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Trends in Research and Development (R&D) Using the Inquiry Model in Science Learning: A Systematic Literature Review

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Abstract

This study is a systematic literature review (SLR) that maps trends in research and development (R&D) using inquiry-based approaches in science learning. The review protocol was prepared a priori, and reporting follows PRISMA 2020, with procedures adapted from Kitchenham and Charters' systematic review guidelines. In the context of 21st-century education and the growing use of digital learning, inquiry-based learning has been promoted as a way to cultivate higher-order thinking and scientific practices. The mapping synthesis draws on 43 eligible studies and shows that inquiry models are widely used to guide students in investigating problems through structured questioning, experimentation, and evidence-based reasoning.

Keywords: inquiry model, 21st-century skills, science learning.

Introduction

Research is a systematic scientific endeavour that contributes to solving problems through evidence-based investigation. The problem-solving process reflects actions that are systematic, consistent, operational, objective, logical, and empirically verifiable to achieve targeted goals (Kurniawan, n.d.). In this study, improving learning quality is closely linked to the capacity to generate new processes and products. Innovations produced through research and development (R&D) can help address challenges in classroom learning (Alvarado et al., 2021) by enabling more varied and engaging learning experiences for students (Dharmawan et al., 2021).

Effective learning requires appropriate strategies and sustained interaction between teachers and students. Recent work indicates that inquiry-based learning plays an important role in supporting successful learning (Kriewaldt et al., 2021). Inquiry learning is an inductive approach in which students engage with a topic, generate investigable questions about the natural, cultural, or material world, identify the information required, collect and synthesize data, and then communicate and evaluate their findings (Kriewaldt et al., 2021).

However, inquiry-based learning is interpreted and enacted differently by educators and students in science classrooms. Inquiry learning reflects contemporary perspectives on thinking and inquiry activities that can promote deeper science learning (Murphy et al., 2021). Research also shows that many teachers struggle with both science content and ways to engage students in inquiry-based scientific practices, which are central to learning science (Haug & Mork, 2021).

Inquiry-based science learning can be strengthened through technology-enhanced learning, which continues to expand rapidly. Several studies have developed inquiry-oriented learning resources by leveraging educational technologies (Liesa-Orús et al., 2020), with the aim of improving learners' 21st-century skills. These innovations include electronic learning materials such as e-books, e-modules, e-worksheets, and other interactive learning media (Nurhayati et al., 2021).

Based on the background above, this study aims to examine and map trends in R&D studies that employ inquiry learning models in science education. By identifying dominant inquiry types, developed products, educational contexts, measured outcomes, and development models, the findings can inform researchers, teachers, and practitioners when selecting and designing inquiry-based learning in classrooms. The review was guided by six research questions aligned with the mapping objectives (see the Research Method section).

Methodology

This study employed a systematic literature review (SLR) approach to identify, classify, and synthesize research trends on inquiry-based R&D in science learning. Unlike effectiveness-focused systematic literature reviews (SLRs), an SMR primarily aims to map the research landscape (topics, methods, settings, products, and gaps). Protocol and reporting guideline. A review protocol was developed before the search was conducted, covering the review questions, databases, search strings, eligibility criteria, screening steps, data extraction fields, coding rules, and quality appraisal. Reporting of identification, screening, eligibility, and inclusion follows a PRISMA-style flow (PRISMA 2020). Research questions. The review was guided by six questions: (1) what inquiry model types are used in science learning R&D studies, (2) what products are developed, (3) what education levels are targeted, (4) what science domains are addressed, (5) what variables/outcomes are measured, and (6) what development models are applied.

Search strategy. Searches were conducted in four sources: Google Scholar, DOAJ, ResearchGate, and targeted journal websites (publisher/journal homepages). The search was limited to publications from 2016–2021 and to articles that report inquiry-based R&D in science learning. Table 1 presents the databases and example Boolean search strings; the same core keywords were translated into Indonesian where relevant (e.g., inquiry/inkuiri, research and development).

Table 1. Databases and search strings used in the review

Criterion	Inclusion (operational)	Exclusion (operational)
Publication type	Peer-reviewed journal article or full conference paper reporting inquiry-based R&D in science learning.	Book chapter, thesis/dissertation, editorial, opinion piece, abstract-only, or non-scholarly report.
Publication year	2016–2021 (inclusive).	Before 2016 or after 2021.
Language	English or Indonesian.	Other languages without accessible translation.
Topical focus	Inquiry model applied within science learning (IPA/biology/physics/chemistry) context.	Not about inquiry learning or not in science learning context.
Study type	R&D / development research (e.g., 4D, ADDIE, Borg & Gall, Design-Based Research) producing a learning product/intervention.	Non-development studies (pure experiment without product development; surveys; theoretical essays) unless explicitly R&D.
Population/setting	Any education level (elementary to higher education) where inquiry-based science learning is implemented or developed.	Outside educational setting (industry training, non-science subjects).
Outcome reporting	Reports at least one mapped attribute: inquiry type/product/level/domain/variables/development model.	Insufficient information to code the mapped attributes.

Accessibility	Full text available for screening and extraction.	Full text not accessible after reasonable attempt.
Duplicates	Most complete version retained.	Duplicate record removed.
Quality threshold (optional)	Meets minimum quality score in Table 5 (if exclusion applied).	Very low quality if exclusion is applied (report in Table 3).

Eligibility criteria. Inclusion and exclusion criteria were defined operationally to ensure consistent screening and to support the SMR objective (mapping trends). Table 2 summarizes the criteria used during title/abstract screening and full-text eligibility assessment.

Table 2. Operational inclusion and exclusion criteria for the mapping review

Category	**Inclusion Criteria**
Publication type	Inquiry-based research development research articles
Publication year	2016-2021
Aspect	Science, Physics, Biology, Chemistry
Research subject	Students and educators at the elementary, junior high, high school and college levels
Research type	Empirical and theoretical

Study selection and PRISMA counts. Records were exported into a screening list, duplicates were removed, and studies were screened by title and abstract. Full texts of potentially relevant studies were retrieved and assessed for eligibility. The number of records at each stage and reasons for exclusion are reported in Table 3 and visualized in Figure 1.

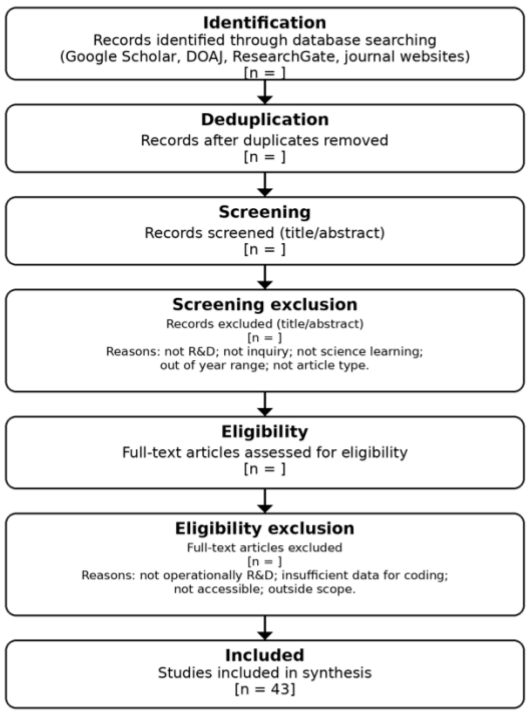

Figure 1. PRISMA 2020-style flow diagram of study identification, screening, eligibility, and inclusion.

Data extraction and coding. A structured extraction sheet was used to code each included article: year, country/context (if reported), inquiry model type, developed product, education level, science domain, measured variables/outcomes, development model, and key findings relevant to the mapping questions. Coding followed a codebook (Table 3). Ambiguous cases were re-checked against the full text and resolved through discussion among the authors.

Table 3. Quality appraisal checklist and scoring rule

Item	Criterion	Score	
		Yes (1)	No (0)
QA1	Clear objectives and rationale for the developed product reported.		
QA2	R&D/development procedure described (model/phases) sufficiently for replication.		
QA3	Participants/setting described (education level, context).		
QA4	Validation/evaluation method described (expert review, trial, effectiveness test).		
QA5	Data analysis described and aligned with results (quantitative/qualitative).		
QA6	Limitations or threats to validity discussed.		

Note: Sum QA1–QA6 (0–6). Recommended interpretation: 5–6=high, 3–4=medium, 0–2=low.

Quality appraisal. To address methodological credibility, each included study was appraised using a brief checklist adapted from common SLR guidance (e.g., clarity of objectives, adequacy of methods, description of development/validation, and transparency of data analysis).

Synthesis. The mapping synthesis used descriptive statistics (frequencies and percentages) to summarize trends, followed by narrative interpretation to explain patterns, gaps, and implications for inquiry-based R&D in science learning.

In summary, the systematic literature review was conducted through (1) formulating review questions, (2) conducting database and website searches using predefined strings, (3) screening and eligibility assessment using operational criteria, (4) extracting and coding data with a structured codebook, (5) appraising study quality, and (6) synthesizing the mapped evidence descriptively and narratively to answer the review questions.

Result and Discussion

Overview of included studies. A total of 43 articles met the eligibility criteria and were included in the synthesis. Because this study is a systematic literature review, the synthesis emphasizes distributions (frequencies/percentages) and thematic patterns rather than estimating effect sizes. Quality appraisal results (Table 5) are used to interpret the strength of evidence behind the mapped trends.

1. Inquiry Learning Model Types

Inquiry-based learning R&D studies published between 2016 and 2021 were conducted by researchers in Indonesia. The topic is well established; however, the mapped literature shows that publications continued to increase across the period.

The reviewed studies applied several inquiry types. Table 2 indicates that guided inquiry (59%) is the most frequently used approach, followed by inquiry models reported as “inquiry” (30%) and argument-driven inquiry (5%). Other variants—process-oriented guided inquiry, guided-inquiry laboratory, and interactive demonstration inquiry—collectively account for 6%.

The dominance of guided inquiry suggests that many developers prefer a structured inquiry approach that still allows students to investigate while receiving scaffolding from teachers or learning materials. This is consistent with the needs of classroom implementation where time, curriculum coverage, and students' prior experience can limit the use of open inquiry. Therefore, guided inquiry is often selected to balance scientific investigation with practical constraints. Future studies may compare the effectiveness of guided inquiry versus more open inquiry types across different learner readiness levels.

Table 4. Trends in inquiry learning model types

Inquiry models type	Percentage
Guided Inquiry model	59%
Inquiry model	30%
ment Driven Inquiry model	5%
Process Oriented Guided Inquiry model	2%
Guided Inquiry Laboratory model	2%
Inquiry Interactive Demonstration model	2%

Table 4 also suggests that guided inquiry receives the greatest attention. One study reported that students perceived guided inquiry lessons as interesting and interactive because teachers posed questions that were then investigated experimentally. Such activities can stimulate discussion and enrich science learning activities (Septiani & Susanti, 2021).

2. Research and Development Results

Regarding developed products, the most common output was complete learning-tool packages (23%), typically consisting of worksheets, modules, syllabi, lesson plans (RPP), and test instruments. This was followed by worksheets (20%), modules (16%), and other instructional materials. Overall, inquiry-based R&D mainly targets classroom-ready materials intended to foster students' inquiry skills and other 21st-century competencies.

The high proportion of learning tools (including worksheets, modules, syllabus/RPP, and assessment instruments) indicates that inquiry-based R&D in science learning is largely oriented to improving classroom implementation through concrete teaching packages. However, the relatively smaller proportion of technology-rich products (e.g., interactive media, simulations, or digital platforms) signals a potential gap for future developments, especially considering the increasing relevance of digital learning environments. Further research can explore how digital inquiry environments influence inquiry skills and higher-order thinking.

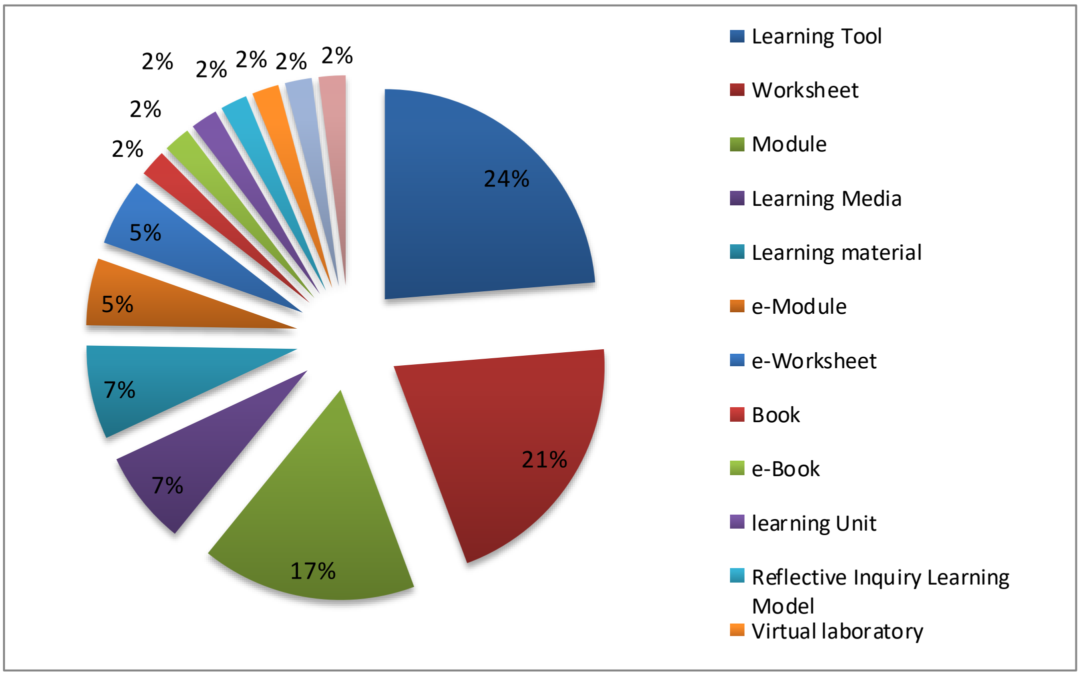

Figure 2. Trends in inquiry-model-based development product topics

3. Education Stages

The mapped studies were most frequently conducted at the senior high school level (SMA/MA; 58%), followed by junior high school (SMP/MTs; 35%) and higher education (7%). The predominance of SMA/MA contexts may reflect the suitability of inquiry activities for learners who can engage in knowledge construction and concept development by building on prior understanding (McKibben & Murphy, 2021). Interpretation. The concentration at the senior high school level may reflect curriculum demands for scientific reasoning and laboratory-based activities, which align well with inquiry learning. The lower representation in higher education suggests an opportunity to develop inquiry-based R&D products tailored to university contexts, such as inquiry-based virtual laboratories, research-method courses, or inquiry-oriented STEM projects. In addition, more studies at the elementary level could clarify how inquiry scaffolding should be adapted for younger learners.

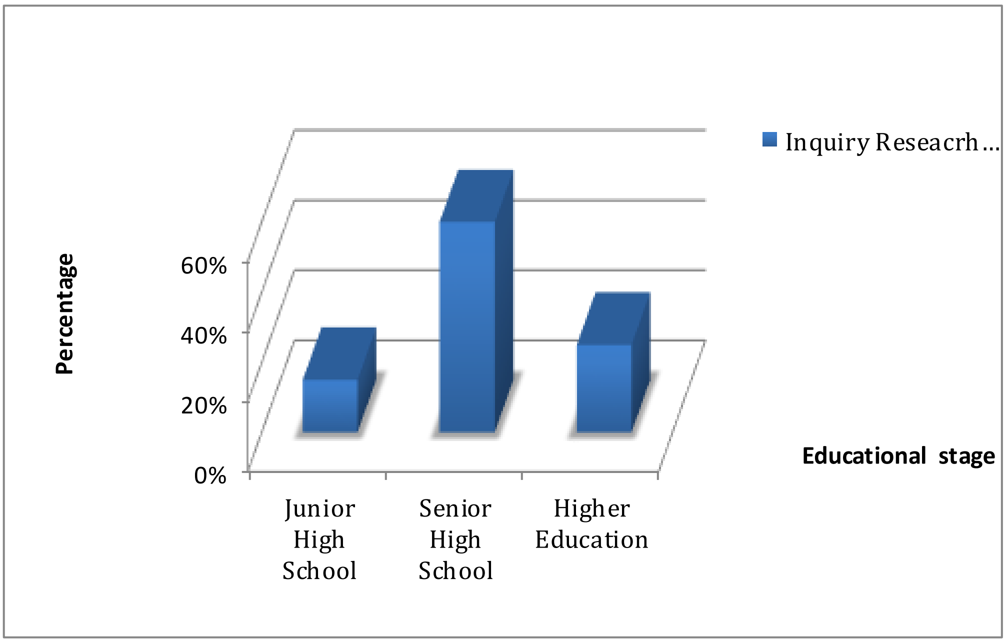

Figure 3. Educational level of inquiry model-based development research trends

The tendency in the SMP/MTs education environment is lower because the learning context that is built is not as complex as that in high school level learning. Meanwhile, in universities, the interest of researchers in conducting development research related to the inquiry model for the last 7 years is very little found, due to several possibilities, such as universities having the right to contribute to innovation in learning.

4. Science Learning Types

Across science domains, biology accounted for the largest share of studies (41%), closely followed by physics (40%), with general science (14%) and chemistry (5%) comprising the remainder. The high proportion of biology and physics studies is consistent with the dominance of SMA/MA settings in the dataset. Biology and physics dominate the inquiry-based R&D literature in this sample, while chemistry appears underrepresented. This imbalance may be related to differences in laboratory requirements, safety constraints, or the availability of inquiry-friendly contexts. Chemistry inquiry developments could be strengthened through the use of microscale experiments, virtual labs, or context-based inquiry tasks that reduce resource barriers. Cross-disciplinary inquiry products may also help integrate science domains more effectively.

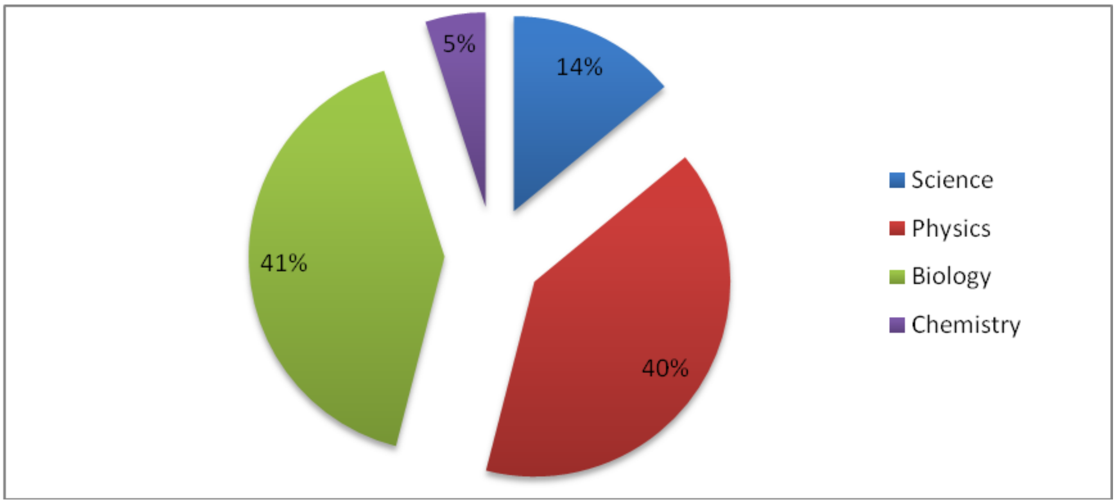

Figure 4. Science domains addressed in inquiry-model-based development research

5. Variables Related to Inquiry Research

Inquiry-based learning research commonly examines learning outcomes alongside specific variables. In this review, critical thinking was the most frequently measured variable (41%), followed by creative thinking (18%), science process skills (15%), scientific literacy (11%), and 21st-century skills (2%), with the remainder distributed across other outcomes. Critical thinking is the most frequently measured outcome, indicating that inquiry-based R&D is often justified by its potential to improve higher-order reasoning. Nevertheless, the relatively low percentage of 21st century skills suggests that many studies still focus on specific cognitive skills rather than broader competencies (collaboration, communication, creativity, and digital literacy). Future inquiry-based R&D studies may employ validated multidimensional instruments to capture these broader competencies and to examine trade-offs among outcomes (e.g., critical thinking versus scientific literacy).

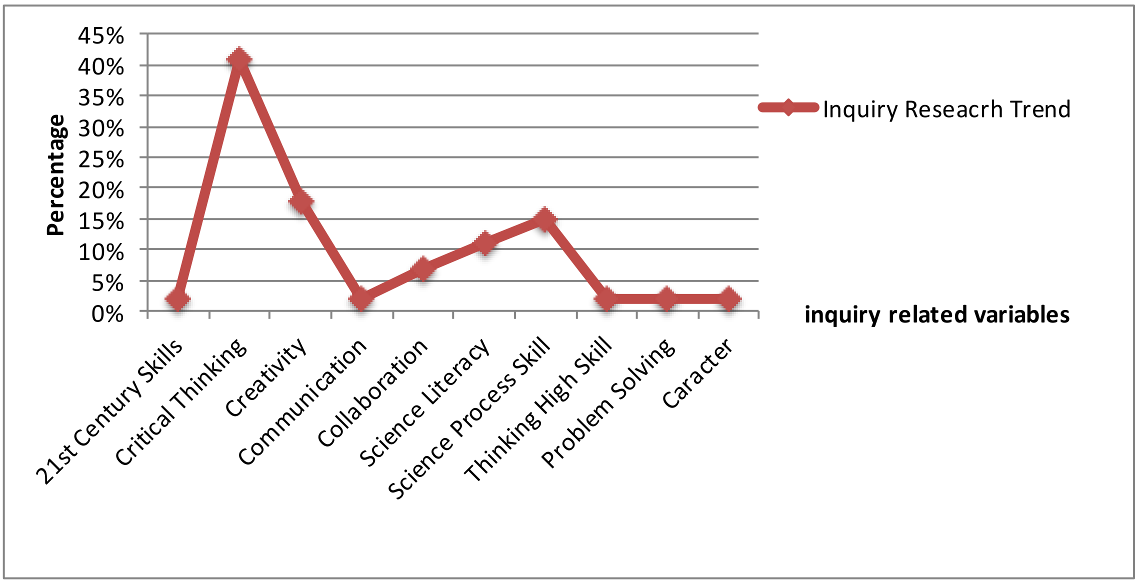

Figure 5. Outcome variables examined in inquiry-model-based development research

Graph 5 shows the distribution of outcome variables examined in inquiry-based R&D studies. Critical thinking and creative thinking together account for about 40% of the measured variables. This pattern aligns with the view of inquiry learning as a problem-solving process that engages students in investigation. Prior studies recommend investigation-centered activities to promote 21st-century learning, particularly critical thinking. The mapped evidence supports this view, suggesting that inquiry lessons encourage students to actively construct knowledge through critical thinking processes. One study also reported a significant positive effect of inquiry learning on students' critical thinking in science (Novitra, 2021).

6. Development Model

The literature indicates that instructional development methods are widely used to design inquiry-based learning products. Researchers employed various development models, including 4D, ADDIE, Borg and Gall, Plomp, Dick and Carey, Kemp, Fenrich, and others. In this review, the 4D model was most common (49%), followed by ADDIE (19%), Borg and Gall (16%), Plomp (7%), Dick and Carey (5%), and Kemp and Fenrich (2%). The preference for the 4D model may be driven by its clear stages (define, design, develop, disseminate) and its compatibility with developing learning tools such as modules and worksheets. However, researchers should justify the choice of development model based on the nature of the product and validation needs. For example, more complex digital products may benefit from iterative design-based research cycles or usability testing stages that are not always emphasized in traditional instructional development models.

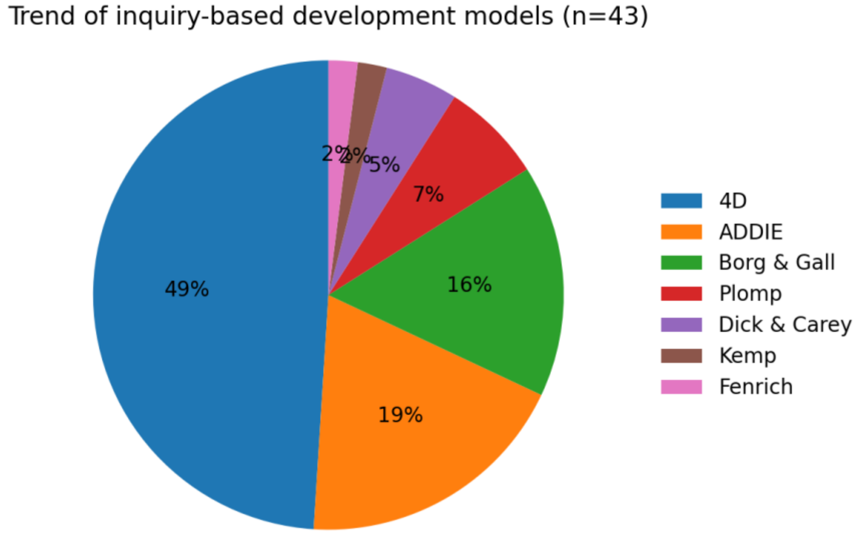

Figure 6. Development models used in inquiry-model-based research

The preference for the 4D development model may be influenced by researchers' perceptions that it is relatively simple while remaining systematic and well structured.

7. Cross-study critical synthesis

Across the 43 included studies, several consistent patterns emerge when the mapped categories are interpreted together. First, inquiry-based R&D in Indonesian science education is dominated by guided inquiry and by the development of classroom-ready learning tools (e.g., modules, worksheets/LKPD, lesson plans/RPP, and assessment instruments). This combination suggests that the field prioritizes feasibility and scaffolding: researchers tend to translate inquiry principles into structured learning packages that can be implemented within typical constraints of time, curriculum coverage, and learner readiness. Second, the concentration of studies at particular education stages and topics indicates that inquiry development efforts are not evenly distributed across the science curriculum; certain grades and topics receive more attention, while other topics and levels remain underdeveloped. Third, the frequent use of conventional instructional development models (especially 4D and ADDIE) shows that inquiry is often treated as the pedagogical content of the product, whereas the development process itself follows standard design-and-validation routines. This alignment is productive for generating validated materials, but it can also limit the depth of evidence about enactment and impact in real classrooms.

8. Differences, contradictions, and depth of impact

The mapped evidence base is not uniform, and a critical reading reveals differences that should be acknowledged. Many studies report positive trends (e.g., improvements in thinking skills, inquiry skills, or learning outcomes), but the depth of impact is often difficult to compare across papers because outcome measures, research designs, and reporting practices vary. Some studies evaluate products primarily through expert validation and limited trials, while fewer studies report robust classroom implementation evidence (e.g., larger samples, multiple schools, longer durations, or follow-up measures). In addition, inquiry 'type' is rarely treated as a comparative variable; guided inquiry dominates, but direct comparisons with more open forms of inquiry are uncommon. This creates an apparent contradiction: inquiry is theorized as a continuum from highly scaffolded to open investigation, yet the empirical R&D literature tends to concentrate on the scaffolded end, making it unclear whether reported gains are attributable to inquiry per se, the provided scaffolds, or other accompanying design features (e.g., worksheets, structured prompts, teacher guidance). Where outcomes appear inconsistent, plausible explanations include differences in implementation fidelity, teacher facilitation skill, learner prior knowledge, and the alignment between assessment tasks and inquiry objectives.

9. Linking findings to inquiry learning frameworks

The dominance of guided inquiry and product-focused R&D can be interpreted through established inquiry learning frameworks. From a constructivist perspective, inquiry supports knowledge construction through active investigation, but effective inquiry requires scaffolding, particularly for novice learners (Vygotsky, 1978; Hmelo-Silver, Duncan, & Chinn, 2007). Guided inquiry aligns with the idea of 'fading' support: learners begin with structured prompts and gradually assume greater epistemic responsibility. This also resonates with cognitive apprenticeship (modeling, coaching, scaffolding, and reflection) and with inquiry cycles commonly operationalized in science education (e.g., orientation/questioning, hypothesizing, planning and conducting investigations, analyzing data, and communicating explanations) (Pedaste et al., 2015). However, the mapping indicates that many products emphasize procedural steps without always documenting how core inquiry elements are enacted: how questions are generated, how evidence is evaluated, how explanations are justified, and how reflection is facilitated. Therefore, future development work should explicitly align product components (tasks, prompts, media, and assessments) to the targeted inquiry framework and to the intended level on the inquiry continuum (Bell, Smetana, & Binns, 2005).

10. Explicit research gaps

Based on the mapping and the critical synthesis above, the following gaps are explicit in the 2016–2021 Indonesian inquiry-based R&D literature: (1) limited comparative evidence across inquiry types (guided vs. structured vs. open inquiry) and across different levels of scaffolding; (2) limited reporting of implementation fidelity, teacher facilitation practices, and classroom enactment processes; (3) overreliance on short-term trials and product validation evidence, with few longitudinal or multi-site studies; (4) uneven coverage across topics and education levels, indicating opportunities for inquiry product development in underrepresented domains; (5) limited use of standardized or comparable outcome measures (including effect sizes) that would enable stronger cumulative claims about impact; and (6) limited integration of digital inquiry environments (e.g., virtual labs, simulations, data-logging) relative to current learning needs.

11. Theoretical and practical implications

This mapping suggests that inquiry-based R&D in the Indonesian context is evolving toward a scaffolded, implementation-oriented form of inquiry, where guided inquiry is a pragmatic translation of inquiry theory into classroom constraints. A useful next step is to articulate an explicit conceptual model that connects the inquiry continuum (level of openness), scaffolding mechanisms (prompts, tools, teacher moves), and learning outcomes (conceptual understanding, process skills, scientific reasoning). Practical implication. For developers and teachers, the findings imply that inquiry products should specify (a) the targeted inquiry level, (b) the scaffolds provided and how they will be faded, (c) the teacher facilitation moves required, and (d) assessments that capture inquiry processes (not only final answers). For researchers, future R&D reports should include transparent descriptions of classroom implementation, clearer outcome measures, and quality appraisal information to strengthen the evidence base.

12. Scientific contribution and future research directions

This article contributes by providing a transparent, PRISMA-style systematic mapping of inquiry-based R&D studies in Indonesian science education (2016–2021), including a coding framework that classifies inquiry types, developed products, education stages, research topics, and development models, supplemented by a quality appraisal checklist. Specific future research. Future work should (a) conduct comparative studies that manipulate inquiry level and scaffolding intensity; (b) evaluate inquiry products through multi-site classroom trials with fidelity measures; (c) report effect sizes or standardized outcomes to enable cumulative synthesis; (d) expand inquiry development to underrepresented topics and levels; and (e) explore technology-supported inquiry (virtual labs, simulations, and data analysis tools) and how these environments mediate students' scientific reasoning and process skills.

Conclusion

This systematic literature review (2016–2021) synthesized 43 inquiry-based R&D studies in Indonesian science education. Overall, the field is dominated by guided inquiry and by the development of classroom-ready learning tools (e.g., modules, worksheets/LKPD, lesson plans/RPP, and assessment instruments), most often developed using conventional instructional development models such as 4D and ADDIE. While many studies report positive learning-related outcomes, the depth of impact is difficult to compare across papers because implementation evidence, fidelity reporting, and outcome measures vary substantially.

Beyond summarizing trends, this article provides a transparent PRISMA-style mapping procedure, an explicit coding framework, and a quality appraisal checklist that can be reused in subsequent reviews. The implications are that inquiry products should clearly specify the intended inquiry level, scaffolding and fading mechanisms, required teacher facilitation moves, and assessments that capture inquiry processes. Future research should prioritize comparative studies across inquiry levels and scaffolding intensity, multi-site or longitudinal evaluations with fidelity measures, and technology-supported inquiry environments (e.g., virtual labs and simulations) to strengthen cumulative claims about impact.

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