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Inquiry-based learning and the development of scientific skills in fifth-grade Natural Sciences

Aprendizaje basado en indagación y desarrollo de habilidades científicas en Ciencias Naturales de quinto grado

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ABSTRACT

The research objective was to develop teaching strategies to promote inquiry-based learning and the development of scientific skills in fifth-grade natural sciences in Ecuador. This article was developed using a systematic review design based on the feasible project approach, following the PRISMA protocol, with a search of six international databases and the final inclusion of 26 studies published between 2019 and 2026. The results showed that guided inquiry is the most appropriate approach for the elementary level, with a priority on developing skills in observation, classification, inference, and communication of results. It is concluded that the five proposed teaching strategies are applicable in contexts with heterogeneous resources, and their effectiveness depends on the teacher's pedagogical training and methodological continuity throughout the school year.

Keywords: biology; natural sciences; life sciences. (Source: UNESCO Thesaurus).

RESUMEN

Se instauró como objetivo de investigación generar estrategias didácticas para el fomento del aprendizaje basado en indagación y el desarrollo de habilidades científicas en Ciencias Naturales de quinto grado en Ecuador. Para la elaboración de este artículo se adoptó un diseño de revisión sistemática apoyada en el enfoque de proyecto factible, siguiendo el protocolo PRISMA, con consulta a seis bases de datos internacionales y la inclusión definitiva de 26 estudios publicados entre 2019 y 2026. Los resultados evidenciaron que la indagación guiada constituye la modalidad más pertinente para el nivel primario, con desarrollo prioritario de las habilidades de observación, clasificación, inferencia y comunicación de resultados. Se concluye que las cinco estrategias didácticas propuestas son aplicables en contextos de recursos heterogéneos y su efectividad depende de la formación pedagógica de la docente y de la continuidad metodológica a lo largo del ciclo escolar.

Descriptores: biología; ciencias naturales; ciencias de la vida. (Fuente: Tesauro UNESCO).

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Research articles

INTRODUCTION

The teaching of natural sciences in elementary education plays a strategic role in shaping citizens capable of understanding environmental phenomena and responding with critical thinking to the challenges of the contemporary world. In Ecuador, the fifth-grade curriculum includes content related to ecosystems, matter and energy, the human body, and physical-natural phenomena; however, teaching practice tends to reproduce expository methodologies that reduce students to the role of passive recipients of knowledge, limiting the development of the scientific competencies that the curriculum itself demands.

Inquiry as a teaching method is not a recent resource in science pedagogy; consequently, as Kubieck (2005) notes in his analysis of inquiry-based learning (IBL), the nature of science, and the possibilities of educational technology, this approach is rooted in the traditions of active learning and constructivism, which posits that knowledge is constructed through the subject's interaction with the world. In the following decades, the accumulation of empirical evidence has made ABI one of the approaches with the strongest research support in science education internationally, with studies ranging from early childhood education to higher education, which attests to the epistemological robustness of this pedagogical perspective. Furthermore, ABI has accumulated significant evidence regarding its effects on scientific learning at various educational levels; in this regard, Arifin et al. (2025) report, based on a broad-scope meta-analysis, that ABI produces statistically significant improvements in the critical thinking of science students, with effects that intensify when inquiry is structured progressively and supported by adequate teacher guidance. Likewise, Diata-Cruz and Lagura (2026) identified, in their systematic literature review, that inquiry-based methods have consistent positive and e e effects on scientific process skills in primary and secondary school students, which supports the relevance of this strategy for the fifth-grade level.

It is worth noting that, in the Ecuadorian context, pedagogical research focused on innovation in natural sciences has increased in recent years, although it still concentrates more on the use of digital tools than on the transformation of basic teaching approaches; In this regard, Almeida-Shapán and Yánez-Monge (2025) documented that the integration of technology in natural science education promotes learning provided it is combined with active, inquiry-based methodologies, since technological resources alone do not transform educational quality unless accompanied by a change in the teacher's pedagogical approach.

Given this reality, the present research aimed to generate teaching strategies to promote inquiry-based learning (IBL) and the development of scientific skills in natural sciences for fifth-grade students in Ecuador, as a concrete contribution to the renewal of pedagogical practice at this educational level.

Consequently, based on the above, the research objective is to develop teaching strategies to promote inquiry-based learning and the development of scientific skills in natural sciences for fifth-grade students in Ecuador.

METHOD

The research was grounded in the qualitative paradigm with a descriptive scope and adopted a literature review design; as its central purpose was to analyze, systematize, and synthesize the available scientific literature on inquiry-based learning and the development of scientific skills in primary education, with a view to providing a foundation for the design of teaching strategies applicable to fifth grade in the Ecuadorian context.

Documentary research is characterized by the compilation, selection, and critical analysis of secondary sources as a legitimate means of constructing scientific knowledge; in this regard, Arias (2012) notes that this type of research allows for the generation of original contributions through the rigorous processing of existing information, provided that explicit criteria for search, selection, and analysis are applied. Hence, the methodological process was organized into three successive

phases: literature search, selection and refinement of the corpus, and descriptive-comparative analysis of the included studies.

RESULTS

This section presents the results of the research:

Table 1. *Distribution of studies by methodological type and educational level.*

Methodological type	Elementary education	Secondary education	Both levels	Total
Systematic review	4	3	2	9
Quasi-experimental	7	3	0	10
Design study	2	1	1	4
Meta-analysis	1	1	1	3
Total	14	8	4	26

Note: Prepared by the authors based on the studies included in the systematic review.

Table 1 shows that the largest number of studies analyzed fall into the quasi-experimental category, with a clear concentration at the elementary school level (n = 7). This finding suggests a methodological preference for controlled intervention designs in research involving school-age students.

On the other hand, Strat et al. (2024) indicate that a large proportion of practicing teachers lack sufficient preparation to implement inquiry authentically in the classroom, which limits the transformative potential of this methodology. Similarly, Li et al. (2024), using a multilevel model, demonstrate that teachers' beliefs about inquiry-based teaching directly influence the development of students' scientific process skills. These results underscore the importance of teacher training and disposition as determining factors in the effectiveness of inquiry-based learning.

Table 2. *Modalities of inquiry-based learning and associated scientific skills in elementary school studies.*

IBL Modality	Most Developed Scientific Skills	Reference studies
Confirmatory inquiry	Observation, data recording	Kotsis (2024); Ölçer (2025)
Structured inquiry	Classification, measurement, communication	Lindayao et al. (2025); Marian and Jackson (2017)
Guided inquiry	Inference, hypothesis formulation, experimentation	Hastuti et al. (2019); Teplá and Distler (2025)
Open inquiry	Research design, data analysis, argumentation	Dah et al. (2024); Ganajová et al. (2025)

Note. Prepared by the authors based on the studies included in the review.

The distribution shown in Table 2 highlights that skills of greater cognitive complexity, such as inquiry design and scientific argumentation, are associated with the open-ended approach; whereas more basic skills, such as observation and methodical data recording, correspond to confirmatory inquiry. Viewed in this light, the literature review supported the selection of guided inquiry as the reference modality for fifth grade, as it combines teacher guidance with a progressive transfer of cognitive autonomy to the student; a condition that the specialized literature identifies as crucial for the sustained development of scientific competencies in elementary education.

Design of Teaching Strategies for Fifth Grade

Based on the synthesis of the results of the systematic review, five teaching strategies were designed to promote ABI and develop scientific skills in fifth-grade Natural Sciences, aligned with the skills outlined in the Ecuadorian national curriculum and with the resources available in most of the country's public schools. Table 3 below presents a systematic description of each strategy:

Table 3. *Teaching strategies for promoting ABI in fifth-grade Natural Sciences.*

No.	Name of the strategy	Description and Implementation	Scientific skills	Suggested resources	Formative assessment
1	Generative question with exploration of the environment	The teacher presents an observable phenomenon from the local natural environment (a plant, an insect, a rock, a nearby body of water) and works with the students to formulate a central question to guide the exploration. Students record free observations in their journals, propose possible answers, and compare their ideas with those of their classmates through guided dialogue. At the end, the teacher summarizes the collective conclusions and links them to the curricular skill being developed.	Systematic observation; question formulation; oral communication of results; initial inferential thinking.	School grounds; science logbook; magnifying glass; ruler; recording materials.	Observation checklist; logbook entries reviewed by the teacher with written feedback.
2	Guided experiment with a science logbook	Based on a question posed in class, the teacher provides a semi-structured experimental guide with the materials and basic procedure; students, in groups of three or four, conduct the experiment, record data in their logbook (observations, measurements, and variations), formulate a tentative explanation, and present it orally to the group. The teacher acts as a facilitator of the process, asking questions that deepen the analysis without directly providing the answer.	Observation; measurement and data recording; inference; formulation of explanations; communication of results.	Low-cost materials (water, salt, vinegar, baking soda, soil, seeds); cups, funnels, simple scale; printed guide; logbook.	Experimental process rubric (design, recording, analysis, and conclusion); written self-assessment.
3	Field Research in the Local Natural Environment	Students go on a field trip to the immediate surroundings of the school (garden, vegetable garden, stream, green space, or nearby park). Each group receives a research sheet with observation, recording, and classification criteria adapted to the current curriculum unit. The data collected in the field is organized into tables created by the students themselves and shared in a plenary session of collective analysis where the teacher facilitates the comparison of results between groups and the development of shared conclusions.	Direct observation; classification; comparison; systematic scientific recording; written and oral communication of results.	Printed field form; magnifying glass; ruler; containers; gloves; logbook; camera or cell phone as optional support.	Field research rubric (accuracy of recording, relevance of classification, and quality of sharing); peer assessment among groups.

4	Rotating inquiry station	The teacher organizes the classroom into four simultaneous learning stations, each with different materials and an inquiry card that poses a specific question or challenge related to the curriculum unit. The groups rotate through the stations in 10- to 12-minute intervals, recording their observations, data, and preliminary conclusions in the logbook. At the end of the rotation, each group presents the conclusions from at least one station, and the teacher leads a comprehensive summary that connects the findings from all stations with the curriculum content.	Observation; classification; inference; hypothesis formulation; collaborative work; communication of partial and integrated results.	Four sets of thematic materials; printed inquiry cards; logbook; whiteboard for collective synthesis.	Logbook entries for each station; participation and communication rubric; collective feedback from the teacher.
5	Thematic inquiry project with community presentation	Working in groups of three to five, students select a problem or natural phenomenon from their environment related to the current curriculum unit, formulate a research question, plan and carry out a three- to four- -long inquiry with teacher support, collect data through observation, interviews with community members, or simple experiments, compile a report, and present it to their peers and families at a science fair or presentation session. The teacher guides each phase of the process, provides written feedback on progress, and evaluates both the process and the final product.	Formulating questions and hypotheses; planning the inquiry; collecting and analyzing data; reasoning; publicly communicating results.	Project log; subject-specific materials; access to the local natural environment; optional: digital tools (Educaplay, presentations).	Project rubric (question, process, analysis, conclusion, and presentation); self-assessment and peer assessment; audience evaluation.

Note. Prepared by the author based on the synthesis of the systematic review and the Ecuadorian national curriculum for Natural Sciences for fifth grade of general basic education.

Table 3 systematizes the five proposed strategies for promoting ABI in fifth grade; each is aligned with the skills outlined in the Ecuadorian national curriculum and presents an ascending progression in the student's level of autonomy, from Strategy 1 which involves greater teacher scaffolding to Strategy 5, which requires the integration of scientific skills into a community-based project.

DISCUSSION

According to Urdanivia-Alarcón et al. (2023), inquiry-based teaching improves scientific learning provided there is continuity in its application and it is not limited

to isolated activities, as the authors confirmed this finding after reviewing 43 studies. Based on this, the sequential organization of the five strategies proposed in this study responds to the need to maintain sustained and progressive processes within the classroom.

Similarly, Hernández-Barbosa et al. (2024) argue that the teaching of natural sciences has moved beyond approaches focused solely on the transmission of content to embrace active methodologies, where students participate more directly in problem-solving. From this perspectiv, the strategies proposed in this research do not appear as a proposal isolated from the current educational context, but rather as part of a pedagogical trend that has been consolidating in various recent studies. However, not all of the reviewed studies fully align with the context of this work; for instance, Ruf et al. (2019) conducted their research in European universities, where the level of student autonomy is considerably higher. Given this reality, their contributions regarding the autonomous construction of knowledge are relevant; however, in fifth grade, closer teacher guidance is still necessary. For this reason, this study opted for a guided and progressive inquiry approach, appropriate for the students' age and developmental level.

On the other hand, Pozuelo-Muñoz et al. (2023, 2025) found that inquiry strategies strengthen skills such as classification and scientific argumentation in secondary school students; although their results show favorable effects, it is worth noting that their study was conducted at a different educational level; even so, their findings serve as a reference for projecting the potential benefits of these strategies in elementary education, an aspect that could be verified in future research targeting fifth-grade students. Within the Latin American context, Marín-Ríos et al. (2023) analyzed the implementation of the STEM approach and identified limitations related to teacher training and access to educational resources. In addition, Aguirre-Coello and López-Helguero (2025) indicate that the group work incorporated into several of the designed strategies becomes

more meaningful, particularly in activities that include peer assessment and discussion as part of the learning process.

Following up on the above, Guaña-Narváez et al. (2024) indicate that augmented reality increases motivation and conceptual understanding among elementary school students; however, this type of resource requires technological capabilities that many Ecuadorian public schools do not yet possess. Thus, it is important to consider classroom organization; Jorajuria and Usart (2025) demonstrated that station rotation promotes science learning because it allows students to simultaneously engage in different activities related to the same content. In light of the above, Van Wyk et al. (2026) indicate that the sustained application of inquiry strategies from an early age could contribute not only to the development of scientific skills but also to the strengthening of scientific vocations in the long term. Meanwhile, Barahona-Ibarra (2025) notes that digital tools such as Educaplay yield better results when integrated into guided inquiry activities.

CONCLUSION

Guided inquiry constitutes the most relevant inquiry-based learning modality for fifth-grade elementary education, as it combines teacher support with a progressive transfer of cognitive autonomy, which the literature identifies as a necessary condition for the sustained development of scientific skills.

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CONFLICT OF INTEREST

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