RIDI
Revista de Investigación
Desarrollo e Innovación

The influence of pedagogical practices in natural sciences on the development of scientific competencies in basic education: a systematic review

Influencia de la práctica pedagógica en ciencias naturales para el desarrollo de competencias científicas en la educación básica: una revisión sistemática

Research article

Recibido: mayo 26 de 2025
Aceptado: octubre 01 de 2025
Publicado: febrero 15 de 2026

Cómo citar este artículo: Mejía-Vargas, S. I., & Carmona-Alvarado, F. A. (2025). The influence of pedagogical practices in natural sciences on the development of scientific competencies in basic education: a systematic review. *Revista de Investigación, Desarrollo e Innovación, 16* (1), 27-46.

doi: https://doi.org/10.19053/uptc.20278306.v16.n1.2026.20701

Sergio Iván Mejía-Vargas*
Colegio Ecológico de Floridablanca, Floridablanca, Colombia.
E-mail: sergio.mejia@unisimon.edu.co
Orcid: https://orcid.org/0000-0001-9758-2251

Farid Alejandro Carmona-Alvarado
Universidad Simón Bolívar, Barranquilla, Colombia.
E-mail: farid.carmona@unisimon.edu.co
Orcid: https://orcid.org/0000-0002-3669-6746

Abstract

The aim of this article is to review the existing literature on pedagogical practices in natural sciences that promote scientific competencies, and to identify the central categories that characterize such practices for basic education students. This article presents the results of a systematic review using the PRISMA methodology during the period 2020 – 2024. The results showed bibliometric data of 50 articles selected from databases such as: Scopus, Web of Science and SciELO. A qualitative analysis was performed, identifying three main categories that allow stablish that to promote scientific competencies in the pedagogical practice of natural sciences, the textbook is not enough, textbook activities do not develop scientific skills of high cognitive demand. To promote these processes, it is necessary to incorporate active methodologies that facilitate scenarios and dynamics for participation, mediated by a contextualized pedagogical discourse of the teacher that fosters the dialogue of knowledge.

Keywords: scientific knowledge, natural sciences, basic education, pedagogical practice.

Resumen

El objetivo de este artículo es revisar la literatura existente sobre prácticas pedagógicas en ciencias naturales que promuevan competencias científicas y determinar las categorías centrales que caracterizan dichas prácticas en estudiantes de educación básica. Este artículo muestra los resultados de una revisión sistemática haciendo uso de la metodología PRISMA durante el periodo 2020 – 2024. Los resultados muestran datos bibliométricos de 50 artículos seleccionados en bases de datos como: Scopus, Web of Science y SciELO. Se realizó un análisis cualitativo identificando tres categorías centrales, las cuales permiten establecer que para promover competencias científicas en la práctica pedagógica de ciencias naturales no es suficiente el libro de texto, las actividades de los textos no desarrollan habilidades científicas de alta demanda cognitiva. Se concluye que para promover estos procesos es necesario incluir metodologías activas que propicien escenarios y dinámicas de participación mediadas por un discurso pedagógico contextualizado del docente, promoviendo el diálogo de saberes.

Palabras clave: conocimiento científico, ciencias naturales, educación básica, práctica pedagógica.

1. Introduction

The main foundation of sciences is answering humanity's great questions and serve as a method of proposing explanations to these great questions. This perspective tends to be neglected in school education. To a certain extent, this is due to the underestimation of the popular knowledge that comes from cultural heritage and the people who formulate these simple explanations of natural phenomena that they experience in their daily lives. While it is true that the sciences are constituted as a means to reach objective truth, they are based on analyses and contrasts based on the subjective experiences of the individual (Husserl, 2008).

It is essential to contextualize science in order to promote contexts where the student feels involved and not just recites ready-made knowledge. Equally important are discussion environments that foster debate, comparison and experimentation to enrich scientific knowledge and give it meaning (Akilli & Kutur, 2023).

> (…) "The teaching of natural sciences and environmental education should emphasize the processes of knowledge construction rather than the methods of transmitting results, and should make explicit the relationships between science, technology and their impact on the life of man, nature, and society" (Ministerio de Educación Nacional, 1998, p. 43-44).

This framework directly involves the role of the teacher in education, prompting a rethinking of their praxis and teaching methods, whether it focuses on rote memorization or instead proposes a more creative approach to knowledge. Creativity implies originality, but at the same time it implies usefulness; the teaching of the natural sciences must create learning environments that ground theory in practical problems connected to the students' reality.

In this context, it is necessary to promote initiatives and strategies that assign the central role to the student, who is the main actor in the teaching-learning process. John Dewey, through his active school approach, proposes a pedagogy characterized by encouraging the activity of children, developing both the cognitive and motor aspects to make learning more effective.

According to Rodriguez (2015), Dewey's contributions to education, identifies four innate impulses of children: to communicate, to construct, to inquire, and to express themselves appropriately. This can be observed in classroom experiences with children, where children have countless questions, ways of participating, and ways of communicating that are often restricted and blocked in school by teachers and traditional teaching methods.

With the aim of identifying the categories influencing the development of scientific competencies in basic education, this paper formulates the following review question: which factors characterize natural science educational practices that foster scientific competencies in basic education? Thus, a systematic review of the existing literature on educational practices in natural sciences over the past five years was carried out to analyze their objectives, methodologies, resources and results.

2. Methodology

A systematic review of the literature was conducted to examine the educational practices in the field of natural sciences aimed at fostering the development of scientific competencies in basic education. The PRISMA framework was selected due to its rigorous structure, which includes a protocol designed to mitigate author bias arising from revisions in study results. These potential revisions can influence decisions and lead to deviations from the research objectives (Urrutia and Bonfill, 2010). The following section outlines the preliminary selection criteria used in the search for the articles included in this study.

The review covered articles published between 2020 and 2024 in English and Spanish. These records were obtained through institutional access provided by Universidad Simón Bolivar library account. The databases and research areas included in the study were Scopus: social sciences, arts and humanities, biological sciences, environmental sciences, computational sciences; Web of Science (WOS): social sciences, education, environmental sciences, biology, scientific educational disciplines, multidisciplinary sciences, humanities; and SciELO: Social sciences, education, environmental sciences, biology, scientific disciplines in education, multidisciplinary sciences, and humanities. A total of four categories were selected for the study, and terms in both Spanish and English were chosen based on broad search terms.

The terms included in the first category were: Scientific Competencies (SCo), Scientific Skills (StS); in the second category: Educational Practice (EPr), Pedagogical Practice (PPr), Teaching Practice (TPr); in the third category: Basic Education (BEd), Basic Primary Education (EseE); and in the fourth category: Natural Sciences (NS).

The next step was to construct the combinations for the Boolean search formulas, that were consulted on October 27, 2024. The search formulas for the categories and corresponding terms used are detailed as follows:

SCo + EPr: (“Scientific Competencies”) OR (“Scientific Skills”) AND (“Educational Practice”) OR (“Pedagogical Practice”) OR (“Teaching Practice”).

SCo + BEd: (“Scientific Competencies”) OR (“Scientific Skills”) AND (“Basic Education”) OR (“Basic Primary education”) OR (“Basic Secondary Education”).

SCo + NS: (“Scientific Competencies”) OR (“Scientific Skills”) AND (“Natural Sciences”).

SCo + EPr + NS: (“Scientific Competencies”) OR (“Scientific Skills”) AND (“Educational Practice”) OR (“Pedagogical Practice”) OR (“Teaching Practice”) AND (“Natural Sciences”).

SCo + EPr + BEd + NS: (“Scientific Competencies”) OR (“Scientific Skills”) AND (“Educational Practice”) OR (“Pedagogical Practice”) OR (“Teaching Practice”) AND (“Basic Education”) OR (“Basic Primary education”) OR (“Basic Secondary Education”) AND (“Natural Sciences”).

A total of 2,285 documents were retrieved from the Scopus, Web of Science and SciELO databases. These records were downloaded in RIS format and uploaded to the online platform Rayyan IA, where they were subsequently filtered, categorized and analyzed. The article selection and evaluation was done using the Rayyan IA system (Universidad del Bosque, 2025). This tool automatically detects duplicate files and facilitates their review by calculating the percentage of duplication and establishing comparisons between documents. Following this analysis, the titles and abstracts of the articles are reviewed, and inclusion and exclusion criteria were applied. These criteria were filtered through keywords that correspond to the selected terms, as well as those unrelated to the objectives of the review. A subsequent filtering process was conducted based on the full texts uploaded to the system (see Figure 1).

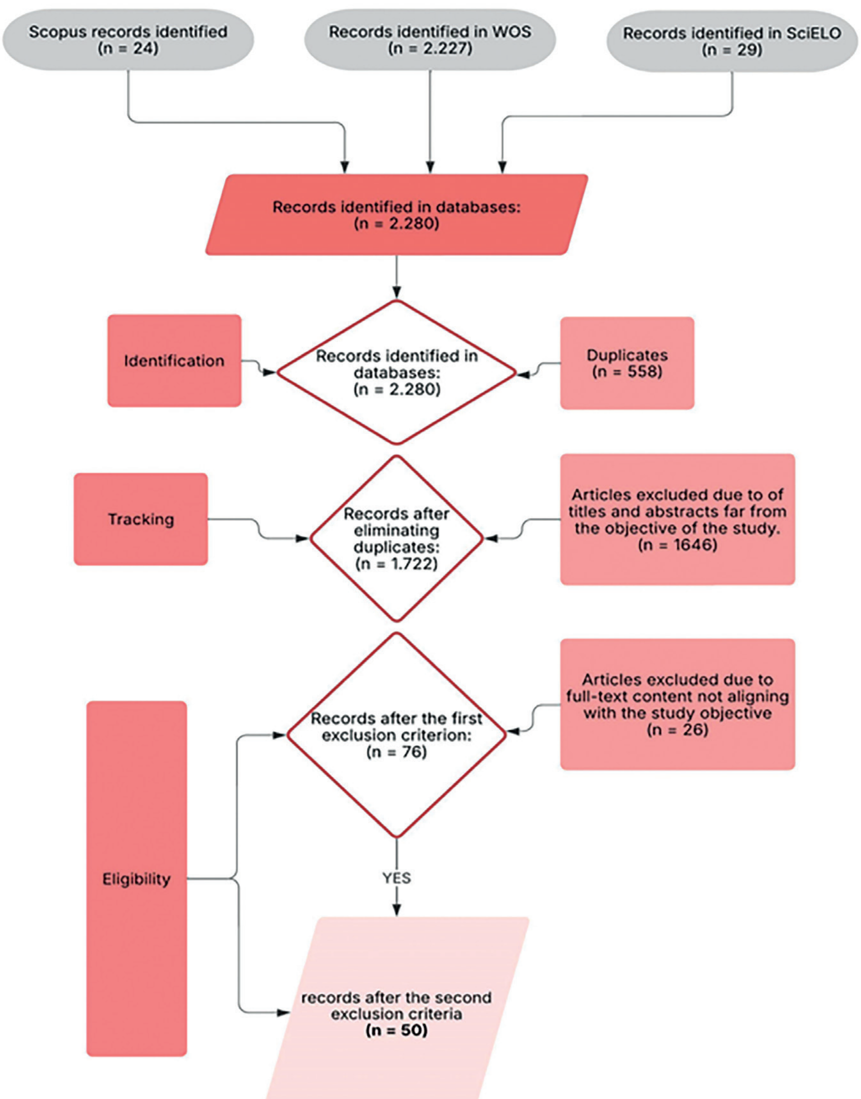

Figure 1. Flowchart of the selection phase.

As a result of the selection process, 50 articles were obtained for the analysis phase. These documents were organized into matrixes in order to identify trends and contribute to the definition of the main categories.

3. Results and discussion

3.1. Bibliometric analysis

Table 1 presents the bibliometric variables, which summarize the contextual information of the selected articles. The synthesis incorporated a total of 50 articles.

Table 1. Bibliometric analysis.

No.	Database	author (s)	Year	Type of research	Country	Language
1	Web of Science	Cramer, et al.	2024	Quantitative	Netherlands	English
2	Web of Science	Höper	2024	Qualitative	Norway	English
3	Web of Science	Fazio, Kemmis, & Zugic	2024	Qualitative	Canada	English
4	web of Science	Bónus, Antal, & Korom	2024	Quantitative	Hungary	English
5	SciELO	Morales-Silva, Álvarez-Durán, Álvarez-Iriarte, & Rivero-Diegues	2024	Mixed	Chile	Spanish
6	Web of Science	Fuentealba-Cruz, Miño-Gonzalez, & Neira-Morales	2024	Quantitative	Chile	Spanish
7	Web of Science	Lhardy & Reina	2024	Qualitative	Mexico	English
8	Scopus	Delgado-Iglesias, Bobo-Pinilla, Reinoso-Tapia, & Vega-Agapito	2024	Qualitative	Spain	English
9	Scopus	Eka-Putra, Harianto, Pudjaningsih, & Eriyani	2024	Quantitative	Indonesia	English
10	Web of Science	Kopcha & Ocak	2023	Qualitative	United States	English
11	Web of Science	Baur	2023	Qualitative	Germany	English
12	Web of Science	Akilli & Kutur	2023	Quantitative	Turkey	English
13	SciELO	Sepúlveda-Obreque, Minte-Münzenmayer, Villalobos-Clavería, Peña-Troncoso, & Diaz-Levicoy	2023	Mixed	Chile	Spanish
14	Web of Science	Okada, Steimber de Pereira-Okada, & de Olivera-Campolina	2023	Qualitative	Brazil	Portuguese
15	Web of Science	Muñoz Martínez & Charro Huerga	2023	Quantitative	Colombia	Spanish
16	Web of Science	Arana -Tuesta & Solis-Trujillo	2023	Quantitative	Peru	Spanish
17	Scopus	Hernández-Gil, Cardozo-Jiménez, & Perdomo-Rojas	2023	Qualitative	Colombia	Spanish

No.	Database	author (s)	Year	Type of research	Country	Language
18	Web of Science	López-Banet, Martinez-Carmona, Soto-Cascales, & Reis	2023	Mixed	Spain	Spanish
19	Web of Science	Lima Diniz, da Silva, & Fernández-Florêncio de Araujo	2023	Qualitative	Brazil	Portuguese
20	Web of Science	Holguin-Alvarez, Cruz-Montero, Ruiz-Salazar, & Ledesma-Pérez	2023	Quantitative	Peru	Spanish
21	Web of Science	García-Gaitán, Ramírez-Díaz, & Arriaga-Santos	2022	Qualitative	Mexico	Spanish
22	Web of Science	Jiménez & Álvarez-Hevia	2022	Quantitative	Spain	English
23	Web of Science	Landinho, Mendonça-Duarte, & Biscalquini-Talamoni	2022	Qualitative	Brazil	Portuguese
24	Web of Science	Santini, Sensevy, Quilio, Forest, & Blocher	2022	Qualitative	France	English
25	Web of Science	Albertos-Gómez	2022	Quantitative	Spain	Spanish
26	Web of Science	Vieira-de Moraes, Simões-Girotto, & Pereira-de Oliveira	2022	Qualitative	Brazil	Portuguese
27	Web of Science	Ochoa-López, Canquíz-Rincón, & Lubo-De la Rosa	2022	Quantitative	Colombia	Spanish
28	Web of Science	Palacios, Moreno-Mediavilla, & Barreras	2022	Quantitative	Spain	Spanish
29	Web of Science	Pey-Betrán, Villa-Orduna, & Mazas-Gil	2022	Mixed	Spain	Spanish
30	Scopus	Vela-Acero & Jiménez-Cortés	2022	Quantitative	Colombia	Spanish
31	SciELO	Vargas-Velandia & Morales-Silva	2021	Mixed	Colombia	Spanish
32	Web of Science	Philander & Botha	2021	Qualitative	South Africa	English
33	Web of Science	Chávez-Charro, Neira , & Lacalle-Calderón	2021	Quantitative	Cambodia, Ecuador, Guatemala Honduras, Paraguay and Senegal	English
34	SciELO	Jaime-Muñoz	2021	Qualitative	Chile	Spanish
35	Web of Science	Asimakopoulou, Nastos, Vassilakis, Hatzaki, & Antonorakou	2021	Qualitative	Greece	English
36	Web of Science	Holguín-Álvarez, Figueroa-Hurtado, Apaza-Quispe , Montañez-Huancaya, & Cruz-Montero	2021	Quantitative	Peru	Spanish
37	Web of Science	Sandoval, Kawasaki, & Clark	2021	Qualitative	United States	English

No.	Database	author (s)	Year	Type of research	Country	Language
38	Web of Science	Tavarez, Marques-Vieira, & Pedro	2021	Mixed	Portugal	English
39	Scopus	Earle	2021	Qualitative	England	English
40	Web of Science	Borić & Zečević	2021	Quantitative	Croatia	English
41	Web of Science	Jimenez-Liso, Delgado, Castillo-Hernandez, & Baños-González	2021	Qualitative	Spain	Spanish
42	Web of Science	García-Barros, Martínez-Losada, & Rivadulla-López	2021	Quantitative	Spain	Spanish
43	Web of Science	Sotomayor-Soloaga	2021	Qualitative	Chile	English
44	Web of Science	Rodríguez-Mora & Blanco-López	2021	Qualitative	Spain	Spanish
45	SciELO	Zúñiga-Meléndez, et al.	2020	Qualitative	Costa Rica	Spanish
46	Web of Science	Reis, Tinoca, Baptista, & Linhares	2020	Quantitative	Portugal	English
47	Web of Science	Perez & Meneses-Villagrá	2020	Qualitative	Spain	Spanish
48	Scopus	Ribau	2020	Mixed	Portugal	English
49	Web of Science	Castelblanco-Sánchez, Cifuentes-Garzón, Pinilla-Saavedra, & Pulido-Buitrago	2020	Qualitative	Colombia	Spanish
50	Web of Science	Blanchar-Añez	2020	Quantitative	Colombia	Spanish

The articles are distributed as follows: Web of Science (39), Scopus (6), SciELO (5). The year 2021 recorded the highest number of selected publications (14), while 2020 had the lowest number (6), The remaining years showed similar numbers; 2024 (9), 2023 (11) and 2022 (10). Regarding the type of research on scientific competencies in natural sciences in basic education, the studies were divided into qualitative (24), quantitative (19) and mixed methods (8). For the country variable, the distribution of articles is as follows: Spain (10), Colombia (6), Chile (5), Brazil (4), Portugal (3), Peru (3), Mexico (2), United States (2), Chile - Colombia (1), Ecuador - Honduras - Guatemala - Cambodia - Senegal - Paraguay (1), Costa Rica, England, Indonesia, Canada, Germany, Croatia, France, Greece, Hungary, Norway, Netherlands, South Africa and Turkey (1). The language variable is divided into three categories: Spanish (25), English (22) and Portuguese (4). It should be noted that although the search filters only included English and Spanish, some of the full-text documents were in Portuguese.

Some key findings from the bibliometric analysis show that scientific competencies in basic education are studied in a wide range of countries; however, there is a particular emphasis on Spanish-speaking contexts such as Spain, Colombia and Chile. Another relevant aspect is that the methodologies used to address issues related to educational practice in natural sciences tend to be applied in a relatively balanced manner. Although qualitative studies predominate, the difference compared to quantitative approaches is not substantial, and several studies employ mixed approaches.

3.2. Categorical analysis

In relation to the second objective of the review which aimed to identify the categories that characterize educational practices in natural sciences among basic education students, the analysis revealed three central categories, derived from nine subcategories and, in turn, 27 first-level codes. The coding and categorization process was conducted deductively, based on the selected articles: first through open coding, then axial coding that formed second-level codes, and finally the extraction of the central categories of the analysis, for which the Atlas ti Cloud software was used to carry out this coding process. The three categories into which the selected studies are grouped are presented and described below.

Natural science textbooks that guide educational practice require low cognitive demands

This category is derived from the way many teachers use textbooks in the field of natural sciences. While these materials are often regarded as support for pedagogical work, some studies have indicated that the cognitive skills developed through the activities proposed in these textbooks are not of high level. In the study by Sepúlveda-Obreque, et al (2023), cognitive skills were grouped according to levels of thinking development and classified as basic, investigative, reflective, and critical. The results show that the activities in the analyzed textbooks primarily foster basic scientific thinking, allowing the improvement of skills such as observing, answering, and explaining, while neglecting leaving aside experimentation.

Arana-Tuesta & Solís-Trujillo (2023) conducted a quantitative study in which they classified textbooks activities into four types according to levels of thinking development. Type 1 (36.8%) includes activities such as identifying characteristics, establishing relationships, comparing, and defining. Type II (33.4%) involves activities that apply knowledge to specific situations. Type III (19.2%) consist of activities such as observing, searching for information in different sources, hypothesizing and proposing their own work strategies. Finally, Type IV (10.6%) includes analyzing information and drawing conclusions based on scientific evidence. The study concludes that the analyzed textbooks primarily promote activities of lower cognitive demand, suggesting the need to transform these materials and emphasizing that textbooks should not be considered the sole means of supporting educational practice.

Active methodologies and the pedagogical use of technologies promote training in scientific competencies

Active methodologies are a recurring category in the development of scientific competencies. These methodologies promote constructivism, which emphasizes the student as the main actor in the learning process. Therefore, it is necessary to provide learning scenarios that foster the development of competencies and give meaning to the process. The impact of pedagogical technologies on this process, however, is not yet fully understood.

Many active learning methodologies prioritize experimentation. Holguín-Álvarez et al. (2021), conducted a study to assess the efficacy of a school-based scientific learning initiative that implemented a planting project. This project fostered skills related to competencies associated with the scientific method, facilitating the exploration of information, the formulation and testing of hypotheses, and critical engagement through didactic interaction.

The increase in overall post-assessment scores demonstrated improvements across several dimensions. Many participants learned to understand specific scientific situations, formulate theoretical associations with observable phenomena, interrogate underlying mechanisms, propose explanations grounded in assumptions, and articulate hypotheses guided by convergent or divergent scientific insights (Holguín-Álvarez et al., 2021).

Other experimentation-based strategies included outdoor approaches such as educational field trips. This alternative was implemented in multi grade classrooms in the Coquimbo region of Chile, integrating science teaching with environmental awareness. The field trip theme was "Structure, functions, and relationships of organisms with their environment" and students demonstrated progress according to their level of engagement in each grade. Notably, first- and second-grade students exhibited an understanding of plant anatomy. Third-grade students demonstrated the ability to differentiate seven different autochthonous plants, classifying them into three endemic, three autochthonous, and one introduced species. Fourth-grade students exhibited an understanding of biotic and abiotic factors during their field trip, identifying bodies of water and local fauna characteristic of the area visited. Finally, fifth- and sixth-grade students studied food chains, which facilitated their comprehension of the relationships among colliguay, tenca, peuco, and Fox. One student's reflection, recorded in a notebook, read: "The colliguay is very important for other living beings. For example, its flower and seeds are food for insects that come to the area in search of food". This outdoor strategy also fostered parental participation in the educational process and encouraged broader community in achieving the learning objectives (Jaime-Muñoz, 2021).

The most frequently reported active methodology among the selected articles was Inquiry-Based Science Education (IBSE). As highlighted in several studies, this methodology has shown positive outcomes. Delgado-Iglesias et al. (2024) indicate that the implementation of IBSE allowed conceptual development and familiarizes students with scientific procedures such as observation, measurement, representation, and argumentation. Albertos-Gómez (2022) confirmed that: "There are statistically significant differences in the development of scientific competence between students following an inquiry-based science teaching methodology and those using a traditional approach".

These findings are based on an experimental study that employed a 24-item objective test administered during both the pre-test and post-test assessments.

In the study conducted by Jimenez-Liso et al. (2021), the authors proposed a sequence of activities framed within inquiry and modeling to address an environmental impact problem (death of fish and algae due to dehydration on the beach). The main contribution of this sequence according to the authors was "to help students in the first cycle of secondary school (12-14 years) to explain, through the osmosis model, the problems of dehydration or hyperhydration of fish and algae at the cellular level" (p. 20). Furthermore, the authors suggest that such progress can support the development of sophisticated explanations at higher educational levels.

Sotomayor-Soloaga (2021), conducted a study aimed to characterize the good practices in science education implemented by teachers within an IBSE program. The study revealed that teachers' pedagogical practices transcend the classroom into a reflective dimension, where they continuously evaluate and adjust their teaching approaches. The study also identified that these practices encourage autonomy and discovery, promoting a collaborative learning environment. Teachers were found to view error as integral part of the learning process, providing positive feedback that nurtures a safe environment for learning and experimentation, encouraging active student participation.

Concerning the use of technologies, Vela-Acero & Jiménez-Cortés (2022) conducted a study exploring the learning experience with digital technologies and in scientific competencies (both self-perceived and observed) while also considering gender differences. Although the study did not demonstrate a direct impact of technology in the learning experience, the findings support the hypothesis that learning depends more on the quality rather than the quantity of technology use. This study also highlights that there are no significant differences between boys and girls in terms of self-perceived scientific competencies. In addition, the observed scientific competencies revealed that most students displayed a moderate performance across domains such as the living environment, the physical environment and science, technology, and society.

In Athens, Greece, the satellite-based Earth Observation (EO) technology was integrated into educational initiatives aimed at teaching climate change in schools. Asimakopoulou et al. (2021) state that modern EO satellite technologies provide striking visualizations of the Earth's climate system and its transformations. Although the participating teachers initially expressed concerns about the use of these systems, once they became familiar with the available resources and educational tools, they recognized their potential to capture students' interest and foster active learning. The participating teachers were primarily from the STEM fields; however, they believe that this tool can be used in non-STEM fields such as history, social studies, literature, art, and others.

The training of natural science teachers and its impact on the development of scientific competencies

Another category involved in the development of scientific competencies is the qualification of teachers who teach science subjects. Akilli & Kutur (2023) conducted a study examining the relationship between elementary school teachers' level of scientific literacy and their self-efficacy in teaching science. The results indicate that teachers with greater scientific knowledge perceive their practices as more effective, whereas those with lower levels of scientific literacy also report reduced self-efficacy in science teaching.

One factor associated with teacher qualification is the discourse used in their educational practice. Sandoval et al. (2021) assert that discourse affects the learning opportunities available to students. In this regard, a discourse that fosters active participation and dialogue can strengthen students' epistemic agency, enabling them to engage more deeply in the learning process.

Zúñiga-Meléndez et al. (2020), conducted an assessment of the training needs of natural science teachers. From a disciplinary perspective, the study found that biology teachers should strengthen areas such as ecology, evolution, genetics, cell biology, environmental care and biotechnology; in chemistry, areas such as chemical compounds, chemical bonds, stoichiometry, and organic chemistry; and in physics: kinematics, modern physics, work, energy, and electricity. It is important to note that this disciplinary knowledge must be complemented with pedagogical knowledge; student-centered strategies should be developed instead of relying on the mere transmission of content. The study concludes that the use of technology requires proper training to promote more dynamic and effective learning in science education.

Philander & Botha (2021) proposed an alternative to address issues related to unqualified natural science teachers, as most of them had limited teaching experience. Their strategy sought to strengthen the effective functioning of communities of practice, thereby contributing to teachers' professional development. According to Philander & Botha (2021), a community of practice helps participants to develop specific competencies. The study found that such communities were characterized by interactivity, collaboration, diverse experiences, motivation, friendship, trust, responsibility, a sense of belonging, and mutual support, as well as the involvement of a facilitator.

Through interactive collaboration, participants enhanced their content knowledge, developed the ability to teach scientific theory in ways relevant to real-life situations, and gained greater confidence in conducting demonstrations and laboratory activities. Opportunities for self-reflection proved instrumental in embedding newly acquired teaching practices. These positive changes resulted from fostering teacher autonomy by involving participants in key aspects of the design and operation of the community of practice (Philander & Botha, 2021).

To provide a deeper interpretation of the information condensed in the review documents, a categorical analysis was carried out to group the selected articles and identify the factors that characterize the teaching practices of natural science in basic education. As a result, the first relevant category that emerged was the use of textbooks by some science teachers. Although it is an accessible resource, in many cases they do not include activities that cognitively challenge students. Sepúlveda-Obreque et al. (2023) indicate that, although the relationship between scientific thinking skills in professional literature, curricular foundations, and textbooks is strong, these skills are not developed at the same level: "using the school textbook as the sole teaching resource may lead to discouraging results in student learning, since, as research has shown, it tends to strengthen lower-order cognitive skills at the expense higher-order ones".

According to the weaknesses in the analyzed textbooks, it is necessary to adopt other alternative resources that can complement pedagogical practice and foster the development of scientific skills and competencies. An alternative, which also emerged as the most significant category based on the number of related articles, was the use of active methodologies and the pedagogical integration of technologies to promote training in scientific competencies. López-Banet et al (2023) highlight the motivational effect of inquiry and active learning in carrying out activities in laboratory settings, where experimental testing proves to be motivating for students. These spaces for the dialogue of knowledge are more closely related to a democratic society, as they foster the development of vital capacities. In this way, learners acquire life skills that make their existence richer and more meaningful (Rodriguez, 2015).

Within this category, one of the most frequently applied active methodologies is Inquiry-Based Science Education (IBSE). Multiple articles highlight its potential; however, for some teachers, knowledge of this methodology is limited. Lima-Diniz et al. (2023) examined science teachers' conceptions of IBSE. The teachers identified certain scattered characteristics of the methodology, although these were incomplete. The authors conclude that being unfamiliar with this methodology which offers a range of possibilities for fostering the research process while taking into account reality, as well as the social, environmental, and economic context, remains a limiting factor in science learning today.

Husserl (2008), points out that the study or knowledge of the sciences must be carried out through the transcendental attitude, which consists in relating evidence to intuition, in other words, in clarifying the meaning of the world for us in our daily lives. The lifeworld is: "The world we all share: scientists and non-scientists. It is the world of the streets with their people, cars and buses; the world of the shops with their goods, buyers and sellers; the world of the neighborhoods, the marketplaces, the parks, and rural communities" (Ministerio de Educación Nacional, 1998).

From this perspective, IBSE shows considerable potential because it encourages interaction and contextual awareness, which is reflected in the positive outcomes of its application. As Jimenez-Liso et al. (2021) previously demonstrated, high school students improved their ability to construct scientific explanations regarding the environmental phenomenon of fish mortality.

According to the analysis of this category, active methodologies are also supported by the pedagogical use of technologies. Holguin-Alvarez et al. (2023), conducted a social responsibility experiment based on a robotic ecology program designed to promote the sustainable care of a polluted beach. The program integrated creativity into scientific inquiry processes through a STEAM approach within the experimental group, functioning as a form of scientific feedback. These programs not only connect with the local context but also establish dynamic, purpose-driven participation among students. They foster skills that enable learners to apply scientific knowledge to understand real-world situations, explain observed phenomena, verify hyphoteses, and, when necessary, formulate new questions.

The third category complements the previous ones: textbooks alone are insufficient for teaching science, and active methodologies are effective in developing scientific competencies, they require some teachers who are committed to these new dynamics, assertive in their discourse, up to date in their discipline, and willing to use technology to foster new skills.

This process calls for self-reflection on the part of the teacher, who must constantly evaluate his educational practice. In this regard, Earle (2021) documented a training process based on an evaluation activity designed to assess elementary science teachers (TAPS: Teacher Assessment in Primary Science). The findings indicated that TAPS influenced teaching practice in multiple ways: in decision-making; as some teachers modified the structure of future lessons; in the diversity of actions, as some teachers planned new strategies for later implementation; and in follow-up, as others incorporated changes directly into their ongoing practice. Thus, self-evaluation becomes an essential tool for teachers to implement new dynamics in their classes.

The training needs of teachers are diverse but can be classified into three main areas: disciplinary, pedagogical, and technological (Zúñiga-Meléndez et al., 2020). Various alternative approaches have been identified as beneficial in addressing these needs, such as communities of practice, spaces where educators can exchange methodologies, as well as strategies, and activities with their peers to strengthen teaching practice. Moreover, these collaborative scenarios foster implicit values associated with teamwork (Philander & Botha, 2021).

4. Conclusions

The collected, analyzed, and selected documentary evidence indicates that the development of scientific competencies in the field of natural sciences at the basic education level constitutes a topic of great relevance, which is currently being examined in various schools by stakeholders in both primary and secondary education.

A variety of initiatives can be observed that enrich the pedagogical practices of science teachers. Among these, some emphasize diagnostic exercises based on the analysis of stakeholders' perceptions, while others focus on assessing outcomes related to specific competencies. Certain initiatives examine the media, resources and methodologies proposed as alternatives to foster the development of competencies, whereas others highlight the crucial role of teacher mediation in creating scenarios that enhance pedagogical practice. Numerous alternatives also stress the need to teach science in a contextualized manner, linking scientific knowledge with social understanding and encouraging dialogic exercises rather than relying solely on traditional instruction. the importance of teacher mediation to favor scenarios that enrich pedagogical practice. Furthermore, Technological integration emerges as another powerful alternative that underlies opportunities for innovative practices, significantly contributing to the improvement of scientific skills.

As a result of the qualitative analysis, three central categories were identified that encompass the selected studies. The first indicates that natural science textbooks entail a low cognitive demand; the skills developed through these materials do not challenge students cognitively, as they consist of elementary activities that fail to promote experimentation, critical discussion, and the construction of knowledge.

The second category indicates that active methodologies and the pedagogical use of technologies promote the development of scientific competencies. Active methodologies involve initiatives that encourage students to assume a leadership role in the learning process by providing opportunities to interact, engage in dialogue, ask questions, exchange knowledge, and continuously participate in the construction of their own understanding. In addition to creating these scenarios, in which both contributions and mistakes are regarded as opportunities, many of these initiatives also integrate technology, which offers added value by enriching the learning environments.

It is pertinent to note that relying solely on a textbook is not insufficient; it is necessary to explore active methodologies that foster a conducive learning environment. However, this also requires the presence of a well-trained teacher willing to guide the teaching-learning process. The third category establishes that the training of natural science teachers, together with their discourse, and interactions, has a direct impact on the development of scientific competencies, since teachers are the ones who guide pedagogical actions in the classroom. Therefore, they must possess disciplinary, pedagogical, and technological knowledge that enables them to support students in using knowledge comprehensively, explaining natural phenomena, and formulating their own hypotheses, questions, and conclusions.

Authors' Contribution

Sergio Iván Mejía-Vargas: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft.

Farid Alejandro Carmona-Alvarado: Project administration, Supervision, Validation, Writing – review and editing.

Ethical implications

There are no ethical implications to state in writing or publishing this article.

Funding

The authors did not receive resources for the writing or publication of this article.

Conflicts of interest

There are no conflicts of interest from the authors in the writing or publication of this article.

References

Akilli, M., & Kutur, K. (2023). Does Science Literacy Affect Self-Efficacy in Science Teaching? An Analysis with Structural Equation Modelling. *Revista Romaneasca Pentru Educatie Multidimensionala,* 487-502. https://doi.org/10.18662/rrem/15.2/745

Albertos-Gómez, D. (2022). Evaluation of the effect of guided inquiry on scientific competence in secondary school students. *Didáctica de las Ciencias Experimentales y Sociales, 47 (*1), 162–177. https://doi.org/10.7203/dces.43.22909

Arana-Tuesta, P. M., & Solís-Trujillo, B. P. (2023). Promoción de competencias científicas en textos escolares de Ciencia y Tecnología del segundo grado de educación secundaria de Perú. *Revista Educación, 47* (1), 162–177. https://doi.org/10.15517/revedu.v47i1.49913

Asimakopoulou, P., Nastos, P., Vassilakis, E., Hatzaki, M., & Antonorakou, A. (2021). Earth Observation as a Facilitator of Climate Change Education in Schools: The Teachers' Perspectives. *Remote Sensing*, 1-17. https://doi.org/10.3390/rs13081587

Atlas.ti. (24 de Marzo de 2025). El software nº 1 para el análisis cualitativo de datos - Atlas.ti. https://atlasti.com

Baur, A. (2023). Which student problems in experimentation are related to one another? *International Journal of Science Education,* 781-805. https://doi.org/10.1080/09500693.2023.2175334

Blanchar-Añez, F. J. (2020). Características de la práctica pedagógica en el área de Química. *Revista Científica*, 30-57. https://doi.org/10.14483/23448350.14855

Bónus, L., Antal, E., & Korom, E. (2024). Digital Game-Based Inquiry Learning to Improve Eighth Graders' Inquiry Skills in Biology. *Journal of Science Education and Technology,* 1-17. https://doi.org/10.1007/s10956-024-10096-x

Borić, E., & Zečević, M. (2021). Evaluation of Homework in Science and Social Studies. *Croatian Journal of Education,* 23, 85-103. https://doi.org/10.15516/cje.v23i0.4055

Castelblanco-Sánchez, A., Cifuentes-Garzón, J., Pinilla-Saavedra, D., & Pulido-Buitrago, S. (2020). Prácticas pedagógicas para la aproximación al conocimiento como científico social y natural en estudiantes de secundaria. *Praxis & Saber, 11* (27), e10474. https://doi.org/10.19053/22160159.v11.n27.2020.10474

Chávez-Charro, J. M., Neira, I., & Lacalle-Calderón, M. (2021). Scientific Competence in Developing Countries: Determinants and Relationship to the Environment. *Sustainability*, 1-16. https://doi.org/10.3390/su132212439

Cramer, J., Yazilitas, D., Bruynzeel, A., Romp, S., Smeets, I., & De Bruyckere, P. (2024). The effect of tutoring primary school pupils by university students on STEM interest: a pre-registered randomised controlled trial. *Cogent Education*, 1-12. https://doi.org/10.1080/2331186X.2024.2408834

Delgado-Iglesias, J., Bobo-Pinilla, J., Reinoso-Tapia, R., & Vega-Agapito, M. V. (2024). Is It Possible to Apply Inquiry in the First Level of Primary School without Hindering the Acquisition of Scientific Competencies? Perspectives of Pupils and Their Pre-Service Teacher. *Education Sciences*, 1-23. https://doi.org/10.3390/educsci14010096

Earle, S. (2021). Formative Decision-Making in Response to Primary Science Classroom Assessment: What to do Next? Frontiers in Education, 1-7. https://doi.org/10.3389/feduc.2020.584200

Eka-Putra, R., Harianto, D., Pudjaningsih, W., & Eriyani, E. (2024). The Impacts of the Analysis, Debate, and Finding Models on Learning Natural Sciences. *Qubahan Academic Journal,* 166-174. https://doi.org/10.48161/qaj.v4n3a189

Fazio, X., Kemmis, E., & Zugic, J. (2024). Viewing science teacher learning and curriculum enactment through the lens of theory of practice architectures. *Science Education*, 1-30. https://doi.org/10.1002/sce.21901

Fuentealba-Cruz, M., Miño-Gonzalez, L., & Neira-Morales, J. (2024). Etimología en la enseñanza de las ciencias: una mirada al origen de las palabras. *Revista de Investigación en Educación*, 150-160. https://doi.org/10.35869/reined.v22i2.5375

García-Barros, S., Martínez-Losada, C., & Rivadulla-López, J. (2021). Actividades de textos escolares. Su contribución al desarrollo de la competencia científica. *Enseñanza de las Ciencias,* 219-238. https://doi.org/10.5565/rev/ensciencias.3099

García-Gaitán, C. C., Ramírez-Díaz, M., & Arriaga-Santos, C. (2022). ¿Cómo viaja la luz? La actividad experimental para desarrollar competencias científicas en la infancia. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 13* (25). https://doi.org/10.23913/ride.v13i25.1252

Gómez, R., Palacios, A., Moreno-Mediavilla, D., & Barreras, Á. (2022). Competencias Docentes en el Uso de Simulaciones Virtuales STEM: Diseño y evaluación de un instrumento de medida. *Bordón - Revista de Pedagogía,* 85-102. https://doi.org/10.13042/Bordon.2022.94154

Hernández-Gil, C., Cardozo-Jiménez, C. J., & Perdomo-Rojas, L. T. (2023). Los desafíos de la dirección educativa en el fomento de habilidades científicas. *Revista Latinoamericana de Ciencias Sociales, Niñez y Juventud,* 1-33. https://doi.org/10.11600/rlcsnj.21.2.5191

Holguín-Álvarez, J., Figueroa-Hurtado, F., Apaza-Quispe, J., Montañez-Huancaya, A., & Cruz-Montero, J. (2021). School Learning from the Seeding Project in the Context of Child Care. *Apuntes Universitarios,* 172-185. https://doi.org/10.17162/au.v11i2.642

Holguin-Alvarez, J., Cruz-Montero, J., Ruiz-Salazar, J., & Ledesma-Pérez, F. (2023). Ecología robótica desde el litoral: resultados de un programa fortalecedor de las habilidades para la ciencia. *Revista Publicaciones,* 13-29. https://doi.org/10.30827/publicaciones.v53i2.26816

Höper, J. (2024). Mind the Gap Between Chemistry and Outdoor Education: Primary and Lower Secondary Preservice Teachers' Beliefs During an Outdoor-Based Introduction to Chemistry in Science Education. *Journal of Science Teacher Education,* 1-28. https://doi.org/10.1080/1046560X.2024.2406661

Husserl, E. (2008). Las crisis de las ciencias europeas y la fenomenología trascendental. Buenos Aires: Prometeo Libros.

Jaime-Muñoz, E. A. (2021). Propuestas pedagógicas al aire libre en escuelas rurales multigrado en la Región de Coquimbo, Chile. *Tecné, Episteme y Didaxis,* 277-294. https://doi.org/10.17227/ted.num49-9674

Jiménez, A., & Álvarez-Hevia, D. M. (2022). Perceptions of primary school students toward learning about science: the case of Spain. *Educación* 3-13, 50(8), 1046-1058. https://doi.org/10.1080/03004279.2021.1929381

Jiménez-Liso, Mª R., Delgado, L., Castillo-Hernández, F. J., & Baños-González, I. (2021). Contexto, indagación y modelización para movilizar explicaciones del alumnado de secundaria. *Enseñanza de las Ciencias, 39* (1), 5-25.26 https://doi.org/10.5565/rev/ensciencias.3032

Kopcha, T. J., & Ocak, C. (2023). Children's computational thinking as the development of a possibility space. *Computers and Education Open,* 1-14. https://doi.org/10.1016/j.caeo.2023.100156

Landinho, F. M., Mendonça-Duarte, R., & Biscalquini-Talamoni, A. C. (2022). From Nutrition to Digestion: A Contextualized Proposal for The Digestive System Teaching. *Góndola - Enseñanza y Aprendizaje de las Ciencias,* 607-625. https://doi.org/10.14483/23464712.18937

Lhardy, C., & Reina, A. (2024). Identifications: A Battle Card Game to Learn Chemical Tests and Practice Observation and Reasoning. *Journal of Chemical Education*, 1574-1582. https://doi.org/10.1021/acs.jchemed.3c01142

Lima-Diniz, G. K., da Silva, N. C., & Fernández-Florêncio de Araújo, M. F. (2023). Conceptions of Natural Science Teachers About Teaching through Research. *Revista Eletronica Pesquiseduca*, 204-216. https://doi.org/10.58422/repesq.2023.e1342

López-Banet, L., Martinez-Carmona, M., Soto-Cascales, C. M., & Reis, P. (2023). Investigaciones secuenciadas por grado de autonomía para el desarrollo de prácticas científicas en 2° y 3° de ESO. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias,* 110301-110318. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2023.v20.i1.1501

Ministerio de Educación Nacional, MEN. (24 de marzo de 1998). Lineamientos curriculares. https://www.mineducacion.gov.co/1621/article-89869.html

Morales-Silva, T., Álvarez-Durán, E., Álvarez-Iriarte, C., & Rivero Diegues, N. (2024). Impacto de la enseñanza remota en las habilidades académicas de estudiantes del primer ciclo básico en Calama y Antofagasta: un análisis multidimensional. *Revista Enfoques Educacionales,* 93-116. https://doi.org/10.5354/2735-7279.2024.73656

Muñoz-Martínez, J. I., & Charro-Huerga, E. (2023). El desarrollo de Competencias Científicas a través de una línea de saberes: Un análisis experimental en el aula. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias,* 210101-210120. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2023.v20.i2.2101

Ochoa-López, Y., Canquíz-Rincón, L., & Lubo-De la Rosa, K. (2022). Percepción de estudiantes y docentes de básica primaria sobre competencias científicas asociadas con el desarrollo cognitivo estudiantil. *Revista Electrónica Educare,* 1-19. https://doi.org/10.15359/ree.26-3.22

Okada, A., Steimber de Pereira-Okada, A. E., & de Olivera-Campolina, L. (2023). Open Schooling for Digital Education with Science and Technology- Reflections on European and Brazilian Public Policy Plans. *Eccos - Revista Cientifica,* 1-21. https://doi.org/10.5585/eccos.n65.24689

Perez, S., & Meneses-Villagrá, J. Á. (2020). La competencia científica en las actividades de aprendizaje incluidas en los libros de texto de Ciencias de la Naturaleza. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias,* 1-18. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2020.v17.i2.2101

Pey-Betrán, J., Villa-Orduna, I., & Mazas-Gil, B. (2022). "El aire que respiramos": diseño y desarrollo de un proyecto sobre contaminación atmosférica para trabajar las destrezas científicas. *Didáctica de las Ciencias Experimentales y sociales,* 157-171. https://doi.org/10.7203/DCES.43.21914

Philander, C. J., & Botha, M. L. (2021). Natural sciences teachers' continuous professional development through a Community of Practice. *Revista Sudafricana de Educación,* 1-11. https://doi.org/10.15700/saje.v41n4a1918

Reis, P., Tinoca, L., Baptista, Y., & Linhares, E. (2020). The Impact of Student-Curated Exhibitions about Socio-Scientific Issues on Students' Perceptions Regarding Their Competences and the Science Classes. *Sustainability,* 1-13. https://doi.org/10.3390/su12072796

Ribau, I. (2020). Practical work by laboratory stations: An innovation in experimental work. *Universal Journal of Educational Research,* 17-26. https://doi.org/10.13189/ujer.2020.080103

Rodríguez-Mora, F., & Blanco-López, Á. (2021). Diseño de una secuencia de enseñanza-aprendizaje para el desarrollo de competencias científicas en el contexto del consumo de agua envasada. *Revista Eureka* *sobre Enseñanza y Divulgación de las Ciencias,* 1-19. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2021.v18.i1.1803

Sandoval, W., Kawasaki, J., & Clark, H. F. (2021). Characterizing Science Classroom Discourse Across Scales. *Research in Science Education,* 35-49. https://doi.org/10.1007/s11165-020-09953-7

Santini, J., Sensevy, G., Quilio, S., Forest, D., & Blocher, J.-N. (2022). Semiosis and joint student-teacher action. Contract-milieu dialectics in a case study of two subsequent primary school earth science sessions. *International Journal of Science Education,* 1067-1095. https://doi.org/10.1080/09500693.2022.2066732

Sepúlveda-Obreque, A., Minte-Münzenmayer, A., Villalobos-Clavería, A., Peña-Troncoso, S., & Diaz-Levicoy, D. (2023). Habilidades de Pensamiento Científico en los Textos. *Areté,* 43-61. https://doi.org/10.55560/arete.2023.17.9.2

Sotomayor-Soloaga, P. A. (2021). Good Pedagogical Practices in Science Teaching. Magis - *Revista Internacional de Investigación en Educación,* 1-23. https://doi.org/10.11144/Javeriana.m14.gpps

Tavarez, R., Marques-Vieira, R., & Pedro, L. (2021). Mobile App for Science Education: Designing the Learning Approach. *Education Sciences,* 1-23. https://doi.org/10.3390/educsci11020079

Universidad del Bosque (24 de marzo de 2025). Rayyan - Revisiones de literatura. Biblioteca Universidad del Bosque. https://biblioteca.unbosque.edu.co/programa-integral-de-formacion-pif-para-la-investigacion/nivel-avanzado/rayyan-revisiones-de#:~:text=Permite%20crear%2C%20gestionar%20y%20compartir,y%20la%20resoluci%C3%B3n%20de%20conflictos

Urrútia, G., & Bonfill, X. (2010). Declaración PRISMA: una propuesta para mejorar la publicación de revisiones sistemáticas y metaanálisis. *Medicina Clínica, 135* (11), 507-511. Obtenido de: https://bmjopen.bmj.com/content/bmjopen/suppl/2013/06/10/bmjopen-2012-002330.DC1/bmjopen-2012-002330supp_PRISMA-2010.pdf

Vargas-Velandia, C. J., & Morales-Silva, T. A. (2021). Análisis de habilidades científicas en la enseñanza de las ciencias: caso comparativo entre profesores de Chile y Colombia. *Tecné, Episteme y Didaxis,* 57-75. https://doi.org/10.17227/ted.num50-11129

Vela-Acero, C., & Jiménez-Cortés, R. (2022). Learning experience with digital technologies and its influence on the scientific competence of high school students. *Educar,* 141-156. https://doi.org/10.5565/rev/educar.1319

Vieira-de Moraes, T., Simões-Girotto, C. G., & Pereira-de Oliveira, B. C. (2022). Child Written Records and Scientific Literacy: Focus on Inquiry Based Science Teaching. *Nuances - Estudos Sobre Educacao,* 1-21. https://doi.org/10.32930/nuances.v33i00.9496

Zúñiga-Meléndez, A., Durán-Apuy, A., Chavarría-Vásquez, J., Gamboa-Araya, R., Carballo-Arce, A. F., Vargas-González, X., & Torres-Salas, I. (2020). Diagnóstico de las necesidades de capacitación de docentes de biología, química, física y matemática, en áreas disciplinares, pedagógicas, y uso de tecnologías para la promoción de habilidades de pensamiento científico. *Revista Electrónica Educare*, 469-497. https://doi.org/10.15359/ree.24-3.23