the frequency of use of learning models, this study also identified the distribution of learning outcomes that have been the focus of science education research in Indonesia during the 2016–2025 period. Of the 57 articles analyzed, 12 learning outcome variants were identified, with varying frequencies, from cognitive outcomes, which have been extensively studied, to affective-social outcomes, which are still relatively rarely the focus of research. The complete distribution of these outcomes is presented in Table 4 below.

Table 4. Distribution of Learning Outcomes in Indonesian Science Education Research, 2016–2025

Learning Outcome	Total	Percentage
Critical thinking skills	12	21.05%
Science process skills	10	17.54%
Learning Outcomes/Achievements	9	15.79%
Science literacy	8	14.04%
Conceptual understanding	7	12.2%
PCK/Teacher Competencies	3	5.2%
Creative thinking skills	2	3.5%
Teachers' reflective thinking skills	1	1.75%
Student engagement	1	1.75%
Development of academic and professional identity	1	1.75%
Curriculum integration	1	1.75%
Computational thinking	1	1.75

Table 3 above displays the distribution of 57 articles comprising seven main learning models with a total of 12 identified learning outcome variants. From the overall data, IBL was the most-studied model, with 28 studies, followed by PBL with 11 and PjBL with 9. Meanwhile, models such as ADDIE and the Susan Loucks-Horsley Model appeared only once, indicating a gap in exploration of these models. In terms of outcomes (Table 4), the "use" of critical thinking skills was the most frequently studied, followed by science process skills and learning outcomes. This distribution reflects a strong research focus on developing 21st-century competencies aligned with the demands of Society 5.0 (Jinky Gomez & Gomez, 2025). It should also be noted that the percentage column is calculated based on the total number of model–outcome pairs (N = 57), so the cumulative figures reflect the proportion of each pair within the overall research landscape analyzed.

DISCUSSION

Dominant Learning Models and Underlying Factors

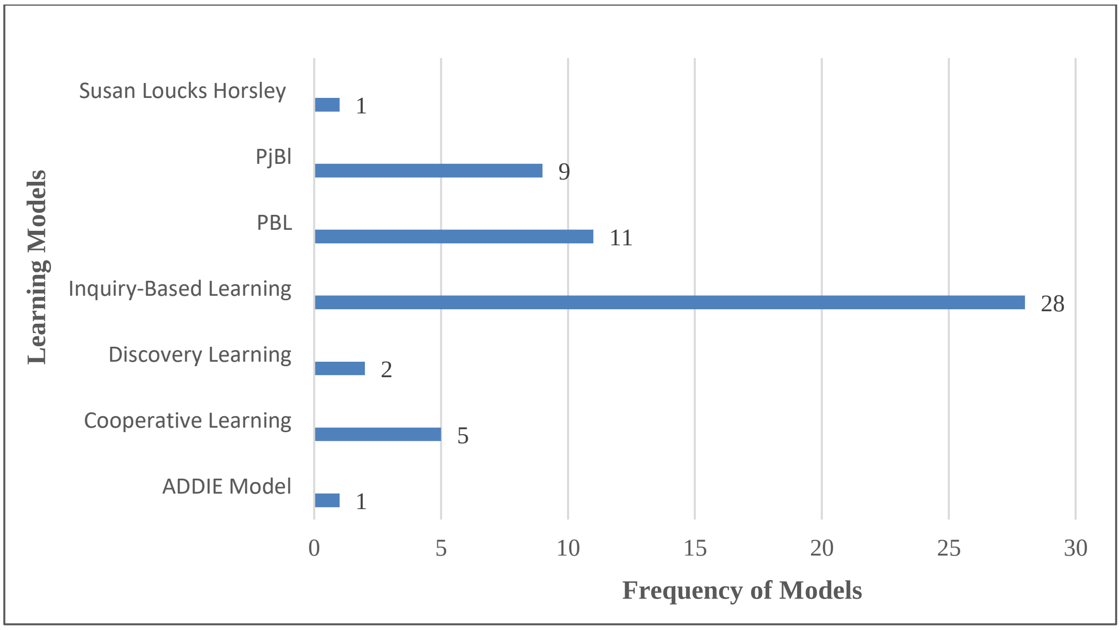

Figure 2. Frequency Diagram of Learning Model Usage in Science Education Research, 2016–2025

Based on the mapping results in Figure 2, IBL is the most frequently used learning model in science education research from 2016 to 2025, with 28 studies covering 8 outcome variants. This dominance of IBL is not coincidental but reflects a fundamental alignment between the philosophy of IBL and the demands of contemporary science education. Epistemologically, IBL is rooted in a constructivist perspective that emphasizes students' active engagement in knowledge discovery (Qablan et al., 2024; Suryati et al., 2024; Tanjung et al., 2023). This approach has proven effective in enhancing scientific thinking skills by positioning students as active agents who formulate questions, design investigations, and construct understanding based on empirical evidence. SLR findings in the K-12 context indicate that IBL supports increased motivation to learn and science literacy through activities such as observation, hypothesis testing, experimentation, and scientific reasoning. Guided inquiry is also reported to be more effective when students receive guidance, task structure, and teacher support during the investigation process (Stefvannof et al., 2025).

Several structural factors also explain the dominance of IBL in science education research. First, science curricula in various countries, including Indonesia, explicitly promote inquiry-based approaches. Indonesia's Merdeka Curriculum, for example, emphasizes learning based on the Pancasila Student Profile, which requires students to think critically and scientifically—competencies that can be directly facilitated through IBL (Agustini et al., 2024; Cahya & Katemba, 2023; Selpianti et al., 2025). Second, IBL offers high flexibility in its application across educational levels, from elementary school to higher education, and can be integrated with STEM approaches and digital technology (Manovtri et al., 2025; Sam, 2024). Third, the availability of established measurement instruments for IBL outcomes, such as critical thinking skills tests and science literacy rubrics, facilitates researchers' design of valid empirical studies (Alias et al., 2022; Kuvikova & Sollar, 2025).

These findings align with the results of a meta-analysis by Farhan (2023), which identified IBL as an effective model for improving science literacy in Indonesia. Furthermore, the consistent implementation of IBL increases intrinsic motivation among students, which serves as a key mediator of long-term academic achievement (Meulenbroeks et al., 2023; Öztürk et al., 2022). Based on the above discussion, IBL is the most dominant learning model in Indonesian science education research from 2016 to 2025, primarily due to its alignment with the characteristics of science learning, its flexibility in application, and its relevance to curriculum requirements and 21st-century competencies.

However, the dominance of IBL must also be viewed critically. The high frequency of studies on IBL does not necessarily indicate the superiority of this model over others; it is largely because IBL is relatively easier to implement in small-scale quantitative research designs and has well-established measurement instruments, making it methodologically easier to study compared to models requiring long-term measurement, such as ADDIE or Susan Loucks-Horsley. This dominance has the potential to create confirmation bias in the literature: researchers tend to choose IBL not for well-considered pedagogical reasons, but rather because of the precedent set by previous research and the ease of replicating the design (Maaß & Artigue, 2013). Consequently, claims regarding the effectiveness of IBL in the literature risk reflecting research convenience rather than pedagogical advantages that have been tested across different contexts.

Dominant Learning Models and Underlying Factors

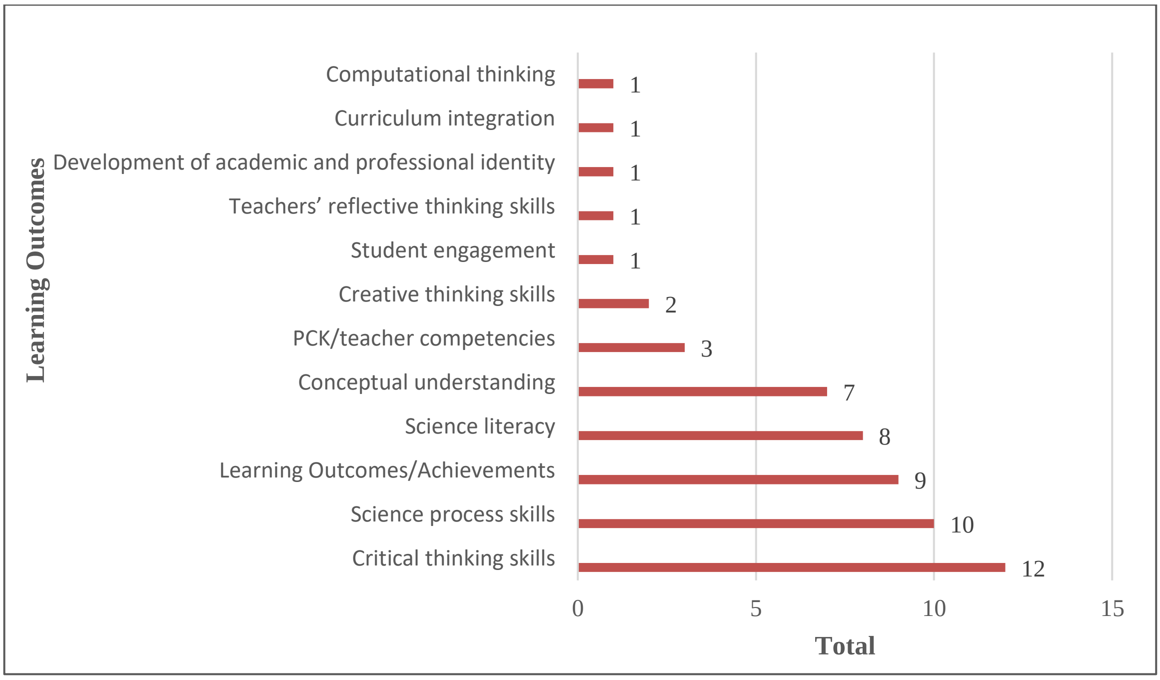

Figure 3. Frequency of Learning Outcomes in Science Research, 2016–2025

Analysis of the outcome distribution in Figure 3 shows that critical thinking skills are the most frequently studied outcome, with 12 studies (21.05% of all entries). The next most common outcomes were science process skills (10 studies), learning outcomes/achievement (9 studies), science literacy (8 studies), and conceptual understanding (7 studies). Meanwhile, outcomes such as computational thinking, student engagement, teachers' reflective thinking skills, the development of academic and professional identity, and curriculum integration each appeared in only 1 study.

The focus on critical thinking skills, science process skills, and science literacy indicates that science education research in Indonesia remains strongly oriented toward cognitive outcomes and scientific skills. These outcomes are relatively easier to operationalize through tests, rubrics, observation sheets, or assessment instruments that have been widely used in science education research (Asbanu, 2023; Khasanah & Prasetyo, 2023; Putri et al., 2024). Furthermore, these outcomes have a strong theoretical foundation and align with 21st-century competency requirements. Conversely, more complex outcomes, such as multi-representation skills, collaborative competencies, attitudes toward science, student engagement, and academic-professional identity, are still rarely studied because they require more complex, contextual, and often longitudinal measurement designs (Toepper et al., 2021).

From a theoretical perspective, critical thinking is a key competency in the revised Bloom's taxonomy by Anderson and Krathwohl and forms part of the 21st-century skills framework (Köksal et al., 2023). In the context of science education, critical thinking skills are important because they help students analyze information, evaluate evidence, construct arguments, and make data-driven decisions (Assistant Professor of

Education, 2024). Thus, RQ2 is answered: the most frequently studied outcomes are critical thinking skills, science process skills, learning outcomes, science literacy, and conceptual understanding. This concentration occurs because these outcomes are directly relevant to science learning, easier to measure, and supported by more established theoretical foundations and assessment instruments.

The prioritization of critical thinking as the primary outcome, while theoretically justifiable, carries consequences that warrant careful consideration. First, the concentration of research on cognitive outcomes risks creating a skewed perception of success in science education as if cognitive achievements reflect overall learning success, while affective and social outcomes, such as attitudes toward science or environmental awareness, are overlooked in evaluations (Good & Nichols, 2001; Lovren & Jablanovic, 2023). Second, this dominance can influence the direction of policy and teacher training, as the evidence-based recommendations available to policymakers largely focus on cognitive outcomes, leaving interventions aimed at developing non-cognitive outcomes with insufficient empirical support. Third, the methodological focus on outcomes easily measured through written tests risks reducing the definition of success in science learning to merely tested cognitive abilities, thereby neglecting the more complex and long-term dimensions of science learning.

Relationship Patterns Between Learning Models and Outcomes and Pedagogical Implications

Figure 4. Relationship Pattern Between Learning Models and Science Learning Outcomes 2016–2025

The relationship pattern between learning models and outcomes forms a complex network, as shown in the Sankey Chart in Figure 4. This visualization illustrates the relationships between the seven learning models on the left and the 12 outcomes on the right across 57 model-outcome pairs during the 2016–2025 period. Each block represents a model or outcome, with its width indicating the frequency of its occurrence. Connecting lines depict relationships within a study; the color follows the source model, while line thickness reflects the number of studies—the thicker the line, the more frequently that pair has been studied. In general, three main patterns can be identified: (1) the one-to-many pattern, in which a single model is linked to various outcomes;

(2) the many-to-one pattern, where multiple learning models lead to the same outcome; and (3) the exclusive pattern, where a specific model–outcome pair is unique and does not share connections with other entities.

IBL exhibits the strongest one-to-many pattern, with connections to 8 different outcome variants. This reflects the flexibility and adaptability of IBL as a pedagogical framework that can be applied to achieve a variety of learning objectives. In contrast, PBL places greater emphasis on four main outcomes: critical thinking skills, science literacy, learning outcomes, and student engagement, reflecting PBL's character as a model specifically designed for authentic problem situations.

The most prominent many-to-one pattern occurs in the critical thinking skills outcome, which is the target of IBL, PBL, PjBL, and Discovery Learning. This convergence indicates that critical thinking is viewed as a universal outcome that can be achieved through various models, provided the learning process involves higher-order cognitive components such as analysis, evaluation, and synthesis (Muthmainnah et al., 2024; A. D. Utami et al., 2025). Similar findings were reported by Ismayilova (2025), who found that active learning models generally contribute positively to the improvement of critical thinking, regardless of variations in their specific procedures. From a pedagogical implications perspective, the identified patterns of relationships offer several practical recommendations for educators and curriculum designers. First, science teachers need to understand that the selection of a learning model must align with the specific outcomes they aim to achieve. If the goal is to develop inquiry skills, then IBL is the most empirically sound choice. However, if the goal is to develop deep conceptual understanding alongside creative thinking skills, PjBL has proven to be more effective (Pinar et al., 2025; Rahmadani et al., 2024). Second, these findings imply that future research needs to investigate outcomes beyond those commonly studied, particularly affective and social outcomes such as scientific ethos, collaboration skills, and environmental awareness, which rarely appear in this mapping.

Trends in Models and Outcomes for the 2016–2025

To understand the current dynamics, readers should first examine the patterns in Figures 5 and 6. Figure 5 displays the trend in the number of studies per year based on learning models, while Figure 6 shows the emergence of new outcomes by comparing two periods (2016–2020 and 2021–2025).

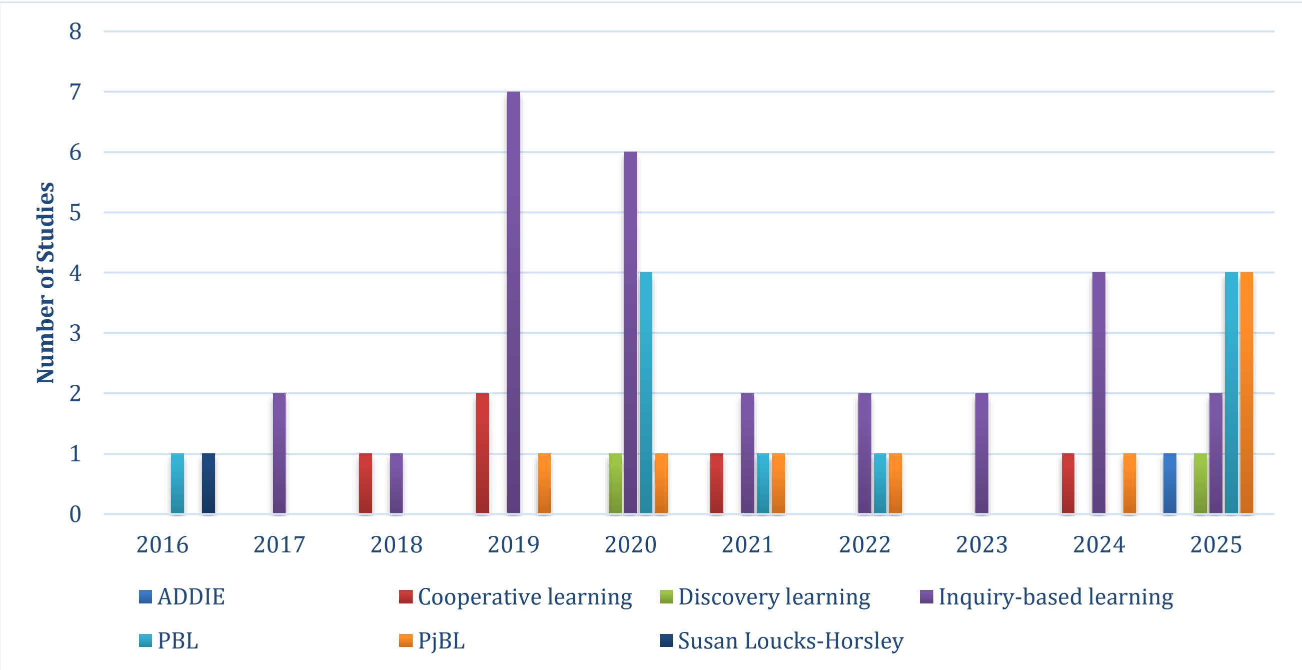

Figure 5. Graph of Trends in the Number of Studies per Year by Learning Model

As shown in Figure 5, the number of studies fluctuated during the 2016–2025 period, with a fairly significant upward trend emerging in 2024–2025, particularly regarding the IBL, PBL, and PjBL models. Meanwhile, other models such as Cooperative Learning, Discovery Learning, ADDIE, and Susan Loucks-Horsley show a tendency toward stagnation or appear only sporadically.

The shift in trends during the 2024–2025 period indicates an adjustment in the focus of science education research in Indonesia toward the dynamics of the Merdeka Curriculum, the strengthening of project-based learning, and the demands for developing 21st-century competencies. The increase in research on these three dominant models can be linked to the transition from the 2013 Curriculum to the Merdeka Curriculum, which has been gradually implemented since 2022 (Aufaa & Andaryani, 2023; Qoffal & Arif, 2025; Yusmadi et al., 2024). The Merdeka Curriculum emphasizes learner-centered learning, interdisciplinary projects through P5, and the development of 21st-century competencies, thereby aligning conceptually with the philosophies of IBL, PBL, and PjBL (NUrafifah et al., 2025; Roif Syahli et al., 2024).

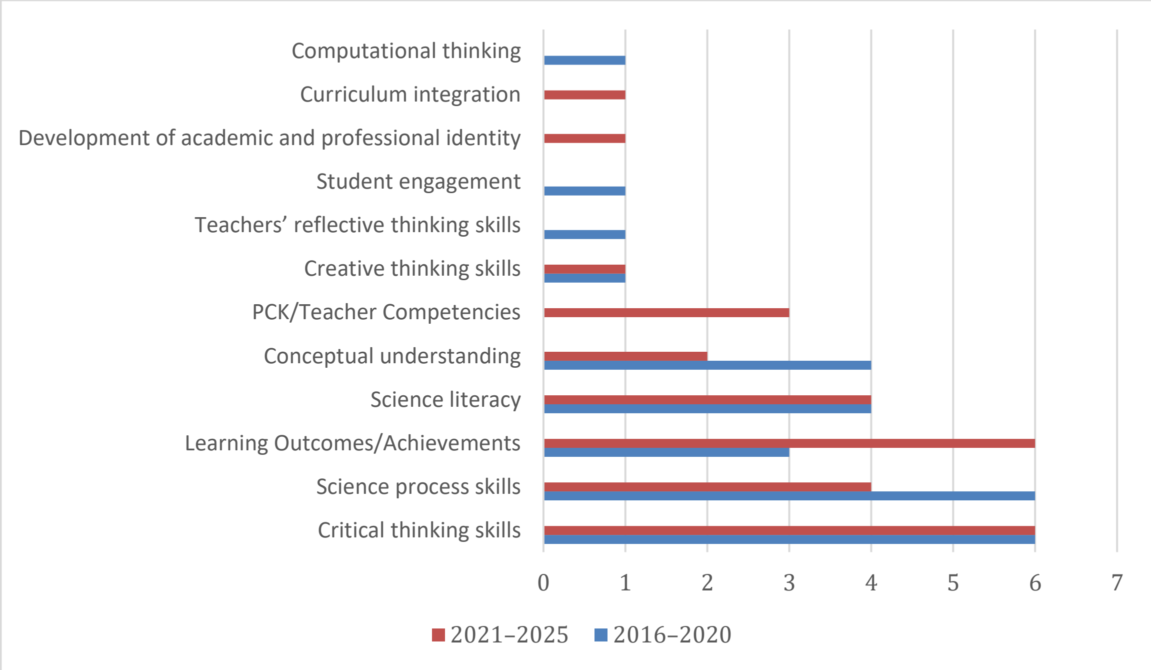

Figure 6. Emergence of New Outcomes by Period (2016–2020 vs. 2021–2025)

Figure 6 illustrates a shift in the types of outcomes examined in science education research. During the 2016–2020 period, research focused more on cognitive aspects and scientific process skills, such as critical thinking, science literacy, and conceptual understanding. Meanwhile, during the 2021–2025 period, a wider variety of outcomes began to emerge, such as PCK/teacher competencies, the development of academic and professional identity, curriculum integration, and computational thinking. This shift can be linked to the dynamics of curriculum policy in Indonesia. During the 2013 Curriculum era, research orientation tended to focus more on achieving cognitive learning outcomes and science literacy as indicators of student competence. Meanwhile, the implementation of the Merdeka Curriculum since 2022 has encouraged greater attention to more holistic 21st-century competency-based outcomes. This direction aligns with the Merdeka Curriculum's emphasis on student-centered learning, learning autonomy, cross-curricular projects through P5, and the development of essential competencies such as computational thinking, reflective skills, and teachers' pedagogical competencies (Sabeliana et al., 2024; Sappaile et al., 2024).

This shift reflects at least four key drivers. First, the transformation of the national curriculum from the 2013 Curriculum (K13) to the Merdeka Curriculum, which structurally shifts the focus of learning outcomes from a dominance of cognitive learning outcomes toward broader 21st-century competencies. This policy likely also encourages researchers to examine outcomes that were previously rarely studied, such as teachers' pedagogical content knowledge (PCK), computational thinking, and reflective skills, as a direct response to the demands of the new curriculum. Second, there is growing global attention to teacher quality in the wake of the COVID-19 pandemic. The "learning crisis" exposed during the pandemic has prompted researchers to examine not only student achievement but also teachers' pedagogical competencies as key variables in learning quality (Parahita, 2022; Teguh Supriyanto et al., 2023). This explains why PCK and teacher competencies have begun to emerge as outcomes in recent studies.

Third, the influence of the Sustainable Development Goals (SDG 4) agenda, which promotes improvements in the quality and inclusivity of science education globally. Sayadi (2025) notes in their review that science education research from 2022 to 2025 shows a sharp increase in studies explicitly linking learning strategies to SDG 4 targets, including through the development of more robust teacher competencies.

Fourth, advancements in artificial intelligence (AI) and the digitalization of learning are also driving the emergence of new outcomes such as computational thinking and digital literacy. Although computational thinking appears only once in this mapping, global trends indicate that this outcome will receive increasing attention in future research on science education, alongside the integration of programming and data analysis into science curricula (Jayawardana, 2025; Rochintaniawati et al., 2024).

Trends in 2024–2025 also reveal a growing tendency toward more holistic research, moving beyond measuring single outcomes to simultaneously exploring relationships among learning models, technological contexts, and multiple outcomes. Kurniawan (2024) notes that integrating augmented reality with inquiry-based learning models yields greater improvements in critical thinking skills than when the model is applied without technological support, indicating that technology, as a mediating variable, will become increasingly relevant in future research.

It should be noted that the surge in research on IBL, PBL, and PjBL during the 2024-2025 period can also be interpreted as a form of academic isomorphism, in which researchers follow trends deemed suitable for publication because they align with the policy narrative of the Kurikulum Merdeka, rather than merely responding to empirically identified pedagogical needs (Noer, 2025). This pattern risks narrowing the epistemological diversity of science education research in Indonesia, as models that do not explicitly meet the requirements of the Kurikulum Merdeka, such as Cooperative Learning or Discovery Learning, are likely to become increasingly marginalized, even though they possess distinct pedagogical value and cannot be replaced by the dominant models.

Research Gaps: Rarely Studied Models and Outcomes and Their Urgency

Based on the mapping of 57 articles in Table 1, the learning models that remain rarely studied are the ADDIE Model, the Susan Loucks-Horsley Model, Discovery Learning, and Cooperative Learning. The ADDIE Model and the Susan Loucks-Horsley Model each appear only once, while Discovery Learning appears twice and Cooperative Learning five times. These findings indicate that science education research in Indonesia remains concentrated on specific active learning models, particularly IBL, PBL, and PjBL.

In terms of outcomes, several learning outcomes also appear only in very limited numbers, such as computational thinking, teachers' reflective thinking skills, student engagement, the development of academic and professional identity, curriculum integration, and PCK/teacher competencies. The low frequency of these outcomes indicates that science education research in Indonesia still focuses primarily on cognitive outcomes and scientific skills, such as critical thinking, science process skills, learning outcomes, science literacy, and conceptual understanding.

This gap is important to address because the rarely studied models possess distinct pedagogical potential. Cooperative Learning, for example, is relevant for developing students' collaboration, communication, social responsibility, and interpersonal skills (Harjun et al., 2025). Discovery Learning can strengthen the process of independent concept discovery. At the same time, the ADDIE and Susan Loucks-Horsley Models can enrich research on instructional design, teacher professional development, and the improvement of the quality of science learning (Matamay et al., 2023; N. Utami & Arju, 2025; Wulandari & Nurhayati, 2018).

In terms of outcomes, the scarcity of research on computational thinking, student engagement, teacher competencies, and academic-professional identity indicates the need to broaden research focus from a dominance of cognitive outcomes toward more affective, social, professional, and transformative outcomes. Therefore, future research needs to expand the variety of learning models and outcomes so that the mapping of science education focuses not only on academic achievement but also on the more holistic development of 21st-century competencies. Thus, the research gap lies in the limited exploration of non-dominant learning models, such as ADDIE, the Susan Loucks-Horsley Model, Discovery Learning, and Cooperative Learning, and the scarcity of studies on affective, social, professional, and transformative outcomes. It is important to address these gaps so that science education research in Indonesia can provide a more comprehensive picture of the development of student and teacher competencies in meeting the demands of 21st-century learning.

If this gap is not addressed immediately, systemic risks need to be anticipated. First, teachers and curriculum designers will continue to rely on recommendations based on dominant models (IBL, PBL, PjBL) even though the characteristics of the students or the actual learning context are better suited to non-dominant models, resulting in a mismatch between the models recommended in the literature and the real needs in the classroom. Second, the lack of research on models such as ADDIE and Susan Loucks-Horsley, which focus on instructional design and teacher professional development, risks slowing capacity building for science teachers in Indonesia, given that both models are conceptually relevant to the needs of continuous professional development under the Merdeka Curriculum. Third, the limited research on affective-social outcomes risks perpetuating a narrow definition of success in science education, resulting in a generation of students who may be cognitively strong but underdeveloped in collaboration, scientific attitudes, and concern for environmental issues, competencies that are precisely emphasized in the 21st-century competency framework and the Pancasila Student Profile itself.

The findings of this study make theoretical contributions in three areas. First, this study reinforces the understanding that the dominance of a particular learning model in the literature cannot be interpreted solely as an indicator of pedagogical superiority but is also influenced by the ease of methodological operationalization. This nuance has rarely been explicitly discussed in bibliometric studies of science education. Second, the identified patterns of one-to-many, many-to-one, and exclusive relationships expand the theoretical understanding of how learning models and outcomes are interrelated, going beyond conventional bibliometric approaches that typically report only frequencies and do not map these relationships. Third, by directly linking shifts in outcome trends to transitions in national curriculum policy, this study contributes empirical evidence to the theory of educational policy diffusion—specifically, how changes in curriculum policy at the national level can be measurably reflected in the direction of the academic research agenda over a relatively short period of time.

CONCLUSION

This systematic review of 57 research articles on science education from 2016 to 2025 not only confirms the dominance of IBL, PBL, and PjBL, as well as the focus on critical thinking skills as outcomes, but more importantly, reveals that this pattern of dominance is most likely shaped by methodological convenience and narrative alignment with curriculum policies, rather than solely by evidence of pedagogical superiority. This finding shifts the way we interpret the landscape of science education research in Indonesia: not as a field that has “matured” around specific models and outcomes, but rather as one that still contains significant areas that have not been explored in proportion to their importance. Theoretically, this study contributes a relational model–outcome mapping framework that can be replicated in other fields of study, while practically, the results of this mapping serve as a basis for teachers, curriculum designers, and researchers to shift some of their attention away from models and outcomes that have been extensively studied toward combinations that are more diverse and relevant to 21st-century competencies as a whole.

This study has several methodological limitations that must be acknowledged. The search scope, which was limited to a single database (Scopus) with an English-language restriction, may have excluded relevant studies from other sources. The thematic coding process, conducted by a single team without an inter-rater reliability test such as Cohen’s Kappa, is susceptible to subjectivity. The study’s focus on the Indonesian context also limits the generalizability of the findings globally. Furthermore, the thematic synthesis approach cannot quantify effect sizes as meta-analyses do. Future researchers are advised to expand the database's scope, include multilingual publications, involve independent reviewers, and consider a meta-analysis to produce more representative and methodologically valid conclusions.

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