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Scientific Literacy in Formal and Non-Formal Contexts: Convergences and Conceptual Expansions

Alfabetização Científica em Contextos Formais e Não Formais: Convergências e Ampliações Conceituais

Alfabetización Científica en Contextos Formales y No Formales: Convergencias y Ampliaciones Conceptuales

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Abstract

Scientific Literacy has been consolidated as a central goal in Science Education, and it can be promoted in both formal and non-formal educational settings. This article aims to articulate different perspectives on Scientific Literacy across these spaces in order to propose a broader understanding of the concept. This is a theoretical essay that adopts, as its theoretical framework, the Structuring Axes, Dimensions of Scientific Literacy, and Literacy Premises for formal spaces, alongside the Scientific Literacy Indicators for non-formal environments. Reflections were guided by identifying points of convergence among the perspectives discussed by the authors. The results show that the indicators applied to non-formal settings introduce innovative elements when compared to other frameworks, particularly by emphasizing interactive and institutional aspects of the literacy process. These elements allowed the development of a new perspective, conceptually expanding Scientific Literacy across different educational contexts. We argue that articulating these theoretical perspectives contributes to the consolidation of a more dialogical and contextualized proposal, with potential to guide future actions toward the effective implementation of these perspectives in the context of scientific education.

Keywords: Science Education, social transformation, scientific literacy indicators, formal spaces, non-formal spaces

Resumo

A Alfabetização Científica tem se consolidado como objetivo central no Ensino de Ciências, podendo ser promovida em contextos formais e não formais de educação. Este artigo objetiva articular diferentes perspectivas de Alfabetização Científica nesses dois espaços, a fim de propor uma compreensão mais abrangente do conceito. Trata-se de um ensaio teórico que adota como referenciais, para os espaços formais, os Eixos Estruturantes, as Dimensões e as Premissas de Alfabetização Científica e, para os espaços não formais, os Indicadores de Alfabetização Científica. As reflexões foram orientadas pela identificação de pontos de convergência entre as perspectivas discutidas pelos autores. Os resultados indicam que os Indicadores aplicados aos contextos não formais introduzem elementos inovadores em comparação aos demais referenciais, especialmente ao enfatizar aspectos interativos e institucionais do processo de alfabetização. Esses elementos permitiram o desenvolvimento de uma nova perspectiva, ampliando conceitualmente a Alfabetização Científica em diferentes contextos educativos. Defendemos que a articulação dessas perspectivas teóricas contribui para a consolidação de uma proposta mais dialógica e contextualizada, com potencial para orientar futuras ações voltadas à efetivação dessas perspectivas no contexto da educação científica.

Palavras-chave: Educação em Ciências, transformação social, indicadores de alfabetização científica, espaços formais, espaços não formais

Resumen

La Alfabetización Científica se ha consolidado como un objetivo central en la Enseñanza de las Ciencias, y puede ser promovida en contextos educativos formales y no formales. Este artículo tiene como objetivo articular diferentes perspectivas de Alfabetización Científica en ambos espacios, con el fin de proponer una comprensión más amplia del concepto. Se trata de un ensayo teórico que adopta como marcos teóricos los Ejes Estructurantes, las Dimensiones y las Premisas de Alfabetización Científica en los contextos formales, así como los Indicadores de Alfabetización Científica aplicados a los espacios no formales. Las reflexiones se guiaron por la identificación de puntos de convergencia entre las perspectivas discutidas por los autores. Los resultados indican que los Indicadores utilizados en contextos no formales introducen elementos innovadores en comparación con los demás marcos, especialmente al resaltar aspectos interactivos e institucionales del proceso de alfabetización. Estos elementos permitieron el desarrollo de una nueva perspectiva que amplía conceptualmente la Alfabetización Científica en diversos contextos educativos. Sostenemos que la articulación de estas perspectivas teóricas contribuye a consolidar una propuesta más dialógica y contextualizada, con potencial para orientar futuras acciones en el campo de la educación científica.

Palabras clave: Educación Científica, transformación social, indicadores de alfabetización científica, espacios formales, espacios no formales

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Introduction

One of the possibilities for Science Teaching, as we know it, is to base it on Scientific Literacy (SL) in order to enhance knowledge of science in general and promote the understanding of its importance in the daily lives of students and other members of society.

> Scientific Literacy is characterized as the individual's ability to understand and relate scientific and technological concepts and knowledge, as well as to measure and apply them in their culture and society. In addition, a reflective and critical awareness of the subject is developed regarding these concepts, theories, and scientific and technological knowledge in order to influence society (Albuquerque, 2024, p. 22).

When provided in formal teaching spaces (classrooms, laboratories, or school environments in general), we cite some basic references such as Chassot (2003), Fourez (2003), Lorenzetti and Delizoicov (2001), and Sasseron and Carvalho (2008, 2011). Contemporaneously, these authors are still very relevant references and serve as a subsidy for research and studies in SL, both in formal and non-formal spaces (museums, science fairs, botanical gardens, etc.).

Considering the formal teaching spaces, we support this article with references based on conceptual and practical visions of SL. Sasseron and Carvalho (2011) make propositions for a theoretical-practical relationship with effectiveness in the scientifically literate individual's social context. Their studies were revisited and updated by Silva and Sasseron (2021) as Premises and Propositions. We also highlight the Dimensions of SL, in which the authors propose a view focused on the teacher who seeks in SL a science teaching that collaborates with the development of the student on issues involving science and society (Leite, 2015; Leite & Rodrigues, 2018).

Beyond formal spaces, authors such as Cerati (2014) and Lorenzetti (2021) propose characteristics of SL for non-formal spaces. For them, SL also occurs in these spaces and can promote the literacy process among individuals, in a similar way to what happens in formal spaces.

Focusing on non-formal spaces, Marandino et al. (2018) proposed a tool that enables the identification of SL in these contexts, composed of the Scientific Literacy Indicators (SLI). This tool is the result of a series of studies conducted over four years, which enabled the identification of characteristics of SL present in non-formal educational environments.

The design used by the authors in these precursor studies (theses and dissertations) to the proposition of the tool allowed us to see it beyond an instrument of data construction. Throughout the work of Marandino et al. (2018), this tool has become widely used in different non-formal spaces (traveling museums, botanical gardens, science museums, science fairs, etc.). In view of this, we understand the tool as a theoretical framework for the approach of SL in these spaces.

The SLI first appeared in Cerati's (2014) study carried out in a botanical garden and finalized in Norberto Rocha's (2018) research when he proposed these indicators in the context of traveling science museums. We used the term *finalized* due to its publication as a tool in the work of Marandino et al. (2018). However, Albuquerque's (2024) research — the master's dissertation that originated this article — uses this tool in a school Science Fair (SF), making adaptations to the context. In this sense, we indicate that, even though it is considered an event that takes place in a non-formal space, CF comprises phases that take place in a formal teaching context (Albuquerque, 2024).

Thinking about this duality of the SF space, we identified the need to address the concepts of SL in a generalized context, encompassing both spaces. Therefore, we understand that it is neither possible nor feasible to treat the conceptions of SL by distinguishing between formal and non-formal spaces as if they were different conceptions of literacy. Thus, even though teaching takes place in different contexts, SL does not change; it is the same in terms of objective and conception.

That said, this text is a theoretical-reflective essay whose objective is to bring together different perspectives on SL in formal and non-formal teaching spaces, based on the assumption that the definitions of SL in formal contexts do not fully contemplate the perspectives of scientific literacy in contemporary contexts. The argument is based on references such as Sasseron and Carvalho (2011), Silva and Sasseron (2021), Leite (2015), Leite and Rodrigues (2018), and Marandino et al. (2018), articulating the concepts proposed by these authors.

This article is organized into three sections: the first establishes the theoretical frameworks and their concepts of SL. The second presents the articulations of SL's perspectives and how they complement each other. In the third section, we emphasize the characteristics of SL present in the literature in non-formal spaces, and finally, we present our considerations about the study.

Perspectives of Scientific Literacy

The perspectives presented here, as well as our understanding, emphasize a view of SL articulated with the term "literacy", which, in turn, is based on the ideas of Paulo Freire. For this author, literacy goes beyond mastering writing and reading, because it is through literacy that the literate individuals insert themselves into the world, influence it, and develop a critical posture, becoming aware of their autonomy and ability to read and interpret the world with lenses that were previously beyond their reach (Freire, 2014).

For a better understanding of the perspectives addressed, based on the selected references, we chose to dialogue with each of them from the perspective of their context and the original concepts of the authors. Of the four references already highlighted in our introduction, three address the idea of Scientific Literacy focused on formal teaching contexts (Structuring Axes, Dimensions of SL, and Premises of SL) and one dialogues with the non-formal context (Scientific Literacy Indicators).

As the first reference on SL, we highlight the three Structuring Axes proposed by Sasseron and Carvalho (2011). Such axes "[...] provide sufficient and necessary bases to be considered When preparing and planning classes and proposals for classes aimed at Scientific Literacy" (Sasseron & Carvalho, 2011, p. 75).

Axis I conceptually characterizes the "**basic understanding of fundamental scientific terms, knowledge and concepts"**, providing students with the "construction of scientific knowledge [...] and understanding key concepts by bringing scientific knowledge and such concepts to their daily lives" (Sasseron & Carvalho, 2011, p. 75).

Axis II refers to the "**understanding of the nature and ethical and political factors that surround its practice**", emphasizing the idea of "science as a body of knowledge in constant transformation" that consists of "processes of data acquisition and analysis, synthesis and decoding of results that generate knowledge" (Sasseron & Carvalho, 2011, p. 75). This Axis "provides support so that the human and social character inherent to scientific investigations is brought into discussion" (Sasseron & Carvalho, 2011, p. 75); and finally, it also brings "contributions to the behavior assumed by students and teachers whenever they are faced with information and new circumstances" (Sasseron & Carvalho, 2011, pp. 75–76), so that they reflect on and critically analyze their own practice before making decisions.

Axis III assumes perspectives of the Science, Technology, Society, and Environment (STSE) relationship, referring to the "**understanding of the existing relationships among science, technology, Society, and the environment**". It addresses the relationship between the scientific, technological, social and environmental spheres, indicating that an unconsidered solution for one of the spheres can directly influence the others; it emphasizes the importance of "understanding the applications of the knowledge constructed by the science, considering the actions that can be triggered by its use"; and when thought directly for the school, it dialogues with the "desire for a sustainable future for society and the planet" (Sasseron & Carvalho, 2011, p. 76).

The three Axes of SL were updated by Silva and Sasseron (2021), based on premises and propositions adapted to the contemporary educational context. According to the authors, the Axes are still fundamental to what SL recommends; however, in practical aspects and in the effectiveness of the scientific literacy process, they are insufficient. Although they present premises and propositions, we will use for this study only the premises proposed by the authors. According to Silva and Sasseron (2021), the premises are findings from the study of the literature on SL. Thus, they are already sufficient for what this study proposes, since the propositions are closely related to the aspects of practical implementation of SL.

The first (1st) premise — "**the relationships among the different views of Scientific Literacy as complementary and not exclusionary"** — indicates a "coexistence and complementarity among the different views of SL in the literature" (Silva & Sasseron, 2021, p. 14). This premise also highlights the role of society and its transformation based on SL, considering that the understanding of science by the individuals strongly influences both social life and the search for social justice, also understood as an "intellectual enterprise" (Silva & Sasseron, 2021, p. 6).

The second (2nd) premise — "**the natural sciences as traditionally approached in the classroom are very different from the natural sciences understood as a form of human knowledge**" (Silva & Sasseron, 2021, p. 7) — is configured as a social practice and, therefore, has norms and values that guide it. The natural sciences, in this premise, demonstrate a transitory aspect and critical thinking, being a "public enterprise" developed by interactions among its subjects. For its integration, it is necessary to recognize science as a collaborative practice among its participants and other forms of knowledge (Silva & Sasseron, 2021).

The third (3rd) premise — "**the understanding of science teaching as a social practice**" (Silva & Sasseron, 2021, p. 8) — is characterized by the conjunction of civic education with social and political actions together with science. It addresses the escape from rigid models of education and teaching to converge in science studies in their complexity, enabling critical conceptions for the individuals' daily experiences (Silva & Sasseron, 2021).

In addition to the Axes and Premises, we highlight the Dimensions of SL proposed by Leite (2015) and Leite and Rodrigues (2018), which focus on the process of teacher training and lesson planning, intending to support the teacher in promoting students' Scientific Literacy. By coming into contact with these three dimensions, students are able to live in society in a conscious and active way (Leite, 2015).

The dimension "**a) understanding of the nature of science and scientific knowledge**" is related to the "understanding of the processes in which scientific activity develops" and to the understanding of "science as human activity". It also involves the teaching of Science in its "provisional and uncertain character", as it constitutes a human construction. Finally, it encompasses reflections on the "provisional character, the conflicts associated with scientific theories, political and economic aspects, and reflections on these themes are given by teachers in the areas of Science" (Leite, 2015, p. 37).

In the dimension "**b) identification and recognition of the importance of the meaning of scientific concepts and theories in daily processes**", the proposal is the "importance of citizens not only knowing and using scientific concepts on a daily basis [...], but also being able to recognize the general importance of this knowledge in their lives". In addition, the "ability to relate the scientific content learned to something from daily life" (Leite, 2015, p. 41) stands out.

The third dimension established is the "**c) clarity of the socio-scientific aspects involved in the various situations of life**", which addresses discussions of "aspects related to environmental, political, economic issues concerning Science and technology". It also involves "STS approaches, in which social issues are problematized" (Leite, 2015, p. 47).

Marandino et al. (2018) establish specific characteristics for non-formal teaching contexts. The proposition of the SLI as a theoretical-methodological tool, as well as its construction and validation in various non-formal teaching spaces, enables its use as a reference in studies on SL. Studies such as those by Cerati (2014), Mingues (2014), Mosquera (2014), Oliveira (2016), Rodrigues (2017), Norberto Rocha (2018), and Albuquerque (2024) validate this tool in different research contexts (museums, botanical gardens, science fairs, etc.) and highlight aspects of its elaboration that lead us to consider it a relevant reference for the area.

This framework is composed of four indicators that have three attributes with numerous characteristics. The attributes and characteristics used in our study are those proposed by Norberto Rocha (2018), since they are presented in Marandino et al. (2018) as the product of several years of study on these indicators.

The **Scientific Indicator** has aspects inherent to scientific knowledge, its concepts, and theories. It is present under three attributes, namely: "1a. Scientific knowledge and concepts, scientific research and its results; 1b. Process of production of scientific knowledge; 1c. Role of the researcher in the process of knowledge production" (Norberto Rocha, 2018, p. 128; Marandino et al., 2018, p. 7).

The **Social Interface Indicator** highlights the actions and understanding of the relationships between science and society, addressing their mutual influence. The attributes of this indicator are: "2a. Impacts of science on society; 2b. Influence of economy and politics on science; 2c. Influence and participation of society in Science" (Norberto Rocha, 2018, p. 130; Marandino et al., 2018, p. 8).

The **Institutional Indicator**, as well as the Interaction Indicator, which we will present below, are little visualized in conceptions of SL for formal teaching spaces. The Institutional Indicator expresses the dimensions of the institutions involved in the production, dissemination, and promotion of science. Its attributes are: "3a. Institutions involved in the production and dissemination of science, their roles and missions; 3b. Funding institutions, their roles and missions; 3c. Political, historical, cultural, and social elements linked to the institution" (Norberto Rocha, 2018, p. 135; Marandino et al., 2018, p. 9).

The **Interaction Indicator** presents the modes and forms of interaction of individuals with the objects, people, and information available in the non-formal space. Its attributes are configured as: "4a. Physical interaction; 4b. Aesthetic-affective interaction; 4c. Cognitive interaction" (Norberto Rocha, 2018, p. 141; Marandino et al., 2018, p. 10).

We will present the definitions and characteristics of these indicators in Figures 2, 3, and 4 in the next section so that the reading does not become repetitive. Thus, we take the next step of our study by indicating how these four references are related and how we can reach a joint understanding of SL for both formal and non-formal teaching spaces.

Articulations Carried Out

During the course of theoretical deepening that supported the master's dissertation and this article, reflections emerged that led us to highlight the relationship between the different — although close — perspectives of SL present in the adopted references.

In view of this, we carried out the extraction of definitions and characteristics presented in each reference. In Figure 1, we organized the general relationship around SL based on the references of Sasseron and Carvalho (2011), Silva and Sasseron (2021), Leite (2015), and Marandino et al. (2018). We have previously highlighted that, with regard to the Axes, the development of SL is anchored in the student's perspective; the Dimensions, in turn, refer to the SL taught by the teacher; and the Premises are configured as a broader reference for the area. The Indicators, on the other hand, focus on the SL present and available to the subject — student or not — in non-formal teaching spaces.

Figure 1

Relationship among the Axes, Dimensions, Premises, and Indicators of Scientific Literacy

SL structuring axes	SL Premises	SL Dimensions	SL Indicators
I. Basic understanding of fundamental scientific terms, knowledge, and concepts	2nd and 3rd Premises	b) Identification and recognition of the importance of the meaning of scientific concepts and theories in daily processes	Scientific
II. Understanding of the nature of the sciences and the ethical and political factors surrounding their practice	2nd and 3rd Premises	a) Understanding of the nature of science and scientific knowledge	
III. Understanding the relationships among science, technology, Society, and the environment	1st, 2nd and 3rd Premises*	c) Clarity of the socio-scientific aspects involved in the various situations of life	Social Interface
-*	2nd and 3rd Premises	-	Interaction
-	-	-	Institutional

Note.* "-" means there is no relationship among the references.

Source: Prepared by the authors.

From the relationships we established, it was possible to identify pre-existing conceptual approximations in each of the references. They are presented in Figures 2, 3, 4, and 5. The figures demonstrate the complementarity in terms of concepts. Each of them presents excerpts from the definitions and characteristics of the texts covered in this article.

Figure 2 contains the relationships that address characteristics such as scientific concepts, key concepts for students' learning of science, the handling of this information, and critical and reflective thinking about it. The learning of concepts and the way in which individuals act on them is one of the fundamental characteristics of SL.

Figure 2

Relationship between Axis I, Dimension b), 2nd and 3rd Premises, and Attribute 1a of the Scientific Indicator

Axis I. Basic understanding of fundamental scientific terms, knowledge, and concepts	**Dimension b) Identification and recognition of the importance of the meaning of scientific concepts and theories in daily processes**
"construction of **scientific knowledge**" "**understanding key concepts**"	"teaching of Scientific knowledge" "use **scientific concepts daily**" "**recognize the importance of this knowledge**"
2nd and 3rd Premises	**Scientific Indicator** **Attribute 1a.** Scientific knowledge and concepts, scientific research, and results
"Their proposals for knowledge can **bring answers to problems about phenomena in the natural world**" "**requests management of information and materials**" "build conceptions about what science itself is and **how its practices and values can be transposed to the analysis of other situations in our daily lives**" "**allows the proposition of explanatory inferences**" "**demands the selection of topics of science studies in their complexity**" "**the identification that the study brings together concepts and laws from the same field**"	"the **concepts, laws, theories, ideas, and general scientific knowledge** on the topics addressed and/or **results and products obtained** in scientific investigations and **research**, including those historically consolidated" "presentation of aspects inherent to **scientific knowledge**" "expresses **scientific concepts, processes, and products of Science**"

Source: Prepared by the authors based on Sasseron and Carvalho (2011), Leite (2015), Norberto Rocha (2018), Marandino et al. (2018), and Silva and Sasseron (2021).

The Axes and Dimensions analyzed emphasize the teaching of systematized scientific knowledge, including concepts and theories, so that these are integrated into the students' daily lives. As discussed by Silva and Sasseron (2021), this knowledge must promote critical and reflective engagement, allowing students to relate the concepts learned to the various situations they face in their daily lives.

When we examine the SLI, particularly its first attribute, we observe that it does not explicitly evidence the daily relationship of the concepts involved. This characteristic stems from the development of the tool itself, which requires a segmentation of the characteristics to enable the visualization of the different perspectives. According to Albuquerque (2024), the characteristics of the Scientific Indicator are often related to those of the Social Indicator, establishing an essential connection for the integrated understanding of science and society. However, the social contexts in these frameworks are not clearly present, but the idea that SL is only effective when it is not dissociated from scientific concepts is unanimous (Sasseron & Carvalho, 2011; Leite, 2015; Silva & Sasseron, 2021; Albuquerque, 2024).

This approach to scientific concepts, when properly worked, constitutes a fundamental path for the effectiveness of SL (Fourez, 2003). In the current educational context, this integration is made possible by emphasizing the relationship between key concepts and theories, as well as by considering their functions and social influences on individuals' realities. This principle can be identified both in the Premises proposed by Silva and Sasseron (2021) for formal spaces and in the relationships established between scientific and social characteristics in non-formal spaces, as indicated by Albuquerque (2024).

In Figure 3, we highlight the importance of the Nature of Science in the construction of scientific knowledge. In this figure, we indicate the correspondence between the two additional attributes of the Scientific Indicator, Axis II, Dimension a) and the 2nd and 3rd Premises.

Figure 3

Relationship between Axis II, Dimension a), 2nd and 3rd Premises, and Attribute 1b and 1c of the Scientific Indicator

Axis II. Understanding the nature of the sciences and the political and ethical factors that surround their practice	**Dimension a) Understanding the nature of science and scientific knowledge**
"Science as a body of knowledge in **constant transformation**" "**human and social character inherent to scientific investigations** should be put discussed" "must **bring contributions to the behavior assumed by students and teachers** whenever faced with information"	"understand **science as a human activity**, and **how scientific knowledge is built**" "**Science and scientists are complementary**" "most important characteristics of the sciences, such as: their **provisional and uncertain character, the clashes associated with scientific theories, the political and economic aspects, and that these reflections take place, mainly, with teachers in the area**"
2nd and 3rd Premises	**Scientific Indicator** **Attribute 1b.** Process of production of scientific knowledge **Attribute 1c.** Role of the researcher in the process of knowledge production

Figure 3

Relationship between Axis II, Dimension a), 2nd and 3rd Premises, and Attribute 1b and 1c of the Scientific Indicator (continuation)

Axis II. Understanding the nature of the sciences and the political and ethical factors that surround their practice	Dimension a) Understanding the nature of science and scientific knowledge
"**Natural Sciences as a field of Humanity Studies**" "**fallible and transitory character of knowledge**" "**the sciences emerge as an activity anchored in values, norms, and actions built by the community**"	"aspects **related to the nature of Science**" "**procedures of science**, such as the formulation of hypotheses, testing, recording, observation, creativity" "**joint production in a collective and interdisciplinary way** or in knowledge networks" "the **questionable character and the degree of uncertainty**, considering the conflicts and controversies internal to its production" "The **Evolutionary, Historical, and Philosophical Character of Science**" "the **actors that influence the process and the non-neutrality** of scientific knowledge" "The **ethical dimension and social responsibility** of researchers" "**Science as a product of human construction**"

Source: Prepared by the authors based on Sasseron and Carvalho (2011), Leite (2015), Norberto Rocha (2018), Marandino et al. (2018), and Silva and Sasseron (2021).

Based on the four references analyzed, we established a relationship between the nature of science and the process of construction of scientific knowledge, considering the human influence indicated in the concepts. There is the notion that scientific knowledge is provisional and subject to revisions, evidencing its non-neutral character and its nature as a human construction. In this way, knowledge must be continuously questioned and subjected to critical reflection.

Sasseron and Carvalho (2011), Leite (2015), Norberto Rocha (2018), Marandino et al. (2018), and Silva and Sasseron (2021) highlight that the production of knowledge must occur collectively, and the construction process must be clearly identified. To this end, they emphasize the importance of making visible the stages of knowledge production and the human influences that act upon them. This collective construction is independent exclusively of the classroom dynamics. This statement is justified because knowledge is produced through the interaction between different agents, whether they are teachers, students, or actors outside the school context.

The approach to the Nature of Science — in the context of teaching Science with a view to SL — allows us to go beyond the simple transmission of isolated concepts, emphasizing the importance of understanding the human role in the formulation of scientific theories and concepts. The references analyzed converge in recognizing that scientific knowledge is influenced by social, cultural, and historical factors and, therefore, cannot be considered fixed, unique, or absolute. In addition, the theoretical conceptions that underlie the work of researchers directly impact the processes of knowledge construction. In this sense, science must be understood by taking into account historical, social, ethical, and environmental aspects, allowing the individual involved to be recognized as an integral part of scientific production (Praia et al., 2007).

From this perspective, which emphasizes the human and social dimension of science, it is essential to analyze how the references address social aspects in the context of knowledge production. In Figure 4, we present a synthesis of the relationships we have established.

Figure 4

Relationship between Axis III, Dimension c), 1st, 2nd and 3rd Premises and Attributes of the Social Interface Indicator

Axis III. Understanding the relationships between science, technology, Society, and the environment	**Dimension c) Clarity of the socio-scientific aspects involved in the various situations of life**
"It is about identifying the **intertwining between these spheres**" "understand the **applications of the knowledge constructed by the sciences, considering the actions that can be triggered by their use**" "desire for a **sustainable future for society** and the planet"	"this dimension **addresses the relationship between science, technology, Society, and the environment** (STSE)" "this dimension proposes to deal with issues involving **environmental, social, political, and economic aspects related to science and technology**"
1st, 2nd, and 3rd Premises	**Social Interface Indicator** **Attribute 2a.** Impacts of science on society **Attribute 2b.** Influence of economy and politics on science **Attribute 2c.** Influence and participation of society in science

Figure 4

Relationship between Axis III, Dimension c), 1st, 2nd and 3rd Premises and Attributes of the Social Interface Indicator (continuation)

Axis III. Understanding the relationships between science, technology, Society, and the environment	Dimension c) Clarity of the socio-scientific aspects involved in the various situations of life
“recognize science as an intellectual enterprise, whose **proposals for knowledge impose and receive influences from society**” “**Considering SL for social transformation”** “t**he understanding of science teaching as a social practice**” “characteristics that circumscribe **scientific activity as a human and, therefore, social practice**” “formation of individuals who understand science **as another actor** that, unfortunately, **contributes to the consolidation of social injustices**, and, therefore, **has a role in the search for justice**”	“r**elationships between science and society**, related to the impacts and participation of society” “c**onception of social appropriation of science** as one that **values** and **promotes citizen participation**” “the **connection with everyday life and the resolution of social problems**” “**Influence of science on social**, historical, political, economic, cultural, and environmental issues” “**political, economic, and commercial factors influencing scientific research** and the development of ST&I” “**Society’s knowledge and opinion about science**, its processes, products, and results” “**the effective participation of society in decisions about science** and the use of science results by society for engagement, **decision-making and empowerment**”

Source: Prepared by the authors based on Sasseron and Carvalho (2011), Leite (2015), Norberto Rocha (2018), Marandino et al. (2018), and Silva and Sasseron (2021).

The perspective of society in these four references shows that the aspects of Science and Technology are intrinsically linked to the social conditions of the human being, also revealing the mutual influence between political and economic factors and scientific and technological development. In addition, Science and Technology play a fundamental role in solving social problems, exerting a significant impact on various aspects of society. This interdependence is highlighted by Silva and Sasseron (2021), who understand science as a human practice capable of influencing and promoting social transformations.

In addition to understanding the interdependence between science and society, the need for effective and critical participation of the population in decisions related to science is highlighted. The references analyzed converge in highlighting that the appropriation of scientific knowledge by society must go beyond conceptual understanding, achieving an active and reflective posture in decision-making. This social aspect reinforces the importance of SL for the formation of subjects capable of recognizing that scientific practices cannot be dissociated from the social contexts in which they are inserted. Such understanding must be promoted in different spaces, whether formal or non-formal, in order to be aligned with social transformation.

When considering the convergences among the analyzed references, we found that, concerning scientific perspectives, the nature of science and the relationship between science and society, there is a deep connection among the different authors. The references indicate that SL constitutes a continuous and integrated construction, regardless of the space in which it occurs. Although it can adapt to the specificities of different contexts, its essence remains focused on the critical and reflective formation of individuals in the face of scientific and technological issues that permeate society.

SL for non-formal space recommends, in addition to the indicators already presented, two indicators that go beyond the definitions and characteristics of SL in formal teaching spaces. We consider this to be the point of greatest attention for these relationships.

Beyond the Scientific and the Social: The Role of Institutional and Interactive Perspectives

In the analysis we carried out, the Institutional Indicator and the Interaction Indicator were not identified in the Structuring Axes or in the Dimensions of SL. Figure 5 presents the relationship between the Interaction Indicator and some characteristics identified in the 2nd and 3rd Premises.

The Interaction Indicator refers to the interactions that occur or can be promoted in non-formal teaching spaces, which we consider essential for the effectiveness of SL in any context. The two Premises presented in Figure 5 refer to the process of cognitive interaction and, according to Silva and Sasseron (2021), constitute fundamental elements for scientific activity.

Figure 5

Characterization of the Interaction Indicator

2nd and 3rd Premises	**Interaction Indicator** **Attribute 4a.** Physical interaction **Attribute 3b**. Aesthetic-affective interaction **Attribute 3c.** Cognitive interaction
"scientific activity as a public enterprise **that develops through dialectics and through dialogues**" **"recognition of the sciences as a collaborative human practice"** "**it is maintained by interactions with ideas and knowledge**"	"identify the **ways and forms of interaction of the public** with the actions" "**allows/requires multiple use**, that is, **simultaneous use by more than one person**" "Physical **interaction has educational value and objectives** and leads to interactions of other types, such as cognitive and aesthetic-affective" "**Reconstruction of the scene, scenery and creation of atmosphere enabling the contextualization of the knowledge** disseminated and/or the immersion and aesthetic appreciation by the public" "**Stimulus to questions and reflection on the information presented and/or on** previous concepts, knowledge, atitudes, and opinions" "**It enables and stimulates a dialogical relationship between the various actors involved, enhancing the construction of knowledge**"

Source: Prepared by the authors based on Silva and Sasseron (2021), Norberto Rocha (2018), and Marandino et al. (2018).

We understand the interaction process as an essential element to amplify the production of scientific knowledge in the context of SL. According to Marandino et al. (2018), interaction can manifest itself in three main spheres: physical, aesthetic-affective, and cognitive. Cognitive interaction can also be found in Silva and Sasseron (2021) as indicated in Figure 5. Each of these forms of interaction contributes in a distinct but complementary way to the construction and consolidation of knowledge and SL, both in formal and non-formal spaces.

Physical interaction occurs through direct contact with objects, materials, and interactive artifacts that require individual or collective manipulation. This type of interaction arouses curiosity and encourages the active exploration of knowledge. According to Colinvaux (2005) and Oliveira et al. (2015), practical involvement favors learning, as direct manipulation helps in the internalization of concepts and promotes appropriation and reflection on the knowledge constructed.

This interaction is manifested in both spaces through interactive experiments — in classrooms, laboratories, or exhibitions — that enable participants to understand scientific phenomena. This occurs through sensory experience and direct experimentation, the use of three-dimensional models, and even the implementation of simulations that favor the manipulation process by students.

Aesthetic-affective interaction, in turn, involves the recreation of scenes and scenarios and the aesthetic appreciation of the way knowledge is presented. This type of interaction is directly related to the evocation of emotions and feelings, which contribute to the retention of information and to the construction of a meaningful bond with knowledge. As Norberto Rocha (2018) points out, visual, narrative, and immersive elements can generate an emotional experience that keeps individuals engaged and attentive to learning.

In non-formal spaces, this interaction is found in historical reenactments and artistic installations that bring the public closer to scientific knowledge through engaging narratives. In the classroom, aesthetic-affective interaction can be stimulated through activities such as scientific dramatizations, the use of stories and metaphors to explain complex concepts, the creation of attractive visual models, and activities that allow students to experience knowledge in a sensory and subjective way.

Cognitive interaction, on the other hand, is associated with dialogue, questioning, and the exchange of ideas between participants and the knowledge presented. This type of interaction stimulates the development of investigative skills, favoring the collective construction of knowledge. As Norberto Rocha (2018) emphasizes, cognitive interaction "promotes cognitive processes and develops skills related to learning, scientific investigation, and critical analysis" (p. 141). This interaction is fundamental for the consolidation and maintenance of scientific knowledge, as it provides moments of debate and reflection that strengthen individuals' engagement with science (Silva & Sasseron, 2021).

In both spaces, this interaction is manifested in debates about a theme or presentation, in conversation circles, and mediated discussions on contemporary scientific themes. In addition, strategies such as the elaboration of questions by the students and the critical analysis of scientific articles also favor the collective construction of knowledge. Thus, both inside the school environment and outside it, cognitive interaction strengthens the analytical and investigative capacity of the subjects involved.

These three forms of interaction do not act in isolation, but complement each other to enrich the SL process. The combination of practical manipulation, emotional engagement, and cognitive reflection creates a dynamic learning environment and favors long-term knowledge retention (Marques & Marandino, 2018; Suart & Marcondes, 2018). In this way, interaction is configured not only as a facilitator of learning but as an indispensable element for the effectiveness of SL, connecting theory and practice in a meaningful way.

In addition to the relationships already presented, Figure 6 presents the characteristics of the three attributes of the Institutional Indicator in isolation. The characteristics of this indicator are not visible in the conceptualizations of the other SL references presented in this study.

Figure 6

Characterization of the Institutional Indicator

Institutional Indicator
Attribute 3a. Institutions involved in the production and dissemination of science, their roles and missions
Attribute 3b. Funding institutions, their roles and missions
Attribute 3c. Political, historical, cultural, and social elements linked to the institution
"expresses the **dimension of the institutions involved with the production, dissemination, and promotion of science, their roles, missions, and social role**"
"identifies what the **scientific institutions are, as well as the political, scientific, and cultural aspects** related to them"
"aspects of the **mission and institutional role related to education and scientific dissemination and innovation**"
"aspects of the **mission and institutional role related to human resources training**"
"**government funding agencies,** such as CNPq, CAPES, MCTI, FAPs, etc."
"**process of production and dissemination of knowledge** of the institution**"**
"**historical dimension of the institution and its role in scientific development**"
"**importance of research and/or collections maintained by institutions**"

Source: Prepared by the authors based on Norberto Rocha (2018) and Marandino et al. (2018).

The Institutional Indicator highlights the role of institutions in the production, promotion, and dissemination of science, aspects that often go unnoticed when considering the evolution of scientific knowledge. In non-formal spaces, the production of projects, experiments, and research often requires the involvement of institutions that provide technical, structural, and financial support. However, the influence of these institutions is not restricted to the promotion of research: they also include educational institutions (basic and higher), regulatory bodies, and centers of scientific production, which play a fundamental role in training, dissemination of knowledge, and production of research.

Although the definitions of SL proposed by Sasseron and Carvalho (2011), Leite (2015), and Silva and Sasseron (2021) do not directly address institutional characteristics, this gap deserves attention. The absence of this aspect can also be found in the definitions of Lorenzetti (2021), Rosa and Amaral (2021), Milaré and Richetti (2021), and Scalfi and Marandino (2021) for SL, and even in studies of Scientific and Technological Literacy, such as Lorenzetti (2023). This suggests the need to expand the scope of SL to include the understanding of the role of institutions in the production of scientific knowledge and its mediation with society.

The insertion of the premises of this indicator in the SL process allows scientifically literate individuals to recognize the role of institutions that promote and regulate science, as well as identify those that disseminate incorrect or pseudoscientific information. This recognition is essential for developing a critical look at the sources of information and for the strengthening of scientific thinking in society. In addition, by recognizing the school as a space for the production of science, the understanding of its role in the construction and valorization of scientific knowledge is expanded.

The discredit attributed to scientific institutions and regulatory bodies during the COVID-19 pandemic, for example, reinforces the need to address this indicator in the educational context. The lack of understanding about the role of these institutions has contributed to the spread of misinformation and resistance to scientific measures. Thus, including the understanding of institutional functions in the SL process enables individuals to critically evaluate the credibility of the sources and understand the importance of institutional support in science. Thus, both in formal and non-formal spaces, the premises of the Institutional Indicator reveal that it is a fundamental element to strengthen SL and its application in daily life.

The institutional perspective can also be incorporated into the classroom context through activities that highlight the role of institutions in the production, regulation, and dissemination of science. An example is the analysis of news and reports on research funded by funding agencies, allowing students to understand the influence of these institutions on scientific advancement and distinguish them from fake news.

Another possibility is to emphasize the school as a producer of scientific knowledge, encouraging the production of research projects and participation in science fairs, for example. Direct contact with researchers from universities and institutes can enrich this experience, bringing students closer to the academic environment. Likewise, the process of scientific literacy can include discussions about the credibility of scientific sources, promoting workshops on information checking and critical analysis of scientific content disseminated in the media.

From the approximations of the references, we evidence the need for a unified approach to SL, in which it is used for formal and non-formal spaces, being proposed in an articulated way. By recognizing that the construction of scientific knowledge is dynamic and contextualized, it becomes possible to overcome the idea of different scientific backgrounds for different educational spaces, promoting a more critical and reflective engagement with the science available and taught to individuals.

Final Considerations and Reflections

With this article, we do not seek to reformulate the already consolidated definitions of SL, but rather **to broaden the understanding of how it can be developed in an integrated way in the different educational spaces**. The effectiveness of SL depends on teaching that values reflective skills and processes, allowing individuals to understand and incorporate scientific knowledge into their daily lives. For this, the school and the teacher must appropriate the practices and references of non-formal spaces, promoting an SL that is not limited to a specific context, but that is configured as a continuous and meaningful process.

By promoting the integration of SL perspectives in formal and non-formal spaces, we seek to expand its applicability in both educational contexts, recognizing that its construction is based on common premises. The relationship between the Structuring Axes, the Dimensions, the Premises, and the SLI shows that, regardless of the environment in which it occurs, SL values the individual as the center of the process and considers both the concepts and theories as well as the historical, environmental, social, interactive, and institutional factors that influence them.

Although the references present different perspectives on SL, the indicators allow for a more detailed analysis of its nuances, highlighting the institutional perspectives and the interaction processes. In the formal context, the approximation between these references strengthens learning by showing how and where scientific knowledge is produced, disseminated, and regulated, allowing students to understand not only the concepts and theories but also how science and society influence each other.

Thus, it is also worth highlighting the adoption of interactive processes in formal education, allowing engagement and favoring learning. Strategies such as recreating scenes and scenarios, presenting information in an impactful way, and using interactive artifacts enable students to establish connections between scientific knowledge and their experiences. Thus, physical, aesthetic-affective, and cognitive interactions become essential elements for the effectiveness of SL, promoting a more dynamic and stimulating teaching, with potential for dialogue between culture and science and their interrelationships.

In addition, we emphasize the importance of making explicit the role of institutions involved with science, from educational institutions to governmental and private agencies that foster and regulate scientific production. For students, understanding these institutions and their missions contributes to the development of critical thinking, allowing them to identify reliable sources of information and recognize the relevance of science in their daily lives. This reinforces the need for teachers not only to use these aspects in the classroom, but also to promote visits to scientific institutions, such as universities, research centers and museums, providing experiences that bring students closer to the scientific work.

The implementation of SL in formal and non-formal spaces depends on the integration between interactive processes and the recognition of the role of scientific institutions. While interactions favor learning by making knowledge more accessible and engaging, the understanding of scientific institutions strengthens critical thinking and the perception of the various actors in the production of science, characterizing this process as dynamic and socially relevant.

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