

ORIGINAL ARTICLE

SIGNS OF SCIENTIFIC LITERACY IN 9TH GRADE STUDENTS: A DIAGNOSTIC STUDY IN URBAN AND RURAL SCHOOLS IN THE MUNICIPALITY OF PENALVA-MA

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ABSTRACT

This article presents the results of a diagnostic investigation on scientific literacy among 9th-grade students from three public schools in the municipality of Penalva, Maranhão, Brazil. The research was conducted with one urban school and two rural schools, aiming to identify signs of scientific literacy prior to the implementation of an Inquiry-Based Teaching Sequence (IBTS). A diagnostic questionnaire was applied, based on the axes and indicators proposed by Sasseron and Carvalho (2008), and the students' answers were qualitatively analyzed using an interpretative framework built from the same theoretical foundation. The results revealed significant disparities between urban and rural contexts: urban students showed a greater command of scientific concepts and argumentative ability, while students from rural schools exhibited considerable weaknesses. The findings confirm the hypothesis that it is possible to diagnose, with clarity and rigor, signs of scientific literacy through well-structured evaluative instruments. Moreover, the study highlights that increased school time alone does not ensure advances in science learning. Intentional, contextualized, and inquiry-oriented pedagogical practices are essential. The data reinforce the relevance of diagnostic evaluation as a formative stage and a guiding tool for more equitable and effective science teaching approaches.

Keywords: Scientific literacy, Inquiry-based teaching, Science education, Public education.

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INDÍCIOS DE ALFABETIZAÇÃO CIENTÍFICA EM ESTUDANTES DO 9º ANO: UM ESTUDO DIAGNÓSTICO EM ESCOLAS URBANAS E RURAIS NO MUNICÍPIO DE PENALVA-MA

RESUMO

Este artigo apresenta os resultados de uma investigação diagnóstica sobre a alfabetização científica de estudantes do 9º ano do Ensino Fundamental em três escolas públicas do município de Penalva-MA. A pesquisa foi realizada com turmas de uma escola da zona urbana e duas da zona rural, com o objetivo de identificar indícios de alfabetização científica antes da aplicação de uma Sequência de Ensino Investigativa (SEI). Para isso, aplicou-se um questionário diagnóstico fundamentado nos eixos e indicadores propostos por Sasseron e Carvalho (2008), e as respostas foram analisadas qualitativamente com base em um roteiro interpretativo desenvolvido a partir do mesmo referencial. Os resultados revelaram desigualdades marcantes entre os contextos urbanos e rurais: os estudantes da zona urbana apresentaram maior domínio conceitual e argumentativo, enquanto os alunos das escolas rurais demonstraram fragilidades significativas. A pesquisa confirma a hipótese de que é possível diagnosticar, com clareza e rigor, indícios de alfabetização científica por meio de instrumentos avaliativos bem estruturados. Além disso, destaca-se que o tempo de permanência na escola não garante, por si só, avanços na aprendizagem científica, sendo indispensável o uso de práticas pedagógicas mais intencionais, investigativas e contextualizadas. Os dados evidenciam a importância da avaliação diagnóstica como etapa formativa e orientadora de propostas de ensino mais equitativas e eficazes no campo das Ciências.

Palavras-chave: Alfabetização científica, Ensino por investigação, Ensino de Ciências, Educação pública.

Indicios de Alfabetización Científica en Estudiantes de Noveno Grado: un estudio diagnóstico en escuelas urbanas y rurales del municipio de Penalva-MA

RESUMEN

Este artículo presenta los resultados de una investigación diagnóstica sobre la alfabetización científica de estudiantes del noveno año de la Educación Básica en tres escuelas públicas del municipio de Penalva, Maranhão, Brasil.



La investigación se llevó a cabo en una escuela ubicada en la zona urbana y en dos situadas en el medio rural, con el objetivo de identificar indicios de alfabetización científica antes de la aplicación de una Secuencia de Enseñanza por Indagación (SEI).

Se aplicó un cuestionario diagnóstico fundamentado en los ejes e indicadores propuestos por Sasseron y Carvalho (2008), y las respuestas fueron analizadas cualitativamente a partir de un guion interpretativo elaborado con base en el mismo marco teórico. Los resultados revelaron desigualdades significativas entre los contextos urbano y rural: los estudiantes de la zona urbana demostraron mayor dominio conceptual y capacidad argumentativa, mientras que los estudiantes de las escuelas rurales presentaron debilidades importantes. Los hallazgos confirman la hipótesis de que es posible diagnosticar, con claridad y rigor, indicios de alfabetización científica mediante instrumentos evaluativos bien estructurados. Además, se destaca que el aumento del tiempo escolar, por sí solo, no garantiza avances en el aprendizaje científico. Son esenciales prácticas pedagógicas intencionales, contextualizadas y basadas en la indagación. Los datos refuerzan la importancia de la evaluación diagnóstica como etapa formativa y orientadora de propuestas de enseñanza más equitativas y eficaces en el campo de las Ciencias.

Palabras clave: Alfabetización científica, Enseñanza por indagación, Enseñanza de Ciencias, Educación pública.

1. INTRODUCTION

Science education in elementary school has historically faced the challenge of overcoming fragmented, content-centered, and decontextualized approaches that often contribute little to students' critical and meaningful development. Within the context of a society shaped by profound technological, environmental, and social transformations, it becomes imperative to rethink the role of school-based science education, recognizing its function not merely as informational, but as formative in preparing individuals capable of interpreting the world, constructing evidence-based arguments, and making informed decisions. In this context, the concept of scientific literacy emerges as a structuring axis for science education, understood not only as conceptual mastery, but also as a process that integrates epistemic practices, scientific language, and critical reflection on the relationships among science, technology, society, and the environment.

The perspective of scientific literacy, as systematized by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008), encompasses three central formative dimensions: (I) the understanding of scientific concepts and processes; (II) the understanding of the nature of science as a social, historical, and discursive practice; and (III) the understanding of the relationships among science, technology, society, and the environment (STSE). Each of these dimensions, when incorporated into everyday school practices, contributes to the development of a scientifically literate individual in a broad sense—not merely someone familiar with terms and definitions, but someone capable of understanding, interpreting, arguing, and critically positioning themselves in relation to the challenges of the contemporary world.

Within this context, scientific literacy is understood not as the exclusive outcome of implementing inquiry-based methodologies or isolated projects, but rather as a process that manifests itself in diverse and gradual ways throughout students' educational trajectories.

Thus, even prior to the implementation of approaches such as Inquiry-Based Science Education, it is possible to identify indicators of students' conceptual, epistemic, and sociocultural development, provided that assessment instruments are sufficiently sensitive and grounded in the indicators of scientific literacy. This premise constitutes the starting point of the present investigation.

This article aims to present the results of a diagnostic study conducted with ninth-grade elementary school students from three public schools in the municipality of Penalva, Maranhão, Brazil, with the objective of identifying indicators of scientific literacy prior to the implementation of an Investigative Teaching Sequence. To this end, a structured questionnaire was administered based on the dimensions and indicators proposed by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008), and the responses were qualitatively analyzed using an analytical framework likewise grounded in this theoretical model. The investigation involved three distinct classes, one located in the urban area and two situated in rural areas of the municipality, thereby enabling a comparative analysis across different educational contexts. The findings reveal significant disparities among the groups investigated, highlighting the need to deepen discussions regarding educational equity, access to scientific knowledge, and pedagogical practices that promote the active and critical construction of knowledge in all school settings.

2. THEORETICAL FRAMEWORK

Science education in elementary school, particularly during the final years of basic education, continues to face structural and epistemological gaps that compromise its formative role. Traditional pedagogical practices, still characterized by a strong emphasis on content transmission, memorization, and a lack of connection to students' everyday experiences, reveal a disconnect between the school environment and contemporary forms of scientific literacy (PEREIRA; MENEZES, 2022). Despite more recent curricular guidelines, such as the Base Nacional Comum Curricular (BRASIL, 2018), everyday school practices still lack instructional approaches that prioritize the development of intellectual autonomy, argumentation, and critical reflection.

These issues are intensified by a school model that, as noted by Eduardo Fleury Mortimer and Philip Scott (2002), tends to suppress students' discourse while privileging the authoritative voice of the teacher, thereby silencing the dialogical potential of science classes. The absence of investigative and discursive practices not only impoverishes the teaching and learning process, but also undermines the development of essential scientific competencies for citizenship education. As emphasized by Freitas and Santana (2021), science learning must integrate conceptual knowledge with the development of epistemic practices and the capacity to critically interpret reality.

This precarious state of education becomes even more critical when considering the structural inequalities between urban and rural schools, frequently identified in the educational literature as a concrete expression of social and territorial asymmetries. Recent studies (SANTOS; PENA, 2020; ALMEIDA; BARROS, 2022) have shown that students in rural areas continue to face significant barriers, including inadequate infrastructure, lack of instructional materials, limited access to technology, and insufficient specialized teacher training.

These limitations are not merely operational in nature; rather, they represent manifestations of a historical inequality that compromises the right to scientific knowledge and reinforces disparities among different educational contexts.

Rural education, as argued by Miguel González Arroyo (2004), must be conceived as a field with its own identity rather than as a simplified adaptation of the urban educational model. Nevertheless, a hegemonic school logic still prevails—one that disregards local knowledge and imposes decontextualized practices upon rural realities. As noted by Klein and Coutinho (2020), this logic produces a form of pedagogical exclusion that compounds social exclusion, thereby weakening the educational development of rural students. In this context, educational equity must be understood not as mere formal equality, but as curricular justice, territorial sensitivity, and a commitment to the democratization of knowledge.

The advocacy of scientific literacy as a formative axis in science education thus emerges as a theoretical and political response to the need for an educational approach capable of developing intellectually autonomous, discursively competent, and socially engaged individuals. As systematized by Luciana Maria Lunardi Campos Sasserón and Anna Maria Pessoa de Carvalho (2008), this process involves fostering an understanding of scientific concepts and processes, the nature of science as a social construction, and the interrelationships among science, technology, society, and the environment (STSE). However, scientific literacy should be understood not merely as an instructional objective, but as a pedagogical practice that is enacted through intentional mediation, problematization, and attentive engagement with students' ideas.

Recent studies have reinforced this perspective by highlighting the importance of diagnostic assessment as a formative resource capable of revealing students' levels of appropriation of scientific knowledge. Silva et al. (2020) demonstrate that the qualitative analysis of students' responses, based on carefully designed instruments, makes it possible to identify indicators of scientific thinking, argumentation, and conceptual development, thereby providing teachers with meaningful support for the replanning of their instructional practices. This conception is reaffirmed by Reis (2023), who argues that the analysis of students' speech, written productions, and justifications can make visible the development of scientific literacy in its multiple dimensions.

It is within this framework that the present study is situated, based on the hypothesis that it is possible to identify, through assessment instruments grounded in the indicators of scientific literacy, evidence of the conceptual, epistemic, and sociocultural development levels of ninth-grade elementary school students in science education prior to the implementation of an Investigative Teaching Sequence. Such a hypothesis aligns with an understanding of assessment as a diagnostic, formative, and mediating process, rather than as a merely classificatory instrument.

By employing a structured questionnaire grounded in the indicators of scientific literacy, together with a qualitative analysis sensitive to the discursive nuances present in students' responses, this investigation demonstrates not only the feasibility of the proposed hypothesis, but also its pedagogical potential.

This study, by emphasizing prior diagnostic assessment, reinforces the need for a qualified pedagogical listening process committed to equity and to the construction of a more just, intentional, and transformative educational practice. More than measuring what students know, the present research seeks to understand how they think, argue, interpret, and appropriate scientific knowledge. It is precisely within this process that the formative impact of this proposal resides.

3. METHODOLOGY

This study is qualitative in nature and was designed based on theoretical and methodological assumptions that emphasize the interpretive deepening of educational phenomena through the situated analysis of subjects, contexts, and school practices. As highlighted by Marli Eliza Dalmazo Afonso de André (1995), qualitative research, by seeking to understand the meanings attributed by participants to the events and practices they experience, proves particularly suitable for educational studies, as it enables the identification of nuances, discourses, and interactions that are not readily observable through quantitative approaches. It therefore constitutes an investigative path that, rather than merely measuring, seeks to interpret in depth the formative processes of the individuals involved.

The investigation was conducted in the municipality of Penalva, in the state of Maranhão, Brazil, and involved three public elementary schools. In each school, one ninth-grade class was selected, resulting in a total of three participating classes. Among the school units, two are located in rural areas of the municipality and one in the urban area, thereby enabling a comparative analysis across distinct educational contexts marked by structural, socioeconomic, and formative inequalities. The choice of this territorial focus is also justified by the interest in discussing educational equity and the asymmetries that characterize access to scientific knowledge across different school realities.

As a data collection instrument, a diagnostic questionnaire was employed, structured on the basis of the formative dimensions and indicators of scientific literacy proposed by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008). The dimensions of scientific literacy that underpin the instrument are presented in Table 1, together with the main indicators that guided both the construction of the questionnaire and the subsequent analytical criteria.

Table 1. Dimensions of Scientific Literacy and Their Indicators

Dimension of Scientific Literacy	Description	Indicators of Scientific Literacy
Understanding of scientific concepts and processes	Mastery of foundational scientific concepts and of the processes that characterize scientific practice, such as observation, experimentation, systematization, and logical reasoning.	Identification of variables; formulation of hypotheses; interpretation of phenomena; construction of evidence-based explanations; use of scientific concepts and terminology.
Understanding of the nature of science	Understanding science as a human, social, historical, and provisional construction, subject to change and influenced by cultural contexts, values, and social practices.	Recognition that scientific knowledge is historically constructed; understanding of the ways in which ideas are validated in science; critical analysis of different sources of information.
Understanding of the relationships among science, technology, society, and the environment (STSE)	Ability to understand the social, ethical, environmental, and political implications of science and technology, critically reflecting on their presence in everyday life and their consequences for society.	Analysis of socio-environmental problems; evidence-based decision-making; recognition of STSE relationships; reflection on the role of science in transforming society.

Source: Prepared by the authors (2025).

Based on these dimensions, a questionnaire composed of open-ended questions was developed and carefully organized to allow students to express their conceptions regarding scientific phenomena, investigative practices, their understanding of science, and its relationships with everyday life. The model of the instrument applied is presented in Table 2.

Table 2. Model of the Diagnostic Questionnaire – Scientific Literacy

Dimension of Scientific Literacy	Diagnostic Question	Related Scientific Literacy Indicator
Understanding of scientific concepts and processes	Q1 – Explain, in your own words, a scientific phenomenon you have already studied. How did you learn about it?	Mastery of scientific concepts and use of scientific language.
Understanding of scientific concepts and processes	Q2 – What do you usually do to understand how something works in nature? Have you ever tried to formulate hypotheses or conduct tests?	Formulation of hypotheses; use of investigative reasoning.
Understanding of scientific concepts and processes	Q3 – Have you ever carried out an experimental activity in Science class? What did you learn from it?	Ability to interpret phenomena through experimentation.
Understanding of the nature of science	Q4 – Do you think scientific knowledge changes over time? Why?	Understanding science as a historical and social construction.
Understanding of the nature of science	Q5 – Do you believe that scientists always agree with one another? Why does this happen or not happen?	Recognition of science as a field characterized by debate and revision.
Understanding of the relationships among science, technology, society, and the environment (STSE)	Q6 – Can you recall a societal problem that involves science or technology? How do you understand this relationship?	Ability to articulate connections between science and society; critical reflection.

Understanding of the relationships among science, technology, society, and the environment (STSE)	Q7 – In your opinion, why is it important to study Science nowadays? How does it help people in their lives?	Evidence-based decision-making and social awareness regarding science.
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Source: Prepared by the authors (2025).

Following the administration of the instrument, students' responses were analyzed using a qualitative analytical framework developed from the same scientific literacy indicators employed in the design of the questionnaire. This framework enabled a more precise identification of evidence related to conceptual, epistemic, and sociocultural development in students' written responses, organizing the data according to analytical criteria consistent with the adopted theoretical framework. The structure of the analytical framework is presented in Table 3.

Table 3. Qualitative Analytical Framework for Students' Responses

Scientific Literacy Indicator	Criteria for the Qualitative Analysis of Responses
Mastery of scientific concepts and use of scientific language	Correctly identifies scientific concepts; uses appropriate vocabulary; demonstrates understanding of the described phenomenon.
Formulation of hypotheses; investigative reasoning	Reports investigative attitudes; mentions tests, assumptions, or hypotheses; demonstrates exploratory thinking.
Interpretation of phenomena and understanding of the experimental process	Demonstrates learning derived from practical experiences; recognizes the role of experimentation in validating ideas.
Understanding science as a historical and social construction	Recognizes that knowledge changes over time; mentions examples of scientific transformations throughout history.
Recognition of science as a field characterized by debate and revision	Identifies disagreements among scientists; understands that knowledge is constructed through debate and validation processes.
Articulation among science, technology, society, and the environment (STSE)	Establishes relationships between scientific topics and contemporary social, environmental, or technological issues.
Evidence-based decision-making and social awareness regarding science	Demonstrates critical awareness; reflects on the role of science in everyday life and its relevance to society.

Source: Prepared by the authors (2025).

It is important to emphasize that the focus of this research was not to quantitatively measure students' conceptual mastery, but rather to identify qualitative indicators of scientific literacy in their discursive manifestations. This analytical perspective made it possible to recognize elements such as the formulation of hypotheses, the construction of arguments, the use of scientific vocabulary, and the articulation of social and environmental issues, among other aspects that express formative dimensions often rendered invisible by traditional assessment approaches.

The decision to conduct the diagnostic assessment prior to the implementation of an Investigative Teaching Sequence (ITS) responds to the need to understand, in depth, students' stage of development and, consequently, to plan pedagogical actions more closely aligned with their actual formative needs.

As emphasized by Luciana Maria Lunardi Campos Sasseron (2015) and Silva et al. (2020), diagnostic assessment, when well structured and interpreted in light of consistent theoretical frameworks, constitutes a valuable instrument not only for instructional planning, but also for valuing learning as a dynamic, discursive, and emancipatory process.

Thus, the methodology adopted in this study integrates a critical conception of teaching and assessment, grounded in pedagogical mediation, active listening to students, and the pursuit of educational practices that genuinely promote equity and the right to science as language, culture, and citizenship.

4. RESULTS AND DISCUSSION

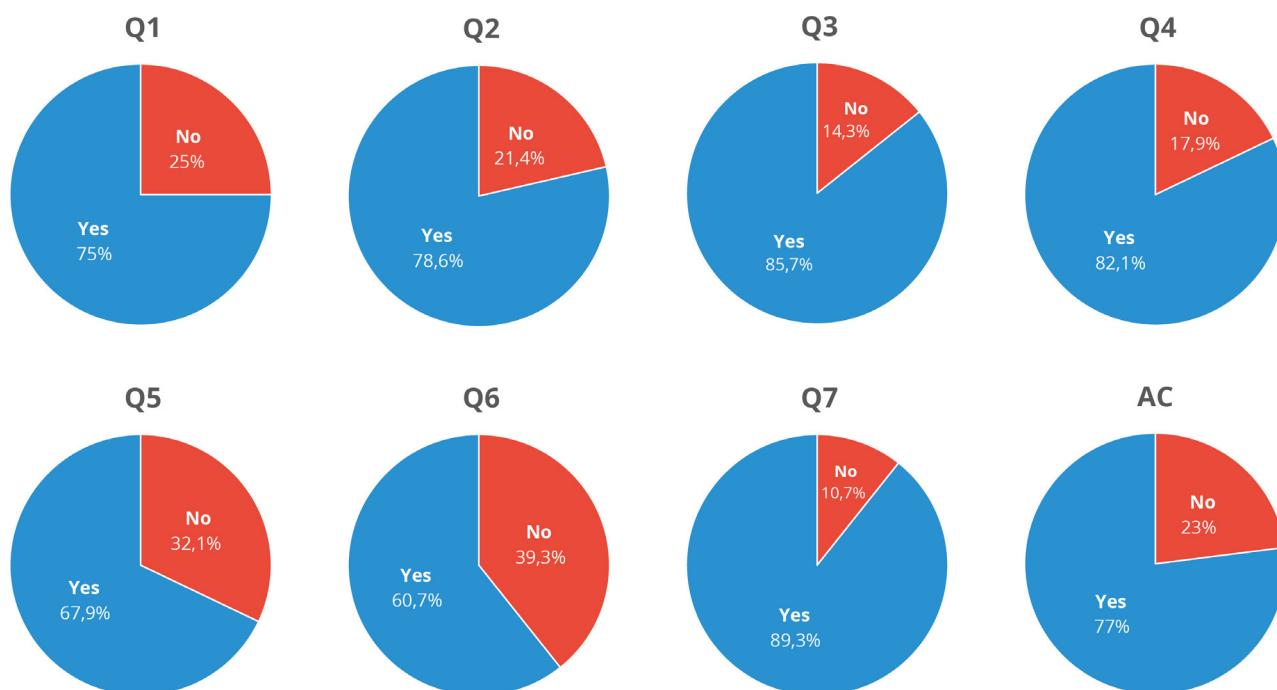
This section presents and discusses the results obtained from the administration of the diagnostic questionnaire structured on the basis of the dimensions and indicators of scientific literacy. The qualitative data analysis focused on identifying evidence of students' conceptual, epistemic, and sociocultural development, in accordance with the adopted theoretical frameworks. To facilitate reading and highlight the particularities of each school context, the results are organized into subsections, each corresponding to one of the schools participating in the study. Subsequently, an interpretive synthesis of the findings is presented in light of the investigated hypothesis.

4.1. UMI Centro Educacional Penalvense – Urban School

The first school investigated was UMI Centro Educacional Penalvense, located in the urban center of the municipality of Penalva, Maranhão, Brazil. It is a full-time public school that serves students from the municipal headquarters and possesses a more consolidated infrastructure in comparison to rural schools. The ninth-grade class selected for the administration of the diagnostic questionnaire consisted of 28 students who were present on the day of data collection.

The results obtained from the seven questionnaire items, developed on the basis of the dimensions and indicators of scientific literacy (Table 2), reveal that, in general, there is significant evidence of scientific literacy among the students of this school. As illustrated in Figure 1, across all seven questions administered (Q1 to Q7), the percentage of responses considered indicative of scientific literacy exceeded 60%, reaching notably high levels in several categories.

Figure 1. Indicators of Scientific Literacy – UMI Centro Educacional Penalvense



Source: Prepared by the authors (2025).

The analysis of Graph P1 in Figure 1, for instance, reveals that 75% of the students were able to describe a scientific phenomenon with conceptual clarity, employing terms and understandings consistent with the vocabulary of school science. Graph P2 reinforces this tendency, with 78.6% of the students reporting forms of exploratory and investigative reasoning, including the use of hypotheses and empirical testing strategies.

Questions Q3 and Q4, which focused on the description of experimental activities and the understanding of the changing nature of scientific knowledge, yielded even higher percentages, reaching 85.7% and 82.1%, respectively. These findings indicate that the students recognize science as both an experiential and socially constructed practice. This represents an important indication that the school, beyond promoting conceptual learning, also fosters a broader and more epistemologically critical view of science.

In Questions Q5 and Q6, which addressed students' perceptions of disagreement among scientists and the articulation between science and society, there was also a substantial presence of responses indicative of scientific thinking: 67.9% in Q5 and 60.7% in Q6. Although these two items presented slightly lower percentages than the others, the data demonstrate that a significant proportion of students are able to recognize science as a field characterized by debate and to relate scientific content to social issues, which aligns with the indicators of the STSE dimension.

Question Q7, which explored the social relevance of science and its application to everyday life, yielded the highest level of agreement: 89.3% of the students expressed critical and well-

founded opinions regarding the importance of science education in the contemporary context, mobilizing arguments related to health, the environment, and technology.

When the absolute frequencies of the seven questions are combined, Graph AC reveals that 77% of the total responses were classified as representative of scientific literacy, whereas 23% of the responses did not demonstrate such appropriation. This overall result reinforces the understanding that the students of UMI Centro Educacional Penalvense exhibit a consistent level of conceptual, epistemic, and sociocultural development, compatible with the parameters of scientific literacy established by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008).

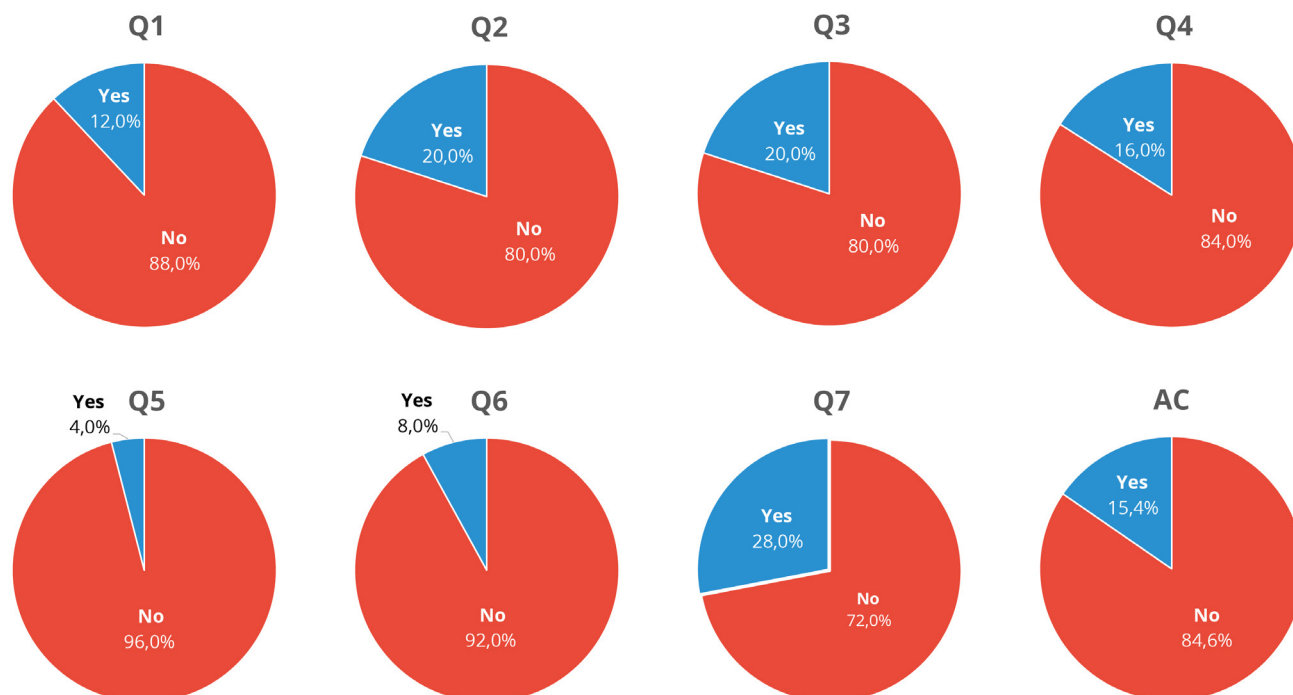
This performance is possibly related to the school's greater pedagogical and structural investment, the continuing education of its teachers, as well as the presence of investigative practices or instructional experiences more closely aligned with the principles of school science. Although the present study is not specifically aimed at directly evaluating teaching practices, the evidence identified suggests an environment more conducive to the active construction of scientific knowledge. The analysis of the data from this school will therefore serve as an important comparative parameter for the other school contexts investigated.

4.2. UMI Gonçalves Dias – Rural School

The second school participating in the investigation was UMI Gonçalves Dias, located in the village of Jacaré, in the rural area of the municipality of Penalva, Maranhão, Brazil. It is a full-time public school affiliated with the National Full-Time Education Program, serving students from rural communities through an extended school schedule. Despite this increase in instructional time, the challenges faced by rural education—both in terms of infrastructure and qualified access to scientific knowledge—continue to significantly shape everyday pedagogical practices. On the day of data collection, 25 ninth-grade students were present and completed the diagnostic questionnaire.

The analysis of the results, as presented in Figure 2, reveals a scenario of considerable fragility in the indicators of scientific literacy among the students of this school. Graph P1 shows that only 12% of the students demonstrated some level of conceptual appropriation regarding scientific phenomena, whereas 88% failed to exhibit any adequate articulation of scientific language in their responses.

Figure 2. Indicators of Scientific Literacy – UMI Gonçalves Dias



Source: Prepared by the authors (2025).

The trend of low levels of scientific literacy remained evident in the subsequent graphs. In Graph P2, 20% of the students demonstrated some element of investigative reasoning, such as the use of hypotheses or attempts at exploratory explanations of phenomena, whereas 80% did not mobilize any cognitive indicators compatible with this formative dimension. Question Q3, which addressed experimentation, yielded the same percentage of 20%, indicating that only one in every five students demonstrated at least a minimal understanding of the role of experimental activities in the construction of scientific knowledge.

Questions Q4, Q5, and Q6 revealed even more critical percentages. Only 16% of the students demonstrated an understanding of science as a historical and social process (Q4), 4% recognized the existence of disagreements among scientists and the non-absolute nature of scientific knowledge (Q5), and only 8% were able to establish relationships between science and society (Q6) within the STSE dimension. These findings suggest a widespread absence of school experiences that foster the appropriation of these epistemic and social dimensions of scientific knowledge.

Question Q7, which addressed the relevance of science in everyday life, reached a slightly higher percentage, with 28% of the responses being considered representative of scientific literacy. Even so, 72% of the students presented weak arguments, disconnected from social reality or lacking conceptual elements capable of justifying the importance of science in everyday life.

The overall sum of the analyzed responses is represented in Graph AC, which reveals that only 15.4% of the total responses were classified as indicative of scientific literacy, whereas 84.6% did not meet the criteria established by the qualitative analytical framework. This discrepancy points to a low level of conceptual, epistemic, and sociocultural development among the students of UMI Gonçalves Dias with regard to the appropriation of school-based scientific knowledge.

This result demands a profound reflection on the materiality of inequalities within the educational field. Although integrated into an extended school-day program, the rural school still faces structural limitations that directly affect the development of scientific literacy, including the scarcity of instructional resources, limited access to experimental practices, and the weak integration between school science and the social realities of rural communities. As argued by Klein and Coutinho (2020), it is not sufficient merely to extend students' time in school; it is necessary to ensure genuine learning conditions by valuing local knowledge and developing contextualized educational practices.

The administration of the diagnostic questionnaire grounded in the indicators proposed by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008) proved, in this case, to be an effective instrument for making visible aspects that everyday school routines often fail to capture. The mapping of students' formative weaknesses provides valuable support for the development of more intentional and transformative interventions, such as the implementation of an Investigative Teaching Sequence (ITS), which may help reverse, at least partially, the deficits identified. In this way, the analysis of this rural school reinforces not only the importance of prior diagnostic assessment, but also the urgency of public policies and pedagogical actions aimed at promoting equity in science education.

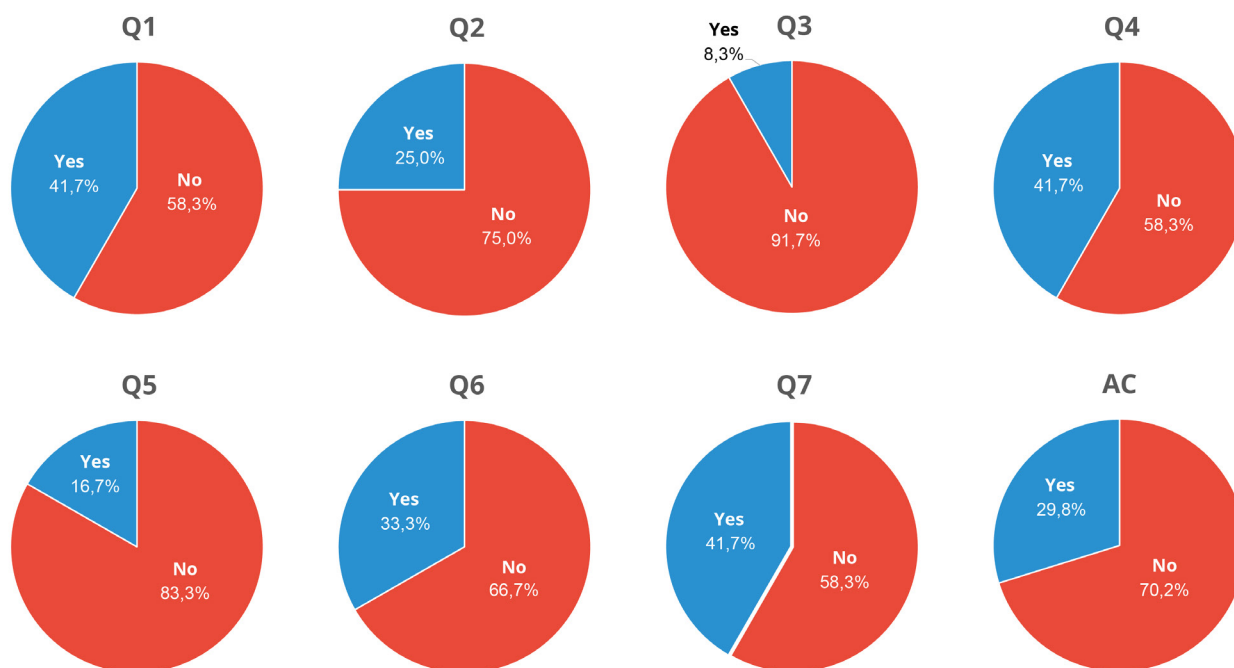
4.3. Unidade Escolar Padre Batista Costa – Rural School

The third school analyzed in this study was Unidade Escolar Padre Batista Costa, located in the village of Ricoa, in the rural area of the municipality of Penalva, Maranhão, Brazil. It is a public regular-education school operating on a standard schedule and possessing a basic infrastructure, serving a rural community with significantly more restricted access to scientific knowledge. On the day the diagnostic questionnaire was administered, 12 ninth-grade elementary school students participated, responding to the seven open-ended questions based on the scientific literacy indicators systematized by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008).

The data, presented in graphical form in Figure 3, reveal variable performance across the questions, with some positive indicators in certain dimensions of scientific literacy, although still marked by significant conceptual and argumentative weaknesses. Graph P1 shows that 41.7% of the students were able to provide some explanation of scientific phenomena using school-based vocabulary and coherent structure, whereas 58.3% did not demonstrate sufficient conceptual mastery.

The same percentage of 41.7% reappears in Question Q4, related to the understanding of science as a historical and non-absolute process, indicating some critical capacity regarding the nature of scientific knowledge.

Figure 3. Indicators of Scientific Literacy – Unidade Escolar Padre Batista Costa



Source: Prepared by the authors (2025).

However, Graph P2, which assesses investigative reasoning, presents a lower result: only 25% of the students expressed ideas related to the formulation of hypotheses or attempts at experimentation, whereas 75% revealed an absence of this type of cognitive construction. This difficulty becomes even more pronounced in Question Q3, which specifically investigates the role of experimentation: only 8.3% of the students provided responses consistent with the expected indicators, while 91.7% demonstrated either a lack of understanding or a devaluation of this practical dimension of school science.

Questions Q5 and Q6, focused on the STSE dimension, also produced limited results. In Q5, only 16.7% of the students recognized science as a field characterized by debate and disagreement, indicating a low level of understanding regarding the social and argumentative nature of scientific production. In Q6, 33.3% of the students were able, albeit partially, to establish relationships among science, technology, society, and the environment, representing the second highest result of this group in percentage terms, although still insufficient to characterize a consolidated understanding.

Finally, Question Q7, which invites students to reflect on the importance of science in everyday life, again presented 41.7% of responses considered indicative of scientific literacy. This suggests that part of the students is able to recognize the applicability of scientific knowledge in social and personal life, even if in a still superficial or poorly articulated manner.

The consolidation of the data is presented in Graph AC, which shows that only 29.8% of the students' total responses were classified as indicative of scientific literacy, whereas 70.2% did not meet the criteria established by the analytical framework. This result points to a slightly higher performance compared to the average of the other rural schools analyzed; however, it remains insufficient to characterize an effective formative process in the context of school science education.

Despite these limitations, the data suggest the existence of latent formative potential among the students of Unidade Escolar Padre Batista Costa. The presence of indicators of scientific literacy in some questions—especially those requiring social reflection or positioning regarding the role of science in everyday life—suggests that there is fertile ground for the development of more investigative, mediated, and intentional pedagogical practices. In this sense, the diagnostic assessment carried out makes it possible to outline pathways for the proposal of a future Investigative Teaching Sequence (ITS) that dialogues with local knowledge, values students' experiences, and promotes progress in scientific literacy indicators, contributing to a more critical, argumentative, and emancipated form of education.

4.4. Interpretive Analysis of the Results

The analysis of the data collected through the diagnostic questionnaire applied to ninth-grade students from the three public schools investigated in the municipality of Penalva, Maranhão, Brazil, revealed a scenario marked by significant inequalities in the appropriation of scientific knowledge, highlighting distinct levels of conceptual, epistemic, and sociocultural development among students from urban and rural contexts. These findings are directly aligned with the initial hypothesis of the study, which posited that it would be possible to identify, through assessment instruments grounded in scientific literacy indicators, relevant formative evidence even prior to the implementation of an Investigative Teaching Sequence (ITS).

The results demonstrated that the school located in the urban area (UMI Centro Educacional Penalvense) presented high percentages of responses consistent with the indicators of scientific literacy across all seven questionnaire items, culminating in 77% of responses classified as qualified. The students from this school generally demonstrated conceptual mastery, argumentative capacity, articulation with social issues, and appropriation of scientific language, suggesting a pedagogical environment more conducive to the development of scientific competencies, although the study did not directly examine teaching practices.

In contrast, the data from the two rural schools—UMI Gonçalves Dias (Jacaré village) and Unidade Escolar Padre Batista Costa (Ricoa village)—revealed significantly lower levels of scientific literacy. The former obtained only 15.4% of responses classified as indicative of scientific literacy, while the latter reached 29.8%, representing the most expressive result among the rural schools analyzed. The main weaknesses observed in the rural classes relate to the understanding of scientific concepts, the ability to formulate hypotheses and arguments, and the articulation between science, society, and the environment—core components of the structural dimensions of scientific literacy.

These marked discrepancies reinforce what has been widely discussed in the educational literature: structural and curricular inequalities between urban and rural schools persist and directly influence students' scientific education (KLEIN; COUTINHO, 2020; SANTOS; PENA, 2020). Although rural students are enrolled in public schools governed by the same legislation and curricular

guidelines, their objective learning conditions—such as infrastructure, access to instructional resources, exposure to investigative practices, and integration with scientific culture—are often significantly more limited, directly affecting processes of appropriation of school knowledge.

Furthermore, the data also indicate that extended time spent in school, in itself, does not guarantee consistent formative progress, as demonstrated by the case of UMI Gonçalves Dias, a full-time school whose students presented lower indicators than those of the regular school in the village of Ricoa. This finding suggests that the quality and intentionality of pedagogical practices are more decisive than the formal amount of time allocated to schooling, particularly in the field of science education.

The implementation of this diagnostic assessment, grounded in the dimensions and indicators of scientific literacy, proved highly effective not only in identifying conceptual and discursive gaps, but also in understanding students' actual level of engagement with the epistemic and argumentative practices inherent to school science. This interpretation reinforces the relevance of the methodological approach adopted in this study and supports the hypothesis that it is possible to diagnose, based on rigorous qualitative criteria, students' formative stage prior to the intervention with an Investigative Teaching Sequence (ITS).

Rather than presenting a static overview, the results interpreted in this stage provide concrete elements for the proposal of more responsive, equitable, and context-sensitive pedagogical practices, reaffirming the importance of diagnostic assessment as a starting point for any transformative educational process. In doing so, the study reaffirms its commitment to a perspective on science education that recognizes the diversity of learners and the urgency of policies and practices that effectively confront the historical inequalities that permeate Brazilian public schooling.

5. CONSIDERAÇÕES FINAIS

The present study had as its central purpose the identification of indicators of scientific literacy among ninth-grade elementary school students, based on the administration of a qualitative diagnostic instrument developed according to the structural dimensions and indicators proposed by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008). The analyzed data, derived from three public schools in the municipality of Penalva, Maranhão, Brazil, allowed for the observation of distinct levels of appropriation of school scientific knowledge, directly reflecting existing educational inequalities between urban and rural contexts.

The analyses revealed that students from the school located in the urban center presented significantly higher performance than those from rural schools, demonstrating greater conceptual mastery, more developed epistemic reasoning, and a stronger ability to connect scientific knowledge to social issues. In contrast, responses from rural schools indicated significant weaknesses in the command of scientific language, the formulation of hypotheses, the understanding of science as a historical construction, and the connections with STSE dimensions. These results confirm the initially formulated hypothesis: it is fully possible to diagnose, through well-structured assessment instruments, the levels of conceptual, epistemic, and sociocultural development of students prior to the implementation of an Investigative Teaching Sequence (ITS).

The use of the theoretical framework proposed by Luciana Maria Lunardi Campos Sasseron and Anna Maria Pessoa de Carvalho (2008), which systematizes scientific literacy into three dimensions—the understanding of scientific concepts and processes, the understanding of the nature of science, and the understanding of the relationships between science, technology, society, and the environment—proved highly effective for the qualitative analysis of the responses. This framework not only enabled precise categorization of the data but also fostered an understanding of the multiple dimensions of scientific literacy as a complex, gradual process, deeply dependent on the school, cultural, and pedagogical conditions in which students are situated.

From an educational standpoint, the results reiterate the urgency of public policies aimed at equity in science education, with an emphasis on critical, contextualized, and argumentative learning. Time spent in school alone proved insufficient to ensure meaningful progress when it is not associated with inquiry-based pedagogical practices, mediated by well-prepared teachers committed to fostering scientific thinking. The weaknesses observed in rural schools reveal not only a lack of scientific content, but above all a shortage of formative experiences that encourage questioning, evidence-based explanation, and the integration of everyday knowledge with scientific understanding.

This study therefore contributes to the consolidation of diagnostic assessment as a fundamental stage in inquiry-based science teaching. Rather than merely identifying what students lack, the proposed diagnostic evaluation makes visible what students already know, how they think, and which pathways can be pursued for further development. The data obtained will thus be essential to support the design of a future Investigative Teaching Sequence (ITS), developed in response to the actual needs identified in each school context. It is believed that, through this articulation between diagnosis and intervention, it is possible to promote a more equitable, emancipatory, and truly meaningful scientific education.

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