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Trends and Innovations in the Development of Inquiry-Based Science Modules: A Systematic Literature Review

Munib[1], Wahab Jufri [1,2*], Agus Abhi Purwoko[1,3], Mahrus[1,4], Joni Rokhmat[1,4], AA Sukarso[1,2]

[1] Doctor of Science Education, Graduate Program Mataram University, Mataram, Lombok, Indonesia
[2] Biology Education Study Program, Faculty of Teacher Training and Education Mataram University, Mataram, Lombok, Indonesia
[3] Chemistry Education Study Program, Faculty of Teacher Training and Education Mataram University, Mataram, Lombok, Indonesia
[4] Physics Education Study Program, Faculty of Teacher Training and Education Mataram University, Mataram, Lombok, Indonesia

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Corresponding Author:
Wahab Jufri
awahabjufri@unram.ac.id

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Abstract: Natural Science (IPA) learning in the 21st century requires students to not only understand science concepts, but also to have 21st century skills such as critical thinking, collaboration, and technological literacy. To answer these challenges, the inquiry learning approach is one of the strategic solutions because it encourages active involvement of students in building knowledge through the scientific process. Inquiry-based learning modules are also rapidly developing as a medium that supports active, contextual, and flexible learning. This research aims to conduct a systematic literature review (SLR) on trends and innovations in the development of inquiry-based science modules. The study was conducted using the SLR method based on the PRISMA guidelines, by analyzing 35 articles published between 2015–2025. The results of the study show that Research and Development (R&D) methods, especially the 4D and ADDIE models, are the most widely used approaches. The inquiry model, especially guided inquiry, is the dominant approach that has proven to be effective in improving students' science process skills, literacy, and critical thinking. Various innovations were identified, including the integration of STEM approaches, PjBL, ethnoscience, as well as the development of digital modules such as e-modules and interactive flipbooks. This study highlights the importance of innovation and contextualization in the development of inquiry-based science modules to improve the quality of learning in accordance with the demands of the Merdeka curriculum and the times.

Keywords: 21st century skills; Inquiry learning; Science modules; Science literacy, SLR.

Introduction

Natural Science (IPA) learning in the 21st century is faced with the challenge of preparing a generation that not only understands science concepts, but also has critical thinking skills, creativity, ability to collaborate, and master technology and information. These competencies are known as 21st century skills (Trilling & Fadel, 2009). To address these challenges, it takes a learning approach that is student-centered and actively engages them in the process of building knowledge.

One of the learning approaches that fits these characteristics is the inquiry learning model. Inquiry places students as the main actors in the learning process, where they are expected to develop questions, investigate problems, and find answers through scientific activities (Pedaste, et al., 2015). Thus, the inquiry model emphasizes not only information transfer, but also on the process of scientific thinking and the construction of knowledge.

Research shows that inquiry-based learning is able to improve students' conceptual understanding, learning motivation, and science process skills (Minner, Levy, & Century, 2010). In addition, this approach is also considered effective in developing science literacy, which is an important indicator in assessing the success of science learning (Bybee, 2013). In the context of the Merdeka curriculum that emphasizes differentiated and project-based learning, inquiry learning is increasingly relevant to be implemented.

Learning modules are one of the important media in supporting the implementation of the inquiry model. Modules are self-paced teaching materials that are systematically designed so that students can learn actively and flexibly. Inquiry-based modules are designed to guide students through scientific stages

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such as observation, problem formulation, hypothesis, experiment, and conclusion (Prastowo, 2012; Nur, 2011). This kind of module not only facilitates the achievement of cognitive goals, but also the students' scientific skills and attitudes.

In the development process, most of the science learning modules use a research and development approach, one of which is the 4D model introduced by Thiagarajan, Semmel, and Semmel (1974). The model consists of four stages: Define, Design, Develop, and Disseminate. This model is widely used because it has a systematic flow and focuses on the validity of the developed product.

The current trend of science module development shows that the inquiry approach is often integrated with other approaches such as STEM/STEAM, Problem-Based Learning, and Education for Sustainable Development (ESD). This integration aims to enrich the learning context and increase the linkage between science materials and daily life (Beers, 2011; UNESCO, 2017). This reflects innovation in module development to answer curriculum challenges and student needs.

Although many studies have developed inquiry-based science modules, so far there have been no systematic literature reviews that analyze emerging trends and innovations. Most studies are fragmentary and do not provide a comprehensive picture of the methodological tendencies, content, development approaches, and implementation outcomes of these modules. Therefore, a systematic literature review (SLR) is needed that is able to systematically collect and evaluate the results of previous research (Snyder, 2019).

SLR as a method allows the synthesis of various primary studies with transparent and replicable procedures. Through this study, researchers can identify common patterns, innovations that are often used, dominant development methods, and potential research gaps that can be used as the basis for future research (Kitchenham & Charters, 2007). Thus, SLR plays an important role in building a solid foundation of scientific knowledge in the field of science education.

Several previous studies have shown the success of the development of inquiry-based science modules. For example, Alimah and Supardi (2019) developed a guided inquiry-based module for junior high school students and showed a significant improvement in students' science process skills. Research by Rahayu, Widodo, and Fauziah (2020) also shows that inquiry-based modules that integrate science literacy are able to increase students' understanding of concepts and learning interest in science. This shows the effectiveness of the inquiry approach in various science learning contexts.

Based on this background, this article aims to conduct a systematic literature review of various studies that develop inquiry-based science modules. This study will focus on the trend of the development model used, the integration method with other approaches, the outputs produced, and the context of implementation. The results of this study are expected to make a theoretical and practical contribution to the development of inquiry-based science modules that are more effective, innovative, and relevant to today's educational needs.

Method

This study method uses the Systematic Literature Review (SLR) approach based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The stages of the method in general are as follows:

Identify Research Questions

It is formulated according to the formulation of problems and objectives, leading to models, trends, and innovations of inquiry-based science modules.

Literature Search (Identification Stage)

Searches were conducted on scientific databases such as Google Scholar, ERIC, ScienceDirect, and Garuda with keywords such as: "*inquiry-based science module development*", "*inquiry-based learning science module*", etc. Publication deadline: 2015–2025, and only peer-reviewed articles are considered.

Study Selection (Screening Stage)

Selection is done by filtering out duplications and reading titles and abstracts to ensure relevance to the topic. The inclusion and exclusion criteria are set as follows:

a. Inclusion: Study on the development of inquiry-based science modules at the junior high/high school levels; using the R&D model; Listing the results of validation/implementation.
b. Exclusion: Opinion articles, non-peer-reviewed, not in the context of IPA/inquiry, or do not contain information about the development model.

Eligibility Evaluation

Passing articles are selected in full-text to check their suitability with the focus of the study: development model, integrative approach, and implementation output.

Data Extraction & Synthesis

The data collected includes: Year and author, Level of education, Development model used, Additional innovations/ methods included, Validation/ implementation results.

The data were analyzed qualitatively and quantitatively descriptive (e.g. trend in the number of publications per year, the dominance of R&D models, the dominance of innovative themes).

Visualization of Findings

The results were presented using a PRISMA diagram, an article categorization table, and a trend/topic graph.

Diagram PRISMA

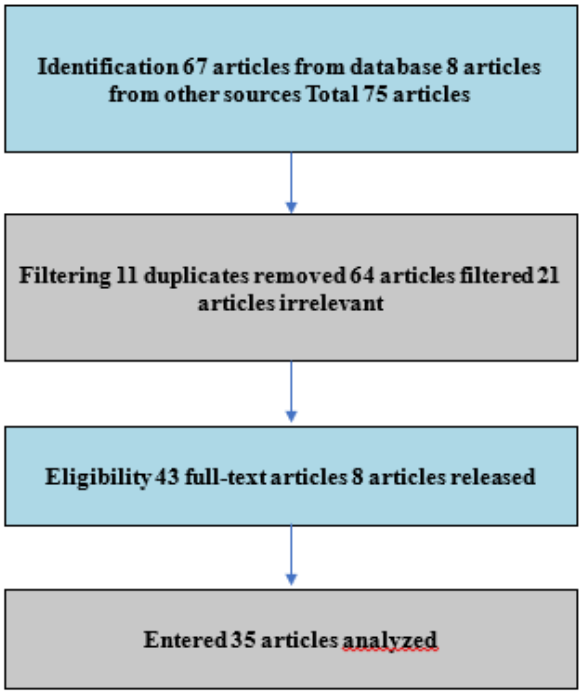

Figure 1. Prism Diagram

Result and Discussion

The results of the synthesis of 35 research articles related to the development of inquiry-based science modules show the level of national journals as shown in Figure 2.

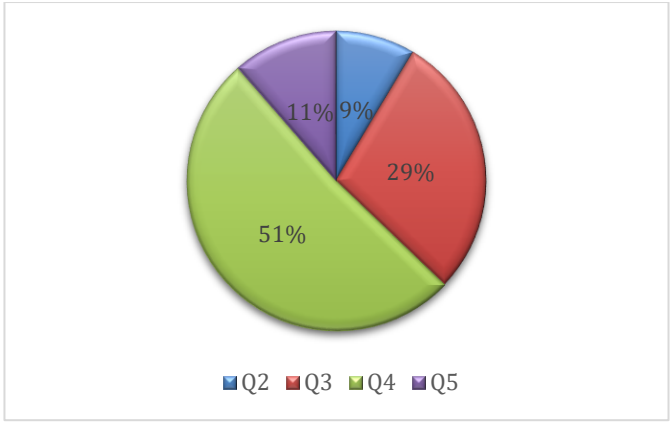

Figure 2. Sinta Level from the Journal

Year of Publication

Distribution of the year of publication from the development of an inquiry-based science module.

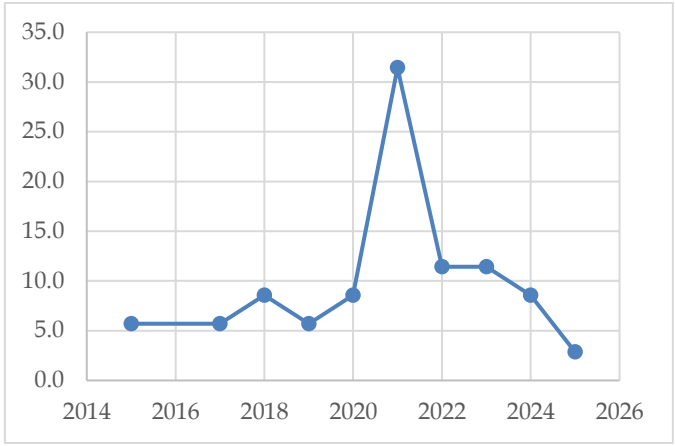

Figure 3. Chart of Year of Publication

Methods used

Frequency bar graph of the research method used in the development of an inquiry-based science module.

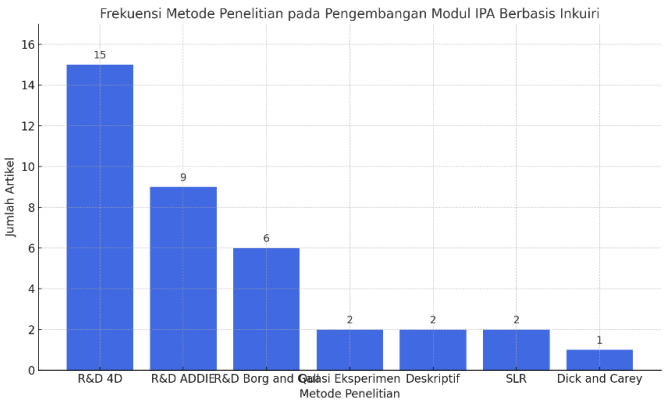

Figure 4. Research Method Frequency Bar Chart

Free Variable

Circle graph of free variable types used in the development of inquiry-based science modules.

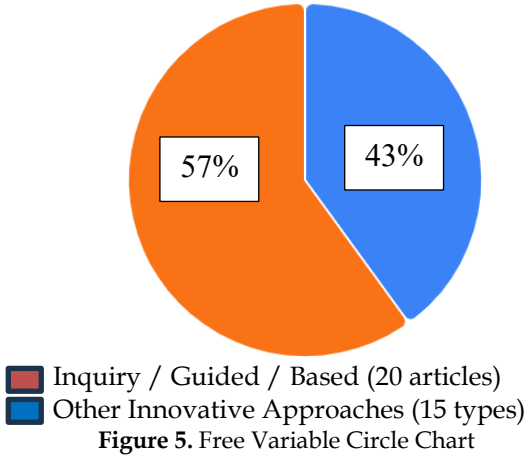

Figure 5. Free Variable Circle Chart

Independent Variables

Circle Graph of bound variable types used in the development of inquiry-based science modules.

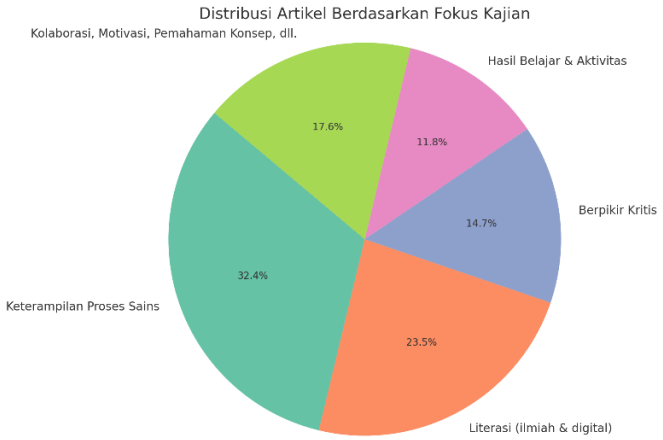

Figure 6. Graph of Bound Variables

Model or Approach Innovation

Circle Graph type Innovation model or approach used in the development of inquiry-based science modules.

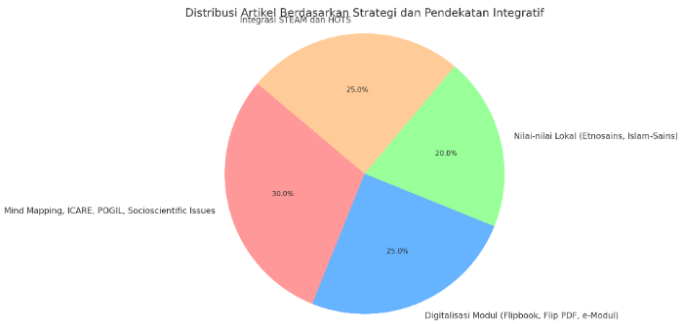

Figure 7. Model/Approach Innovation Circle Chart

The results of the synthesis showed that the majority of the articles analyzed were published in national journals with varying levels of Sinta. This suggests that the development of inquiry-based science modules has been of concern to researchers at the national level, although it has not entirely reached internationally reputable journals. The Sinta level provides an indication of the quality and recognition of the journal where the article was published the most publications are at the Q4 level with a percentage of 51%.

The distribution of articles by year shows an increasing trend from year to year, specifically from 2016 to 2024. This increase indicates an increase in interest and attention from researchers to the development of inquiry-based science modules in recent years. This can also be attributed to the push for a national curriculum to develop more active, collaborative, and problem-solving-based learning.

The research methods used are various research models, with the dominance of Research and Development (R&D) methods, especially the 4D and ADDIE models. This indicates that the development of inquiry-based science modules tends to prioritize systematic design, development, and evaluation stages so that the resulting modules meet effective learning quality standards (Thiagarajan et al., 1974; Molenda, 2003).

The most dominant independent variable in these studies was the inquiry model, specifically guided inquiry. This approach was chosen because it is considered to be able to significantly improve students' science process skills (Setiawan et al., 2017; Rahmawati & Nugroho, 2021). In addition, some studies have also integrated inquiry with other learning models such as Project Based Learning (PjBL), Model Learning Cycle 5E, and STEM-Inquisition, which demonstrate innovative efforts to combine contextual approaches and 21st-century skills such as collaboration and critical thinking (Wahyuni et al., 2023; Kurniawan et al., 2021).

In terms of bound variables, these studies generally measure the impact of module development on students' science process skills, literacy, critical thinking, learning outcomes, and collaboration. Science process skills remain the main focus because they are the foundation for mastering authentic science concepts (Fitriani et al., 2018). Meanwhile, science literacy and critical thinking are also widely raised as targets for improvement, in line with the demands of the curriculum that emphasizes students' ability to understand and interpret scientific information critically and systematically (Mulyani et al., 2022).

In addition, there is also a focus on increasing learning motivation, analytical thinking skills, scientific creativity, and life skills which further enrich the function of the science module as a learning medium that not only masters the content, but also shapes the character and holistic competence of students (Santoso et al., 2019; Dewi & Prasetyo, 2021). Ethnoscience approaches and the integration of local values have also been found in several studies, which provide the perspective that the development of inquiry-based science modules can be adapted to the cultural and social context of learners to improve the relevance of learning (Hidayat & Sari, 2020).

Another innovation that stands out is the development of digital modules, such as interactive e-modules, flipbooks, and online learning modules that utilize information and communication technology. This is relevant to today's learning conditions that require media flexibility and learning accessibility, especially in distance learning or blended learning situations (Putri et al., 2021; Santika & Arifin, 2024).

Overall, the results of this study underline that the development of inquiry-based science modules does not only focus on cognitive aspects, but also affective and psychomotor aspects, as well as the development of 21st century competencies that include literacy, numeracy, collaboration, and creativity. These studies have consistently shown that the use of inquiry models, especially guided inquiry integrated with other innovative learning models and digital technologies, effectively improves the quality of science learning at the high school level.

However, there are further development opportunities that can be done, for example by expanding the integration of sustainability and Education for Sustainable Development (ESD) aspects in the science module, as well as increasing the use of blended methods to gain a more comprehensive understanding of the effectiveness of the modules. In addition, it is also necessary to improve longitudinal studies to see the long-term impact of the use of inquiry modules on learning outcomes and character development of students.

Conclusion

Based on the results of a systematic literature review of 35 articles related to the development of science modules, several important findings were obtained that reflect trends and innovations in research on the development of modules based on learning models:

1. Dominance of 4D R&D Research Methods

The most widely used research method is *the Research and Development (R&D) 4D (Define, Design, Develop, Disseminate) model*, which appears 15 times. This shows that the 4D model is considered the most suitable for module development due to its systematic flow and focus on the validation and implementation of learning products.

2. Popularity of the Inquiry Model

Inquiry learning models, including variations such as guided inquiry and problem-based inquiry, are the most predominantly used independent variables. This model was found in about 20 articles out of a total of 35, suggesting that inquiry was seen as effective in improving learners' science process skills, science literacy, and critical thinking.

3. Diversity of Other Innovative Approaches

In addition to inquiry, a number of other innovative approaches are also used, such as *Project-Based Learning (PjBL), ICARE, HOTS, mind mapping, socioscientific issues*, ethnoscience, and STEM. This approach is generally integrated to develop other aspects of collaboration, creativity, and 21st century skills.

4. Bound Variable Variations

The bound variables studied covered various aspects of students' abilities, with science process skills being the main focus, followed by science literacy, learning outcomes, critical thinking, and collaboration. This shows a strong concern for improving students' overall scientific competence.

5. Digital Module Usage Trends

Some recent studies have begun to develop technology-based e-modules such as flipbooks, interactive pdfs, or other digital platforms, which support online learning or hybrid learning.

6. Integration Trends with Contextual Values

Some modules are designed with an ethnoscience-based approach or the integration of Islamic values, which shows efforts to contextualize science learning to be more meaningful and relevant to students' lives.

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Conflicts of Interest
The authors declare no conflict of interest.

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