

FACTORS CAUSING LOW THE SCIENTIFIC ABILITY OF INDONESIAN CHILDREN: A SYSTEMATIC REVIEW

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ABSTRACT

Factors Causing Low the Scientific Ability of Indonesian Children: A Systematic Review. The low scientific ability of Indonesian children was a serious issue that impacted the quality of human resources and national competitiveness in the global era. **Objective:** This study aimed to identify the main factors causing the low scientific ability of Indonesian children through a systematic literature review of 52 articles indexed in Sinta 1, Sinta 2, and the Scopus database. The thematic analysis grouped the causal factors into aspects of teacher quality and teaching practices, curriculum and assessment, laboratory facilities and infrastructure, basic literacy and numeracy of students, motivation and attitudes toward science, as well as socioeconomic factors. The study results showed that the low mastery of scientific concepts and process skills was caused by a combination of pedagogical challenges, curriculum policies that inadequately supported scientific learning, limited facilities, and uneven socioeconomic concerns. The study implied the necessity of educational reform integrating teacher training, curriculum renewal based on scientific literacy and experimentation, improved learning facilities, and empowerment of student motivation and understanding to sustainably enhance the scientific ability of Indonesian children.

Keywords: low scientific ability, causative factors, Indonesian children

ABSTRAK

Factors Causing Low the Scientific Ability of Indonesian Children: A Systematic Review. Rendahnya kemampuan IPA anak-anak Indonesia merupakan masalah serius yang berdampak pada kualitas sumber daya manusia dan daya saing nasional di era global. Tujuan: Studi ini bertujuan untuk mengidentifikasi faktor-faktor utama penyebab rendahnya kemampuan IPA anak-anak Indonesia melalui tinjauan literatur sistematis terhadap 52 artikel yang terindeks di Sinta 1, Sinta 2, dan basis data Scopus. Analisis tematik mengelompokkan faktor-faktor penyebab ke dalam aspek kualitas guru dan praktik pengajaran, kurikulum dan penilaian, fasilitas dan infrastruktur laboratorium, literasi dan numerasi dasar siswa, motivasi dan sikap terhadap sains, serta faktor sosioekonomi. Hasil penelitian menunjukkan bahwa rendahnya penguasaan konsep IPA dan keterampilan proses disebabkan oleh kombinasi tantangan pedagogis, kebijakan kurikulum yang kurang mendukung pembelajaran sains, keterbatasan fasilitas, dan masalah sosioekonomi yang tidak merata. Studi ini mengimplikasikan perlunya reformasi pendidikan yang mengintegrasikan pelatihan guru, pembaharuan kurikulum berbasis literasi dan eksperimen IPA, peningkatan fasilitas pembelajaran, dan pemberdayaan

motivasi dan pemahaman siswa untuk meningkatkan kemampuan IPA anak-anak Indonesia secara berkelanjutan.

Kata kunci: *kemampuan IPA rendah, faktor penyebab, anak-anak Indonesia*

A. INTRODUCTION

Science must be mastered or understood by everyone. In terms of technology, science is the main foundation that cannot be denied. In other words, technological advancement greatly depends on the progress of science. Furthermore, technological progress becomes a barometer of a nation's advancement. Thus, it is clear how important science is for life and the progress of a nation.

Science is a branch of knowledge that has concrete, rational, and empirically tested characteristics. Science focuses on understanding the state and consequences of events occurring in nature as well as the collection of information obtained methodically. Science is not just a collection of information but also involves the process of exploration, understanding, and systematic logical interaction to produce new knowledge that can be tested and verified (Fitriyati, 2017 and Safira & Ifadah, 2020). Science is a systematic method to acquire new knowledge through logical cycles and investigations that can be directly observed and controlled. Science is described as a discipline focusing on reality and natural events using a rational, empirical, and measurable approach (Kamil, 2022).

Science is a collection of knowledge whose main purpose is to help humans understand natural phenomena, anticipate events, explain the relationships between phenomena, and develop critical thinking and problem

solving based on empirical evidence (Ahmadi & Alinafiah, 2023). This understanding is important so that humans can use knowledge to solve problems related to nature rationally and systematically.

Philosophically, science is viewed as logical knowledge that continuously evolves along with advances in research and technology. As a dynamic discipline, science continues to adapt and expand its scope according to new findings and understandings obtained by humans (Abdullah, 2022).

Science is a discipline related to the systematization of knowledge through observation, experimentation, and logical reasoning to understand natural phenomena empirically and rationally. Science is not merely a collection of facts but also a critical and methodological thinking process to obtain truth that can be tested and verified. According to Rahman et al. (2022), science is a way to understand the world through scientific methods involving systematic data collection and critical analysis. This is supported by the study by Fitriyati (2019) which emphasizes that science integrates empirical knowledge with theory to explain natural phenomena. Furthermore, Kurniawan and Hidayat (2020) state that science is a human activity attempting to develop knowledge based on empirical and rational studies to solve real problems. Meanwhile, Linda (2021) asserts that science is a process of producing structured and systematic knowledge to answer questions about the universe

In the educational context, Susanti (2018) states that science teaches critical thinking, observation, and exploration methods enabling students to develop in-depth understanding of their surroundings. According to Taufik and Ardi (2020), the application of science in learning must emphasize inquiry and experimentation so that students can hone analytical thinking and problem-solving skills. Furthermore, Pratama (2019) and Sari et al. (2021) state that science plays an important role in driving technological innovation and human civilization progress. This aligns with the opinion of Ningsih and Fadhil (2022) who highlight science as a dynamic, ever-evolving discipline oriented towards evidence. According to Lestari (2020), science is also the basis for evidence-based decision making related to various aspects of daily life. Thus, the main goal of science is to produce deep and accurate understanding for both practical and theoretical needs (Yusuf & Dwi, 2023).

Science can thus be concluded as a comprehensive system of information based on observation, experimentation, and logical reasoning, aimed at understanding, explaining, and predicting natural phenomena through an empirical and systematic approach. In other words, science is a combination of knowledge and scientific methods that enable humans to understand reality, develop technology, and improve quality of life through empirical, systematic, and critical approaches.

Science education played a strategic role in developing the scientific abilities of Indonesian children and preparing the younger generation to face 21st-century challenges, including technological developments, climate

change, and the need for skilled workers capable of critical and scientific thinking (Nanang & Mulyanti, 2025). Scientific ability was not only about understanding facts but also included scientific process skills (observation, hypothesis, experimentation, data analysis) and the ability to apply scientific concepts to real-life problems (scientific literacy) (OECD, 2023).

According to PISA, scientific competence was the ability of students to engage with scientific issues and ideas and use scientific knowledge to make decisions in everyday life. This competence included understanding scientific processes, evaluating scientific evidence, and commitment to relevant scientific practices in society. In other words, scientific ability was the individual's capability to use scientific knowledge and concepts to explain natural phenomena, identify scientific questions, and make decisions based on relevant scientific evidence in various daily life contexts. This ability included skills in understanding, interpreting, and applying scientific processes and participating effectively in scientific discussions. This ability was very important given the modern era's challenges such as environmental change and technology (OECD, 2024). Isti et al. (2020) stated that scientific ability or scientific literacy was defined as the ability to use scientific information, understand basic scientific concepts and processes, identify scientific problems, and draw conclusions based on existing data and scientific evidence. This ability enabled individuals to face and solve problems related to science rationally and critically. According to Jufri (2017), scientific ability included the ability of students to identify scientific issues,

explain phenomena with scientific concepts, and use scientific evidence to support decision-making. The thinking processes involved included inductive, deductive, and deep model construction.

Efendi et al. (2021) said that scientific ability was defined as mastery of scientific concepts and facts, including a positive attitude toward science and the application of scientific knowledge to interact with natural and social phenomena scientifically and responsibly. Amalia (2018) said that in early childhood education, scientific ability was the ability to understand the surrounding environment through direct experience, observation, and systematic learning, which became the basis for developing critical and creative thinking skills gradually.

Scientific ability was "the capacity to engage in scientific practices involving questioning, analysis and interpretation of data, constructing explanations, and presenting scientific arguments" (Clark et al., 2020). Scientific ability was a holistic capability including knowledge, skills, attitudes, and values related to the understanding and application of science in everyday life (Martinez & Pereira, 2018). Scientific ability was a scientific competence encompassing cognitive proficiency in understanding scientific content and procedural ability to conduct experimental processes (Nguyen & Lee, 2022). Scientific ability was a scientific capability that fostered analytical thinking and problem-solving skills necessary for technological and societal advancement (Zhang & Kumar, 2023).

From the explanation above, it could be concluded that scientific ability was an integrated ability to understand, apply, and evaluate scientific knowledge and methods. This ability included critical

thinking, problem-solving skills, application of scientific processes, and the use of evidence-based reasoning to investigate natural phenomena and make appropriate decisions.

The scientific ability of Indonesian children, both nationally and internationally, still showed low results, as reflected in various national and international assessments. This condition became a serious problem. According to the PISA 2022 report, only about 34% of Indonesian students reached Level 2 or above in the science domain, far below the average ability of students from other OECD member countries (about 76%). This indicated that the proportion of Indonesian students with basic scientific ability was still low (OECD, 2023).

Furthermore, international surveys and local studies also showed that most Indonesian students had not reached adequate basic scientific literacy proficiency. Based on the PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) surveys, the basic scientific proficiency scores of Indonesian children were below average and far below the average scores of children from OECD countries or East Asian/Pacific countries. TIMSS 2019 also reported that Indonesian students' science scores in certain grades were below those of students from many comparator countries, especially in conceptual understanding and practical application (Muchson, Cobern & Saefi, 2024; Teig, Scherer & Olsen, 2022; IEA, 2019 & OECD, 2018). These data raised questions: why were science achievements relatively low, and what factors contributed the most?

The main objectives of this study were: (1) to identify the main factors causing the low scientific ability of Indonesian children; (2) to synthesize evidence concerning the mechanisms of these factors' influence; and (3) to formulate evidence-based policy and practice recommendations to generate ideas or solutions for improvement.

B. METHOD

This study utilized a systematic literature review method. Data were obtained from 52 research and review articles indexed in SINTA 1, SINTA 2, and Scopus journals that were relevant to the topic of the low scientific ability of Indonesian children. The source collection process applied strict inclusion criteria, including articles published in the last ten years that contained empirical data, learning models, and reviews of factors causing low scientific ability in Indonesian children (Fuadi et al., 2020; Yusmar, 2023). The data analysis method employed was thematic and comparative synthesis, grouping the causes and solutions that had been studied.

To obtain the 52 articles, systematic searches were conducted in databases and sources such as the SINTA portal (Kemdikbudristek), Scopus/ScienceDirect database (public access), Google Scholar, and international reports (OECD PISA, IEA TIMSS). Keywords used included: "science education Indonesia" (3,420,000 results), "science achievement Indonesia" (1,120,000 results), "teacher quality science Indonesia" (829,000 results), "laboratory facilities Indonesia" (239,000 results), "inquiry-based learning Indonesia" (35,700 results), "scientific literacy

Indonesia" (533,000 results), "science learning Indonesia" (385,000 results), "school science laboratory" (48,000 results), and "science literacy" (209,000 results).

Some references were published on multiple sites, generating a total of 5,625 references. These references were arranged by relevance, resulting in 2,173 references. Based on certain researcher criteria, 538 references were selected from these 2,173. Finally, at the last stage of filtering, the remaining references were read individually to identify the research year, context, objectives, methods, and results. The final number of references analyzed in this study was of 52 articles.

C. RESULT AND DISCUSSION

The results from 52 articles identified thirteen main factors causing the low scientific ability of Indonesian children, explained as follows.

- (1) **Low Quality of Teachers and Teaching Practices**
Many national studies indicate that the quality of pedagogy and teacher content mastery play a significant role. Research indicates the prevalence of teacher-centered learning methods (lectures) and the minimal use of inquiry/experimental strategies, resulting in passive learning experiences for students. Limited in-service teacher training, administrative burdens, and a lack of time for professional development exacerbate this situation. Interventions based on intensive training and coaching have been reported to improve inquiry learning practices and student outcomes in several local studies. This results in

teacher-centered learning reducing opportunities for developing science process skills. Teachers who lack mastery of the material tend to teach with oversimplification or rely solely on memorization without understanding, application, analysis, evaluation, and creation. The lack of laboratory practice prevents students from internalizing concepts through real-world experiences. The lack of application of inquiry-based learning methods and practical exploration results in students lacking meaningful learning experiences (Ardianto & Rubbini, 2021).

Numerous studies demonstrate a strong relationship between teaching quality and student achievement. Teacher quality is influenced by initial teacher education, in-service training, science pedagogical skills (using practicums and inquiry), and supervisory support. In Indonesia, weaknesses in initial teacher education and the uneven availability of training are major barriers to improving science skills (Irnidayanti & Fadhilah, 2023).

Teacher pedagogical and content competencies, as well as teacher perceptions and motivation, significantly determine the quality of science learning. Local studies report that many science teachers have not received adequate training to teach using a scientific literacy approach, are unfamiliar with designing skills-based assessments, and struggle to facilitate scientific discussions and critical thinking. Lack of ongoing training and teacher administrative burdens are also barriers (Fuadi et al., 2020 and Zukmadini, Karyadi &

Rochman, 2021). According to Hasanah (2022), teachers' suboptimal perceptions and motivations toward science learning also affect the quality of learning and overall student learning outcomes. Teachers need ongoing training in innovation and scientific approaches.

According to Rahayu (2018), many teachers have not fully mastered scientific approaches and innovative pedagogical skills. Consequently, they tend to teach monotonously and are less able to create a fun learning environment and challenge students to explore. Research by Dewi (2020) confirms that science learning currently does not stimulate students' critical thinking skills and creativity, which are essential competencies for developing their scientific abilities. This is in line with studies by Asri Azrani et al. (2025) and Dewi et al. (2023), which show that many teachers lack the full competence to implement scientific learning approaches and use learning technology. The lack of training and resources makes it difficult for teachers to conduct effective learning.

- (2) Curriculum, Syllabus, Assessment, and Exam Orientation
A dense curriculum and emphasis on written assessments (mostly rote memory) drove "teaching to the test." Studies recommended competency-based curriculum policies emphasizing scientific practices and authentic assessments (practicum, projects) to foster contextual learning. The heavy factual content

focus and multiple-choice testing encouraged teaching geared towards passing tests, reducing inquiry-based learning essential for science literacy. Local studies suggested adjustment of teaching materials to align more with science literacy/STEAM approaches (Natasya, 2025). Many studies revealed gaps between curriculum goals (higher-order thinking and science literacy) and classroom practice dominated by lectures and memorization. Implementation of practical activities, socio-scientific issues discussions, and projects faced constraints of time, resources, and teacher preparedness. Meta-analyses and case studies showed project-based, STEAM/STEM, and inquiry learning approaches could improve science literacy if properly implemented (Sukma, 2025). The national curriculum's theoretical and less scientific, explorative nature hindered science competence development (Suryanto, 2019). Rigid, non-contextual curricula made concept understanding and practical application difficult (Fuadi et al., 2020; Yusmar, 2023; Kurniawati, 2024). Overloaded curriculum fostered memorization over deep understanding. Conventional, memorization-based teaching dominated science learning, neglecting exploration, experimentation, and critical thinking skill reinforcement (Ichsan et al.,

2023; Maskur et al., 2020). Lack of connection with local context and real life decreased student motivation. Curriculum focusing on textual mastery hampered conceptual understanding and process skill development (Prasetyowati & Suyatno, 2016; Ardianto et al., 2016), leading to low analytic and application skills. Assessment systems emphasizing memorization and basic concept mastery without evaluating process skills and critical thinking hindered science ability development (Setiawan, 2021).

- (3) Lack of Laboratory Facilities and Teaching Aids
Limited laboratories, practicum materials, libraries, and digital learning access negatively affected science learning experiences. Disparities between urban and remote schools determined students' access to experiments and contextual learning (Bashith et al., 2025; Hadi, Sari & Elifas, 2024; Susila & Gularso, 2023). Inadequate facilities like incomplete labs and limited media posed challenges for hands-on science learning and visualization of complex phenomena (Syahrani, 2024; Susanti, 2021).
- (4) Lack of Basic Literacy and Numeracy
Basic reading and numeracy were prerequisites for understanding scientific texts, diagrams, and performing simple data analyses, greatly influencing science learning success. Literature showed positive

- correlations between literacy/numeracy and science achievement, with integrated literacy programs benefiting science outcomes. Low basic literacy and numeracy among Indonesian children inherently limited science ability (Amanda et al., 2025; Karmana, 2024; Wijaya & Suardiasa, 2023; Sutrisna, 2021). Low PISA and TIMSS scores reflected testing of applying scientific concepts, data interpretation, and science argumentation rather than rote facts, but classroom science predominantly involved memorization-oriented lectures and exam drills, underpreparing students for such contextual and higher-order thinking tasks (Rambe & Khairuna, 2022). This lowered performance for higher-level questions. PISA 2022 confirmed fewer Indonesian students reached top science literacy levels compared to OECD peers, corroborated by classroom observations showing limited science process involvement (OECD, 2023).
- (5) Low Motivation, Positive Attitude, and Self-Efficacy toward Science Interest and attitudes influenced learning engagement. Local psychopedagogical studies indicated many students found science difficult and irrelevant, decreasing motivation. Interventions emphasizing science's relevance to daily life (contextualization) and project-based learning tended to improve interest (Zamhariroh & Muhid, 2025; Yanti, Prihatin & Khumaedi, 2020). Negative perceptions of science as difficult, boring, unengaging, and irrelevant contributed to low motivation and active participation (Putri, 2019; Nugrahita, 2022).
- (6) Inappropriate Choice of Science Textbooks
Text-heavy, non-contextual learning materials caused boring and meaningless learning experiences. Many Indonesian teachers relied heavily on textbooks without adequate exploratory activities, limiting children's science ability development (Fuadi et al., 2020).
- (7) Non-Contextual Science Learning Studies showed that contextual learning approaches (Contextual Teaching and Learning - CTL) in elementary science significantly increased learning outcomes and concept understanding by linking content to students' daily life, making learning meaningful and engaging (Yonanda et al., 2025; Gumala Dewi et al., 2023). Memorization-based teaching without integrating culture, tradition, and local potential led to less contextual and less interesting learning and reduced student motivation and understanding (Firda, 2023). Dominance of textbook use without contextual or exploratory learning made science monotonous and boring (Srikandi, Sujana & Aeni, 2017). CTL emphasizing hands-on/minds-on learning and real-life contextualization stimulated interest, memory, and science understanding. Exploratory and contextual teaching supported deeper concept understanding and critical thinking skill development, unlike text- and memorization-based learning which lacked meaningful experiences (Rihasnita, Rahman & Sudrajat, 2025). Conventional, teacher-centered, memorization-based
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methods reduced student activity, interest, and comprehension (Nurhasanah, 2020).

- (8) **Social-Economic Disparities and Lack of Family Support**
Family socioeconomic status (parental education, book availability, internet access) related to differences in students' science ability. Urban-rural disparities reflected unequal access to quality teachers and facilities. Policies reducing access gaps remained priorities to improve Indonesian children's science ability (IEA, 2019). Low socioeconomic status limited access to quality science learning resources and exploratory science activities, impairing ability (Kartika, 2018).

- (9) **Misconceptions in Science Concepts**

Curriculum demands led students to memorize concepts without deep understanding, causing misconceptions, reflecting Indonesia's low science ability (Fuadi et al., 2020; Yusmar, 2023).

- (10) **Systemic Policies and Unbalanced Education Funding**
Uneven funding allocation for science education (laboratories, teacher training) and quality monitoring at regional levels significantly affected children's science ability. Policy studies highlighted mismatches between target policies and field implementation, impeding maximal achievement of science ability goals (Suyana et al., 2024).

- (11) **Underutilization of Local Environment and Potential**
Lack of challenges from the

surrounding environment integrated into learning and suboptimal use of local potential as an educational medium caused poor student engagement in contextual science learning (Hidayati, 2021).

- (12) **Limited Technology Support in Science Learning**
Inadequate integration of technology in science teaching made learning less interesting and interactive for students (Suwandi & Nabila, 2022; Wulandari et al., 2021).

- (13) **Learning Disorders and Special Difficulties**
Recent studies revealed that undiagnosed learning disorders like dyslexia affected children's learning achievement, including in science (Solek et al., 2025).

Based on the above studies, it was found that the low scientific ability of Indonesian children is caused by a number of interrelated and mutually reinforcing factors. The main factor most frequently highlighted is the quality of teachers and teaching practices. Many studies show the dominance of teacher-centered learning methods, such as lectures, with minimal use of inquiry and experimental strategies that actively involve students. This results in students getting a passive learning experience and insufficient development of their science process skills.

Moreover, limited teacher training and lack of continuous competency development exacerbate this issue. Many teachers have not fully mastered scientific approaches and educational technology, which

hampers the creation of a joyful and challenging learning environment. Both pedagogical and content competencies of teachers strongly influence science learning quality. Uneven teacher training and initial education remain key obstacles to their competence improvement.

Other influential factors include an unsupportive curriculum and assessment system. A dense curriculum focused on factual mastery and a memorization-oriented assessment system encourage "teaching to the test" and reduce opportunities for inquiry-based, project, and hands-on learning activities. Such instructional practices are inadequate for building deep understanding, critical thinking skills, and scientific literacy in students.

Availability of facilities and infrastructure also plays an important role. Many schools, especially in remote areas, lack sufficient laboratories and practicum tools. This limited access restricts students' direct experience with experiments and observations, which is essential for internalizing scientific concepts.

External factors such as low basic literacy and numeracy also contribute. Inadequate reading and numeracy skills cause students to struggle with scientific texts and simple data analysis. A lack of libraries and diverse learning resources decreases students' motivation and interest in learning.

Student motivation and attitudes toward science are crucial factors as well. Many students perceive science as difficult, boring, and irrelevant to their lives, lowering their interest and active engagement

in learning. Inadequate contextual and innovative teaching approaches further diminish their motivation.

Socioeconomic disparity is equally important. Inequitable access to quality learning resources, facilities, and qualified teachers between urban and rural areas leads to uneven science ability achievement across the country.

Additional factors such as misconceptions, lack of technology support in learning, and insufficient special programs worsen the situation. Recent studies show that undiagnosed learning difficulties such as dyslexia also negatively impact learning achievement, including in science.

From the above description, it can be concluded that the low scientific ability of Indonesian children is not caused by a single aspect but results from a series of interrelated and mutually reinforcing factors. Therefore, effective solutions must be comprehensive and integrative, involving improvements in teacher quality, curriculum and assessment reform, enhancement of learning facilities, as well as the motivation and socioeconomic empowerment of students. A combination of these approaches will help improve achievements and sustainably enhance the scientific competence of Indonesian children.

The synthesis above indicates that the factors causing low scientific ability do not stand alone but interlink and amplify each other. For example, a skill-demanding curriculum without competent teachers and practical laboratory facilities will struggle to produce expected improvements;

similarly, assessment reform without teacher training will create gaps between policy and practice. Intervention studies involving integrated packages (teacher training + contextual teaching materials + formative assessment) report localized positive impacts, indicating that solutions must be multi-component and adaptive to local contexts.

International literature theoretically emphasizes the importance of alignment between curriculum, pedagogy, and assessment (constructive alignment): when these three are aligned with science literacy goals, learning that supports higher-order thinking skills can develop. In Indonesia, misalignment (e.g., domestic assessments focusing on memorization) is one of the main drivers of low scores in PISA/TIMSS.

D. CONCLUSION

Based on the literature review analysis of 52 relevant articles, it can be concluded that the low scientific ability of Indonesian children is caused by 13 main interrelated and mutually reinforcing factors. These factors include the low quality of teachers and teacher-centered teaching practices with minimal use of inquiry methods, lack of teacher training, a dense curriculum and assessment orientation dominated by memorization, limited laboratory facilities and infrastructure, low basic literacy and numeracy skills, as well as low motivation and positive attitudes toward science. Socioeconomic factors, the use of inappropriate learning resources, lack of contextual learning, minimal technology

support, and special learning difficulties further exacerbate the condition. Therefore, efforts to improve the scientific ability of Indonesian children must be holistic and involve reforms in teacher development, curriculum and assessment management, provision of adequate learning facilities, and empowerment of students psychologically and socioeconomically to sustainably enhance their scientific competence.

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