The meaning and practice of scientific literacy based on its dimensions and indicators: A literature review

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Abstract: Sociocultural elements have expanded the meaning of scientific literacy, which raises the question of how this change is materialized in classroom practice. Through a systematic literature review, we investigated the dimensions and indicators of scientific literacy present in articles in the area, to access the relationships between meanings and practices of scientific literacy. Critical pedagogical theories support our theoretical approach, and the determination of the current domains of scientific literacy took place through discursive textual analysis. We found that pedagogical approaches to scientific literacy prioritize elements of scientific production to the detriment of sociocultural ones, although there are domains and indicators in the literature that collaborate for practices connected with the social context. We conclude that the imbalance in the development of scientific literacy domains leads to a departure from the critical character of its theoretical conceptualization. We also concluded that, although cultural, attitudinal and ideological elements indicate scientific literacy in a concrete sense, they can assume a liberal bias if they focus only on individual skills in the subject's daily practice.

Keywords: scientific literacy, domains, critical pedagogical theories.

Introduction

Discussions about the concept of Scientific Literacy (SL) demarcate its various faces in terms of dimensions or categories, among others. These categorizations describe the breadth of the concept from the exposition of each of its parts. As well, they facilitate the development of the SL through the understanding of the aspects that involve it, guiding pedagogical interventions and the construction of tests to measure the level of SL of certain groups. However, this categorization has not been simple work. As a socially and culturally constructed concept (Mun et al., 2015), the SL has been changing for more than half a century and today assumes a much broader meaning than in the past.

Initially, the SL entered science education research involving the vision of acquiring scientific knowledge at the conceptual and procedural level by the lay public. There was the purpose of familiarizing the population with the new products of science and with government investments in science and technology (Mun et al., 2015). Subsequently, the understanding of the relationship between science, technology, society and the environment was inserted. Then, this knowledge was linked to the individual attitude of the literate subject in the face of social demands. More recently, the idea of a global ecological vision that 21st century subjects should develop has also appeared, since all nations are connected, and local socio-scientific issues have global consequences (Mun et al., 2015).

Mun et al. (2015) state that in a globalized society, science education should seek the formation of global citizens, with an integrated understanding of the central ideas of science, able to participate in issues of socio-scientific interest. The same authors emphasize that global citizens have values of respect for all human groups and the environment, show responsible actions and see science as a product of human endeavor.

The expansion of the SL concept emphasizes cultural and ideological aspects. "Moral values and world views that can lead people to make appropriate choices and decisions to ensure a sustainable planet" (Mun et al., 2015, p. 8). Thus, at the level of discourse, the expansion of the SL concept indicates a belief that the incorporation of scientific culture by the subjects would lead to attitudinal change, with a positive impact on private life, in the community and on the global health of the planet. Under this justification, there are several pedagogical interventions in favor of SL in basic education. In many countries, they are driven by reforms in school curricula (Vieira and Tenreiro-Vieira, 2014).

Therefore, the concept of SL has increasingly acquired a critical sense by encouraging the exploration of scientific knowledge through (1) the relationship between science, technology and society, (2) the understanding of science as a collective historical human enterprise and (3) the cultural and attitudinal reflexes of science on the subject, towards a global citizenship. Which makes us question whether – and how – this concept has been implemented in the approaches developed in basic education.

By understanding that the attitudinal transformations of the subjects go through cultural and ideological constructions, we also ask ourselves how this face of the SL has been treated in the categorizations proposed for the term and in the pedagogical approaches carried out in science teaching. Since, in order to answer these questions, we see the importance of a third element that stands between the SL and the approach implemented, which are the SL indicators. Are there indicators for all dimensions proposed in the literature? What indicators have been used to assess the dimensions linked to the cultural, ideological and attitudinal face of the SL?

The answers to these questions can help to assess whether the implementation of the SL in the practice of science teaching has followed the evolution of the concept itself, whose current emphasis is on training for the exercise of citizenship and social transformation. Thus, we performed a systematic literature review to access publications related to scientific literacy in the context of basic education. The following objectives guide this review: to identify the SL categorizations used by the authors, in order to demarcate the meaning and breadth of the concept in classroom practice; identify and classify the indicators that are being used in the SL practices, in order to assess their reach in the face of multiple categorizations, especially those linked to their cultural, ideological and attitudinal face.

A discursive textual analysis of the SL categorizations present in the review articles allowed a new vision of the concept, which was used as a parameter for evaluating the scope of SL in the results of the articles.

Scientific literacy and critical pedagogical theories

Scientific literacy is a broad concept that refers to the general population's need to grasp the various elements of scientific culture. It ranks as a goal of science education. However, its social purpose is in dispute between the conservation of predatory capitalism, with the formation of citizens focused solely on the labor market and consumerism, on the one hand, and the formation of citizens more aligned with the transformation of the mode of production and adoption of an environmentally sustainable and socially just system, on the other.

Hansson and Yacoubian (2020) explain that SL does not necessarily incorporate social justice as an objective, often reducing the scope of science education, as well as adopting a model that is deficient in relation to the knowledge needs of marginalized students. On the other hand, there are proposals for redefinition of the SL through collective praxis on social situations (Roth and Lee, 2004) and through the incorporation of socio-scientific issues as a means of promoting engagement in socio-political actions (Santos, 2009; Lee et al., 2013).

As an educational objective, SL is linked to other educational elements, such as theories and pedagogical methods. According to Saviani (2017), a pedagogical theory is characterized by its structure based on educational practice and in function of it, in order to formulate guidelines for the teaching and learning process, seeking to equate the teacher-student relationship. Pedagogical theories differ in the way they conceive and guide education, which is disputed by social classes. According to the author, there are four major pedagogical theories: Traditional Humanist, with a Jesuit base; Modern Humanist, derived from the New School; Analytical, with a technicist conception; and Dialectical Criticism (Saviani, 2017).

The first three have in common the uncritical conception of education, ignoring the interference of social aspects, "[...] they are theories that understand education as an instrument for equalizing social problems without transforming the economic/social model that generates inequality" (Teixeira, 2003, p. 5). In the non-critical conception, the school acquires the supposed ability to correct social problems, which are individual and accidental, through social homogenization (Teixeira, 2003). It is the conception of a school as a redeemer of society.

The Dialectical Critical Theory, on the other hand, understands the school as a tool of reaction to the capitalist domination over society, which is marked by the division between classes, which have different conditions for the production of material life. In its view, socio-environmental problems are intrinsic to the structure of class society, due to the appropriation of the social/material production of one class by the other. In this structure, where even natural resources and science are converted into products, it is understood that education and school are socially determined. For the critical theory, the school can lead to overcoming the problem of the marginality of the working class (Saviani, 2018). Libâneo (2006) dialogs with this view by classifying pedagogical theories as Liberal or Progressive, based on the way they relate education and sociopolitical conditions.

Liberal pedagogies reflect the capitalist ideology of defense of freedom and individuality as a justification for defending private property of the means of production and maintaining the segregation of social classes. It abstracts the inequalities of conditions and exercises its criticism on the subjects, who need to adapt to the social roles predetermined by the class society, developing individually according to their abilities (Libâneo, 2006).

In the opposite direction are progressive pedagogies, which are based on the critical analysis of social reality. They conceive education as a sociopolitical tool for both social classes and, therefore, defend the occupation and conscious use of this space in favor of the working class, even understanding the impossibility of its institutionalization within capitalist society (Libâneo, 2006).

As education workers, socially legitimated as holders of historically accumulated scientific knowledge, as well as aware of the social and ecological demands of the present time, science educators should not be alienated from the political struggle that surrounds their practice. Aware that all pedagogical theories are crossed by values, political, moral and ideological objectives, educators are expected to make pedagogical choices, that is, "[...] take a position on objectives and ways of promoting the development and learning of subjects inserted in concrete sociocultural and institutional contexts" (Libâneo, 2005, p. 16).

It is about the background of different pedagogical theories that we analyze the scientific articles, whose discussions focus on scientific literacy in basic education. As a concept that has been incorporating values of social, political and ecological responsibility over time, we understand its alignment with the critical or progressive pedagogies. Since the current socio-environmental problems, of global scope, arise from the capitalist mode of production, it makes no sense to educate in science without criticizing the system that generates the problems.

Without the lens of social criticism, scientific literacy acquires a liberal character, resulting in individual skills, characteristics of scientific work, but destined for production and consumption posts, despite the social and environmental demands of the students' own generation.

Material and methods

The construction of this Systematic Literature Review (SLR) was referenced in the guide called Road Map, whose strategy and method allows the search and analysis of results through cycles that are repeated continuously until the objectives of the review are reached (Conforto, Amaral and Silva, 2011). The SLR Road Map has three phases of work: 1. Input – problem definition and clarity, objectives, primary search sources, search strings, inclusion criteria, qualification criteria, method and tools, schedule; 2. Processing – conducting searches, analyzing results, documentation; 3. Output – alerts, registration and file, synthesis of results, theoretical models (Conforto, Amaral and Silva, 2011). In table 1 we present the elements of the SLR Road Map Input phase, with the exception of the research problem and objectives, already presented in the introduction.

Primary sources	Sucupira Platform (Brazilian journal evaluation system); Bank of articles from selected journals on the platform; Google Scholar.
Search strings	Letramento científico; Alfabetização científica; Scientific literacy; indicadores de; avaliação de; assessment; nível; level.
Inclusion criteria	Articles from 2007-2022 (15 years); evaluation of scientific literacy in the objectives; presentation of indicators; qualis A journals, Portuguese, English, Spanish; search strings in the title or abstract.
Qualification Criteria	Teaching-learning experiences focused on scientific literacy; jobs in basic education, final years of elementary level, and high school; works with explicit scientific literacy indicators and resources used for their identification; assessment work on the level of scientific literacy.
Method and tools	Filter of journals in the area of education and teaching of science qualis A on the Sucupira Platform; different combinations of keywords in the search filters of the journals' websites; reading the titles and keywords of the articles (filter 1); reading the abstracts (filter 2); full reading of the article (filter3); identification of references that could enter the SLR; rereading the article.

Table 1: Planning the Input phase of the systematic literature review.

During the Processing phase, the articles went through three filtering cycles. In the first filter, they were coded and organized in a database in Calc, LibreOffice's free software, with data referring to the title, year of publication and the inclusion criteria that were met. In filter 2, the selected articles were transferred to a new database with details on the objectives of the work, target audience and methodology. In the third filtering cycle, all articles were read in their entirety and information was added about the country of origin, level of education, the meanings attributed to scientific literacy, the dimensions considered by the authors, the SL indicators used, the collection and analysis methodologies of indicators, the curricular contents covered and observations on the results and conclusions.

Then, a descriptive analysis of the variables was carried out, with mapping of the SL’s dimensions and indicators weighted in all articles, as well as the types of instruments used in their collection and analysis. It was examined whether the dimensions considered in its theoretical referential were included in the indicators collection method and evaluation of the SL’s level. With the information collected, the Output phase of the SLR Road Map was carried out, in which the results were synthesized in texts, tables and figures, for analysis and discussion.

The concepts of the different SL dimensions used in the articles or in their references constituted our analysis corpus via Discursive Textual Analysis (DTA) (Moraes, 2003). This methodology enabled the emergence of new categories of meaning from the fragmentation, reconstruction and subjective interpretation of the analyzed concepts, in order to visualize the amplitude of the SL itself, as well as the peculiarities of each of its faces, which after the treatment passed to be called "domains", just so as not to confuse them with the dimensions that were analyzed.

Then, we analyzed the frequency of these domains in the articles and their correlation with the authors' goals, using Pearson's correlation coefficient. We raised the indicators that relate to each domain and their correlation with those reached in the results of the works, as well as, we reflected on the Affective/Attitudinal domain, its importance and relationship with the meanings of SL adopted in the articles.

Results and discussion

In the Sucupira Platform, 25 qualis A journals were found for the area of Science Teaching. Searches on the journals' websites resulted in 1919 articles, of which 73 underwent the first filtering, 35 articles underwent the second filtering and 23 the third. The cross search resulted in ten articles, of which only two passed the filters. Therefore, the corpus of this literature review comprises 25 articles extracted from twelve scientific journals written in Portuguese (Brazil, Portugal), English (Australia, China, South Korea, USA, New Zealand, Turkey) or Spanish (Costa Rica, Spain).

The articles were divided into two groups: (1) SL evaluation articles after pedagogical intervention, with seventeen works and; (2) direct SL evaluation articles, without pedagogical intervention, with eight works. Thus, initially we present an analysis of the first group, considering that it has a differentiating element that is the pedagogical intervention, then we approach the second group together with the first, because in this case the analyzed elements are common to all.

Articles with Pedagogical Intervention

Among the group with SL assessment carried out after pedagogical intervention, sixteen theoretical-methodological arrangements were identified with a focus on the development of skills related to SL (Figure 1).

All the theoretical-methodological arrangements had among the research objectives to assess the potential of pedagogical intervention in the development of one or more SL dimensions. It is noted that eleven pedagogical interventions do not clearly expose their theoretical bases, so that the teaching and learning methodology seems independent of theoretical conception, thus being an uncritical set. Among the six interventions that clarify their pedagogical conceptions, three are anchored in non-critical or liberal theories (Saviani, 2018; Libâneo, 2006) – Rogerian Theory, Constructionism and History of Science. The other three pedagogical interventions refer to the Science, Technology and Society (STS) Movement, creating theoretical-methodological arrangements that align with progressive theories in education.

The justifications that the articles used to carry out the work revolve around the construction of the SL for the development of citizenship, as well as competences for decision-making in personal life and in society. A vision of scientific culture as a catalyst for social transformation is common in all of them. However, it may sound contradictory, looking at scientific literacy as a face of citizen education, enhancer of social change, and aiming for its development through a conservative pedagogical concept.

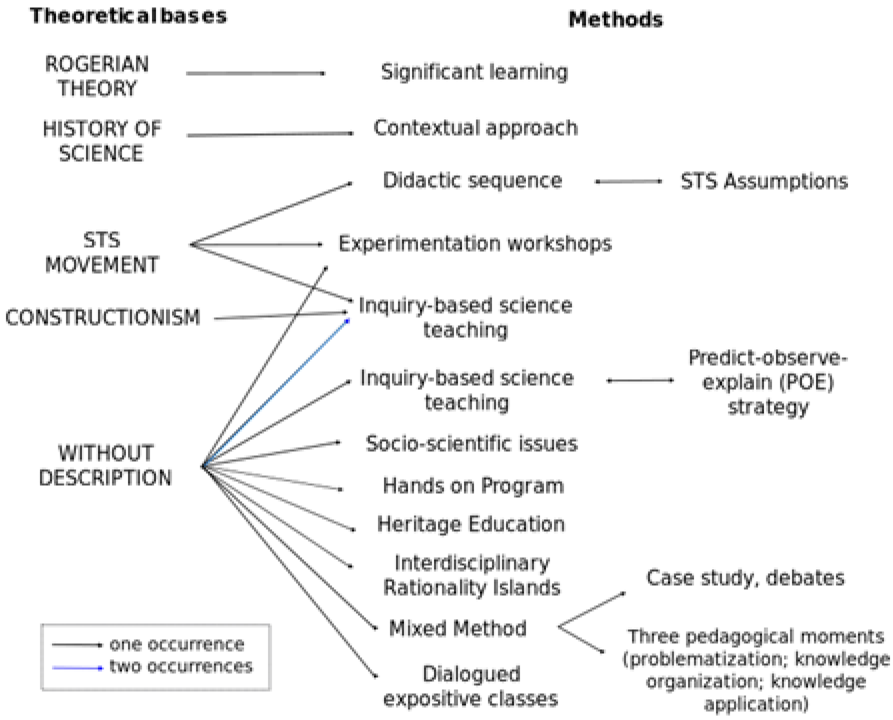

Figure 1: Theoretical-methodological arrangements of pedagogical interventions.

Non-critical pedagogical theories see education as autonomous, independent of the social variants that surround it (Saviani, 2018). For these theories, social problems can be solved by education, whose function is to equalize problems and homogenize society. They have a "[...] naive belief in the redeeming power of education in relation to society" (Saviani, 2018, p. 85), as they disregard the current mode of production as a generator of inequality. There is no intention to transform the model of society that generates social problems, as they are seen as accidental (Teixeira, 2003).

In a critical model of citizenship, the SL must act on the understanding that injustices can be sustained by deliberately misleading scientific appeals, which in certain political and economic scenarios can shape social privileges and economic advantages (Allchin, 2020). In this way, the citizen should ideally be empowered to act in order to expose any flaws or dubious claims in scientific political discourse, which requires understanding not only how knowledge is produced within the scientific community, but also how it is transmitted among social settings (Allchin, 2020).

When talking about SL and citizen education with a view to social transformation, it is necessary to reflect on what sense of citizenship and social transformation is at stake. By being based on non-critical theories, the SL approaches the interests of the current productive processes, which does not criticize its predatory character nor the submission of science to the economic interests of this mode of production. There is, therefore, no real possibility of social transformation, but only a stereo discourse, since the construction of knowledge about science and the construction of skills related to scientific work discuss the individual postures of the subject or of certain groups in the face of socio-environmental problems, but they bypass the economic model that generates such problems.

We take as an example two studies that make up this systematic review, both with pedagogical interventions, aiming to promote the SL with students of the youth and adult education modality (YAE) in Brazil. We carried out more than one reading, contrasting the SL view present in the works with the theoretical basis of the approach and the results achieved.

The first research (code 6.2) aims to verify the viability of the Programa "Mão na Massa" (Hands-on Program) in scientifically teaching an audience that is not initially the focus of the program, thus creating opportunities for the formation in YAE of a critical student. When examining the text, we realize that its theoretical referential points to a vision of SL linked to the following elements: understanding and transformation of the world; participation in socio-scientific issues and; overcoming social problems. The text highlights the importance of the social context in teaching and the need to train critical subjects capable of making conscious decisions. However, it does not expose the pedagogical theory behind the proposal.

The methodology presented in the text does not reach the highlighted elements. We do not perceive in the development of the proposal, in its results and discussion, indicators of the construction of a scientific formation concerned with citizenship or social transformation. It turns to the skills of doing science as if, by themselves, such skills enabled people to exercise citizenship.

The problematization is absent in the approach of the text, since the problem on which the students focus is already posed. In the critical conception, problematization is a space for the generation of problem questions by the students themselves, which could justify the need for the contents worked (Saviani, 2018). Even the contextualization of the approach to the subject occurs in a superficial way, considering that contextualizing is not only inserting known objects in an activity, but using contexts known to the students and enabling the emergence of significant knowledge for a new vision of reality (Ricardo, 2003).

The other text examined (code 12.2) aims to reflect on the contributions of the STS movement to the SL, defending the articulation of scientific knowledge with everyday practices and in the exercise of citizenship. The approach is through a didactic sequence supported by the STS assumptions. We verified a SL perspective that involves conceptual, procedural and affective aspects of science, however, there is no idea of automatic linkage between the promotion of scientific knowledge and the overcoming of social problems. In contrast, the text suggests approaching the class in a consciously directed way to highlight the not always explicit relationships between science, technology and society, taking into account the ideological influences behind these relationships.

Pedagogical intervention is contextualized according to Freire's conception and, although the issue to be developed has already been previously stipulated, there is room for problematization, evidencing the need for learning by students. Furthermore, consistent with the critical view of SL highlighted in its theoretical referential, the intervention presents in the thematic arrangement, around Water, more than conceptual or behavioral aspects at the individual level. There are also those that involve industrial production and its impact on the natural resources, its responsibility as a promoter of problems related to the topic discussed in class, tending to the level of conscience and stimulating reflection on non-casual aspects of contemporary social, scientific and environmental problems.

Therefore, even with a critical conception of SL, the lack of clarity about the theoretical bases of pedagogical intervention planning can harm the direction of actions to their objectives or harm the harmony between the results achieved and the justifications of the work. Thus, the theoretical-methodological arrangements shown in Figure 1 were successful in developing SL skills. However, this does not mean that there has been progress towards the formation of citizenship or towards behavioral and attitudinal changes that contribute to socio-environmental transformations repeatedly mentioned when the promotion of SL levels in the population is justified. This is because, the development of skills inherent to the SL without an approach that explains the political and ideological aspects involved in science and its products, becomes mechanical. Which implies that it will be at the service of interests beyond the student himself.

Uncritical approaches reinforce the model of citizenship restricted to the individual space, with subjects capable of elaborating punctual criticism and actions, however disconnected from the real origins of the problems, since they are not perceived. This SL model contributes little to personal or social changes. Therefore, it is significant that the planning of pedagogical approaches for the SL are built on a critical theoretical basis, which understands education as socially determined and influenced by the conflict of interests that characterizes a society structured in classes (Saviani, 2018). Considering that social problems are inherent to this structure, progressive pedagogical theories understand that knowledge by itself does not transform society, but it can become a cultural tool in favor of transformation. They encourage the approach of curricular contents in ways that make explicit the contradictions of the class structure, coming in consonance with the purposes of science education for effective citizenship.

Articles with and without pedagogical intervention

In sixteen articles, twelve different references were found to describe the categories or dimensions of SL. Nine articles do not mention these divisions, but work with the general concept of SL, seeking guidance in the indicators present in the literature, or in those possible to extract from the very definition of SL adopted in the article.

The twelve references described in the articles differ in relation to the scope of the SL dimension, with some authors preferring broad dimensions and others more specific dimensions. Norris and phillips (2003) and Robert (2007, apud Rodrigues and Quadros, 2019), for example, are references that establish only two dimensions of SL: fundamental sense and derived sense for the first authors and; vision i and vision ii for the second author. The two-dimensional division of these authors shares the idea that there is a set of fundamental elements in science, as well as a second set with elements that derive from the first. Norris and Phillips (2003) highlight the ability to read and write scientifically as a fundamental aspect of scientific work. For Robert (2007, apud Rodrigues and Quadros, 2019) this fundamental set includes general notions about concepts, phenomena and processes, about the nature of science, in addition to skills inherent to the scientific method.

However, authors who see more specific dimensions divide the SL between three and six parts. In an overview, starting from the broader dimensions to the more specific ones, the different descriptions unite at certain points and move away at others, with the occurrence of dimensions that mix elements of the two large groups described, which reflects how much it is problematic to define what is fundamental and what is derived in relation to the SL (Figure 2).

An approximation through the DTA to the concepts extracted from the source articles or from the review articles of each of the dimensions in Figure 2, showed that its multiple meanings converge into five categories, which we will call Domains, which are: Value of Science; Conceptual; Scientific work; Science and Society; Affective/Attitudinal. Next, the characteristics of each one of them, extracted from the categorization via DTA, added to new meanings used by the authors of this article, from the interpretations that emerged from the textual analysis performed.

1) Value of science domain (present in seven references)

This domain involves understanding the importance of science for its cultural, historical and functional contributions, aware that it is the product of human, collaborative work, built throughout history and in dialog with social contexts. It involves understanding science as guided by a particular theory and ideology, promoting an interdisciplinary approach to nature. The following stand out: History of Science; Science as human work; Social historical context of scientific work; Dialectical relations between Science and Human History.

2) Scientific work domain (present in twelve references)

This domain is linked to fundamental aspects of research such as knowledge about the nature of science, the rules and rigor of the construction, establishment and organization of scientific knowledge. It requires an understanding of the scientific method as an essential process for the verifiability of knowledge, its relationship with evidence, and the application of mathematics in science. It implies knowing that there is no universal scientific method, but models that approach reality. It involves the philosophy of science with ontological and epistemological reflections. It enables the understanding of science as a cohesive and coherent body, although formed by different areas and in constant transformation, which results from the process of building new knowledge. This domain requires/promotes the development of important skills for scientific work, such as the ability for scientific reading and writing, critical thinking, systematization, collaboration, communication, abstraction, among others. The skills promoted here are also important for citizen education, given the scientific-technological character that science imprints on society and the resulting problems with which the subject needs to deal. The following stand out: Nature of Science; Philosophy of Science; Scientific method.

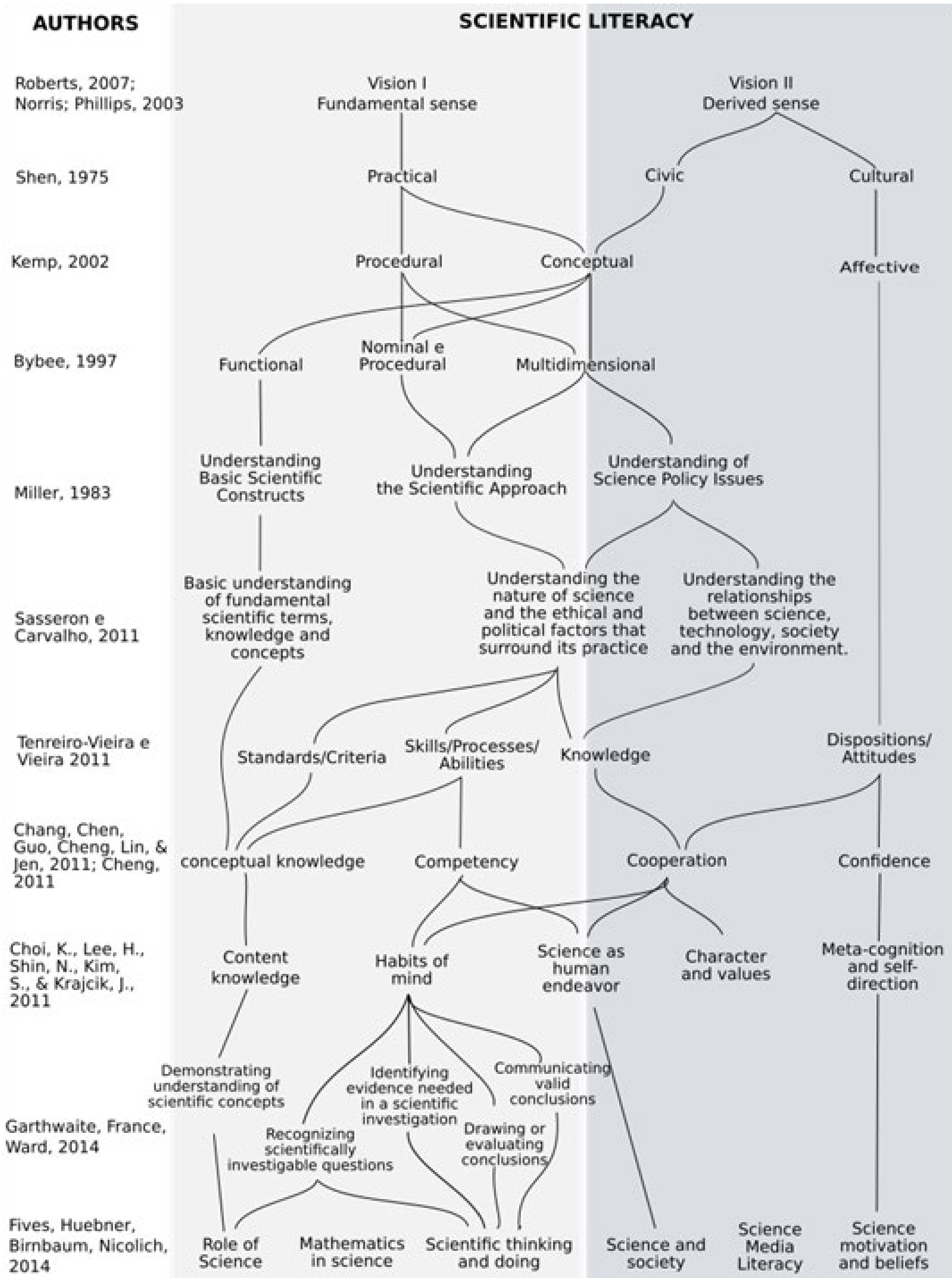

Figure 2: Reference authors and the respective dimensions of scientific literacy.

3) Conceptual domain (present in twelve references)

This domain concerns the learning of scientific concepts widely used in the great areas of Science, considered essential for the understanding of other more complex concepts. This base allows the formation of an integrated conceptual structure in Science and Technology, with the capacity for growth throughout life. As the Conceptual Domain in Science grows, a greater capacity for abstraction is acquired, with the possibility of a high number of mental associations at increasingly complex levels. An important feature for the development of the other SL Domains, especially for the perception of problem issues and the construction of action schemes in the search for solutions. The following stand out: Scientific vocabulary; Ability to relate concepts.

4) Science and society domain (present in eleven references)

This domain involves the perception of elements of science and its products in modern life, as well as the understanding of their influence on the way of life, whether in the social or individual sphere. The interdisciplinary character of science, the value of its products as well as the risks brought by them are considered, but the emphasis is on the present and in the future. It is understood that scientific knowledge, as a human historical product, must be used responsibly with the future, directing towards the common good, respecting human diversity and the environment. Therefore, it involves both the recognition of problems arising from the use or development of science on society and the natural environment, and the ability to think of solutions from a scientific and social point of view. There is, therefore, the recognition that science is not autonomous, but driven by political and ideological influences. The Science and Society Domain calls for itself the civic aspects of science, which requires social political participation of scientifically literate subjects, acting through popular organization, in the struggle for the political direction of scientific work and its products for the common good. It ranges from understanding to the effective participation of subjects in the dialog between science and society. Finally, there is the notion of society as the global set of humanity, crossed by diverse contexts and complex problems. The following stand out: Recognition of Science in personal/social life; Recognition of the interdisciplinary character of Science; Understanding the benefits/risks of Science products; Understanding the political face of scientific work, and the dialogical relationship between Science and Society.

5) Affective/Attitudinal domain (present in ten references)

This domain results from learning from other domains. Based on knowledge about the Value of Science, about Scientific Work and an understanding of the relationship between science and society, it is possible to immerse oneself in a scientific philosophy that is recognized as conditioned by social and historical factors, so that the subject becomes capable of directing his skills to the construction of a posture consistent with his scientific knowledge. In the personal sphere (considering how the accommodation of scientific knowledge and philosophy will take place in the midst of the subject's other knowledge and ideologies), this can generate a responsible attitude towards nature and the various human groups, with judgments of values based on evidence, willingness to overcome personal beliefs and openness to new points of view, besides willingness for scientific dissemination and understanding of science as an element of improving practical and social life. Choi et al., (2011) mention the ability to manage one's own learning, setting goals for intellectual growth throughout life. Still in the personal sphere, there are elements that relate to the Value of Science Domain, such as the voluntary search for culture and scientific knowledge, being emotionally touched by them, contributing to their dissemination and aware that there are no absolute truths. While in the social sphere, the subject can develop an active stance on public issues about science and technology, entering the political environment of the relationship between science and society. Willing to use the skills inherent to scientific work in the reflection and search for solutions to complex problems in social and global contexts. Attitude stands out, as it materializes the other domains in actions. The scientifically literate subject is expected to express philosophy and scientific knowledge in attitudes in personal life towards the common good and towards their own cultural, intellectual enrichment, as well as in the sphere of community/global life.

The division into five domains does not constitute a hierarchical scale of values, with the Scientific and Conceptual Work domains on the side considered fundamental to the SL and the Value of Science, Science and Society and Affective/Attitudinal domains among the derived elements. Because the "fundamental elements" of scientific production lose value when closed in on themselves, disconnected from social, political, environmental demands and the fate of their technological and cultural products. They are a way to develop the ability to systematize thought in a logical way, which does not necessarily involve the critique of reality beyond natural reality. The Conceptual and Scientific Work domains meet the demand of scientific rationality, but are not committed to the construction of a critical view of the world, impregnated by socio-historical cultural aspects, which are inseparable from the work of the scientist and the products of science. If these domains are not contextualized and problematized, they do not reflect social reality and cannot interfere with it, being, therefore, insufficient for the SL, which is committed to citizenship.

Therefore, the five domains are fundamental to scientific literacy, being connected by the relationships of meaning they establish with each other and, at the same time, differentiating themselves by the knowledge, skills or influences that each domain generates in the subject (Figure 3).

The Conceptual and Work of Science domains enable what is most characteristic of scientific culture, while the other domains add skills and knowledge that give meaning and guide learning. Therefore, if there is an intention to teach science for citizenship and social transformation, the SL requires an approach that includes the five identified domains, in addition to a critical pedagogical basis.

However, we observed an imbalance in the approach of the different faces of the SL. The Conceptual and Scientific Work domains predominate over the others, with a strong correlation between the frequency of the domain in the references and its frequency in the research results ($r = 0.91$). For example, Value of Science, which is present in seven of the twelve references of the review, has a relative frequency of only 5% in the results of these articles. The Conceptual domain and the Work of Science domain, present in all referential, have a relative frequency of 32.5% (Figure 4).

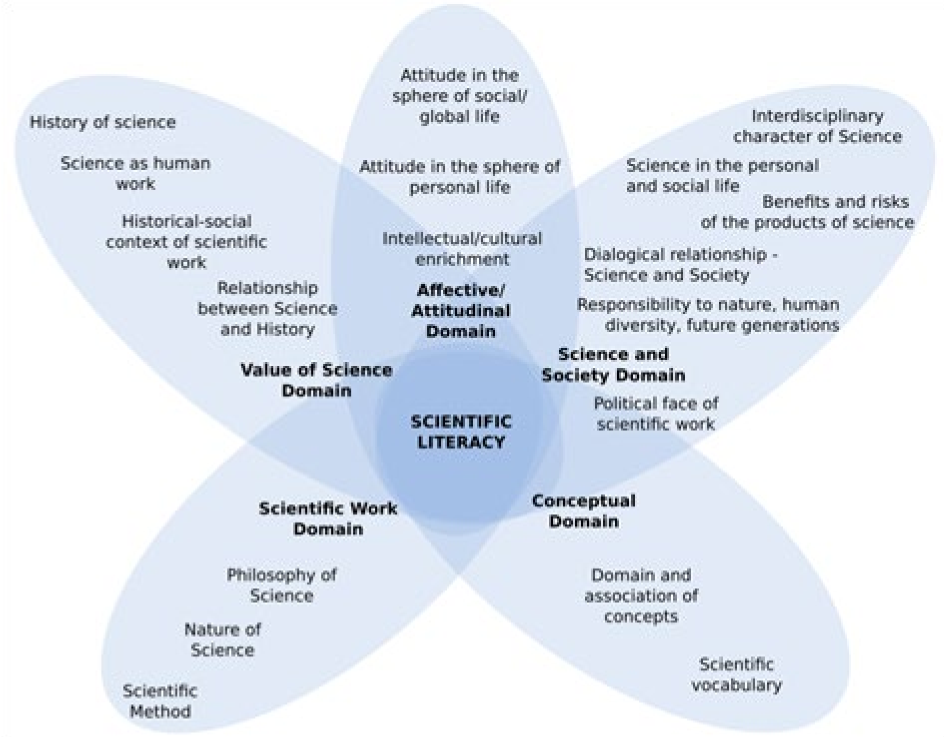

Figure 3: SL domains that emerged from the Discursive Textual Analysis.

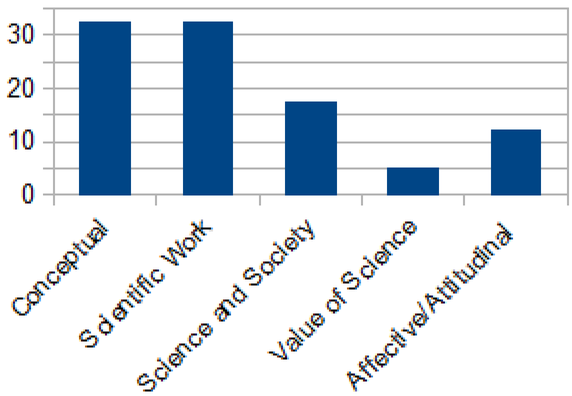

Figure 4: Relative frequency (%) of each domain in the reviewed articles.

The individual examination of the articles showed a moderate correlation (r = 0.52) between the dimensions present in the referential and those reached in the results. Thus, there was a slight tendency towards a greater scope of domains in the approach, when the SL dimensions considered by the authors were explicit in the research design. Of the nine studies without a referential for the SL dimensions, six reached only the two domains linked to scientific production (Conceptual and Science Work), while studies that considered this categorization reached three to five domains. Thus, each domain tends to appear in SL surveys as they are previously considered in the theoretical referential.

Scientific Literacy indicators and their breadth

Indicators are elements that serve as parameters for the teacher or researcher to think about strategies and assess the development of SL in a pedagogical intervention or to assess the SL level of a given group through specific tests. Annex 2 shows the indicators raised in this review, arranged in accordance with the SL domains with which they are connected.

We found that the evaluator can opt for a broad approach aiming to reach the various SL domains or an approach with a restricted focus on a certain domain. Regardless of the approach, the indicators are strongly correlated (r = 1) to the SL domains that are reached in the results of the articles. This means that, if the focus of an intervention is the SL in a broad sense, with its aspects related to scientific production, the value of science, the relationship between science and society and affective/attitudinal elements, it must necessarily take into account in the design of the approach the indicators that will serve as parameters for each of these domains.

However, in the articles of the present review, the relationship between the amplitude of the SL and indicators used was not always in harmony, with ten articles (40%) aiming at the SL in a broad sense, but using indicators only from the Conceptual and Scientific Work domains. This becomes problematic when the meaning of SL presented and defended by the authors goes beyond the procedural aspect of science teaching and learning, connecting with citizenship and taking an attitude towards problems related to science, technology, environment, and society.

Articles that focus only on the Conceptual and Scientific Work domains, dispense with the critical sense present in the concept of SL, or attribute to it a different sense from social criticism, which seeks to expose the contradictions of class society and its impacts on the most diverse sectors. The criticism used is focused on the ability to see scientific knowledge in the practical sense of everyday application, but without a social bias. It seeks the ability to systematize thinking in a logical way to interpret the environment and other attributes related to scientific production, however, it is not reflected for what or for whom such skills would be useful. It does not touch the notion of criticality that socially transforms the world.

In this bias, even the notion of transformation runs the risk of turning into the scientific context, of transformation of matter, manipulation of nature and physical/mechanical transformation of the world. Knowing concepts, processes and epistemology to then transform things, reflecting the notion of scientific advance as transformation and progress. Science and scientific knowledge acquire the status of saviors of the world.

However, this conception of SL is far from the notion of transformation of social relations that generate economic, social, and ecological disarrangements. The only transformation that purely scientific criticism generates is the overcoming of its own assumptions, causing new ways of explaining the world and new technologies. The naivety of the theoretical basis of redemptive education seems to be transferred to the conception or approach of SL, which becomes equally naive in its belief in redemptive scientific knowledge in itself, apart from the criticism to class society.

Nevertheless, fifteen works (60%) showed harmony between focus and SL indicators. Of these, four (16%) made it clear that their focus was restricted to one or two domains, while another eleven (44%) focused on the five domains, using indicators linked to more than three domains.

We found that, although there are indicators in the literature for all domains of SL, the researches make most use of those referring to scientific production, with the groups of indicators less used being those related to the Value of Science domain and to the Affective/Attitudinal domain. Elements linked to these two domains have been present in the science teaching literature since the 1970s, when the first tests interested in students' attitudes towards Science appeared (Mun et al., 2015). However, their approach in the practice of science teaching and learning for the SL has been neglected.

The pedagogy of science education is directly related to scientific content. In the works reviewed here, we find themes from biology, chemistry and physics. In general, students' conceptual mastery of the topic is the main concern of authors. In order to develop this domain, the procedural approach is often used, giving rise to the concern to also develop the domain of Scientific Work. There seems to be an undeclared consensus that in order to reach the Science and Society, Value of Science and Affective/Attitudinal domains, it is necessary first of all to develop the elements linked to the domain of scientific production.

However, by reading the students' dialogs reported in certain articles, we observed that elements from other domains, in addition to the conceptual and procedural ones, were present in the classroom even when the authors' approach was restricted to the latter. Interest in the class, appreciation for knowledge, collaboration with colleagues, self-assessment, changing ideas in the face of new facts, associations with private and/or social life, production of cultural material, among other postures, were noted in these reports, but were ignored by the authors in their evaluation of the results.

The mentioned observation reflects that it is not possible to isolate a single SL domain in a didactic approach because they are connected, they are all part of the same block that is the scientific culture. Nevertheless, it is indicated that the emergence of each domain may or may not be directed and captured by researchers to the extent that it is in their interest, as well as to the extent that they use tools to collect and analyze their indicators. Works that do not consider the Value of Science and Affective/Attitudinal domains tend not to collect data referring to them, even if their elements have figured in the intervention carried out.

Regarding the methods of collecting the indicators, they vary according to the domain that is intended to be observed (Table 2).

This variation in collection methods may reflect the differences between the nature of indicators in each domain, with some being more conceptual, others ideological, others affective, which requires different methods of approach. Thus, works that target the various SL domains must structure a methodology that involves appropriate tools for each of them.

Multiple-choice questions and recording of oral productions (discursive interactions, explanations, justifications) stand out when looking for indicators of the Conceptual and Scientific Work domains, while the preference falls on the Likert-type questionnaire when looking for indicators of the Affective/Attitudinal and Value of Science domains.

	Conceptual	Scientific Work	Value of Science	Science and Society	Affective/ Attitudinal
Multiple choice	7	8	1	5	*
Text production	4	3	*	1	*
Open questions	3	3	*	3	*
Semi structured interview	1	1	*	*	*
Oral production	7	8	2	1	2
Likert-type questionnaire	2	4	5	4	7
Participant observation	2	2	*	*	1

Table 2: Methods for collecting indicators in relation to Scientific Literacy domains.

For multiple-choice and open questions, in general, the authors adapted standardized models such as the Test of Basic Scientific Literacy questionnaire (Laugksch and Spargo, 1996) and the Program for International Student Assessment – PISA (OECD, 2006). The Likert-type questionnaires, in general, were designed by the authors themselves, such as the Global Scientific Literacy Questionnaire (GSLQ) (Mun et al., 2015), the 3C (Competency, Cooperation, & Confidence) scientific literacy questionnaire (Chen and Liu, 2018), the Attitudes Towards Science Scale (Araujo, Morais and Paiva, 2021) and the Scientific Literacy Assessment - motivation and beliefs (SLA-MB) (Fives et al., 2014).

For textual and oral productions, interviews and participant observation, the data were compared to predefined matrices at the authors' discretion, as well as submitted to qualitative examinations through Content Analysis, Discursive Textual Analysis or Discourse Analysis.

Applied scientific literacy and the affective/Attitudinal domain

The meaning of SL that we have been exploring so far is strongly related to sociocultural issues. We agree with the idea that all students should benefit from science education, not just those who wish to pursue a career in science or technology (Vieira and Tenreiro-Vieira, 2014). The scientific literacy of a group is not intended to train future scientists, but citizens who understand the relationships between science and the economic, political, ecological, and cultural aspects of life in society (Allchin, 2020). Scientific literacy represents a part of scientific culture, thus it is part of the capital that gives meaning and guidance to scientific knowledge (Cachapuz, 2016). It should be noted that the SL is not limited to the Conceptual and Scientific Work domains, it is also linked to the Value of Science, Science and Society and Affective/Attitudinal domains, which give it meaning in the context of science education and citizen training.

The purpose of scientific literacy passes through all SL domains so that citizens are able to take action in the face of the challenges of our time, marked by anthropogenic climate change, deep social inequality and mass extinction of biodiversity. However, as described, there is a preference for the use of indicators from domains linked to elements of scientific production and a neglect of those that refer to culture and citizenship. This result shows that it remains a content trend of science teaching and learning (Teixeira, 2003), even though the approaches are far from traditional teaching.

Among the sociocultural indicators, those in the Affective/Attitudinal domain stand out for comprising the indicators that best relate to the practical results of science teaching and learning in the subject's posture, whether in private life or in the community. They indicate whether scientific knowledge is being applied outside the school context, because the elements that function as indicators of this domain are linked to the subject's reading of the world (Shen, 1975), thus revealing their ideologies.

According to Drummond and Fischhoff (2017), in the US, political ideologies polarize with science the public view of the anthropogenic cause of climate change. While political and religious ideologies polarize with science in relation to topics such as the Big Bang, Human Evolution and Stem Cells. As examples of the social impact of these ideological polarizations, a person may understand the biological process behind how vaccines work, yet still refuse to be vaccinated due to an ideological affiliation contrary to science. They can understand climate change and consciously consume goods whose production chain is aggressive to the environment, due to the ideologies they carry behind their consumerism. They can understand the mechanisms of human evolution and continue to see themselves as superior to other groups due to their race or privileged social class. In these cases, scientific literacy does not fulfill its social role, remaining only on a theoretical level, without any practical impact.

It is determined that there are intrinsic relationships between attitude, culture and ideology. Attitude is action, an interference in the environment that reflects back on the subject himself. Culture is generated within this dialog between the subject and his environment, through action, and it is the product of human work on the world (Rios, 2011). Finally, actions are not random, but driven by beliefs and values. The way the subject interprets the environment determines his actions and this interpretation passes through the filter of ideologies. In this way, ideologies shape actions on the environment, generating as a product cultural aspects that end up materializing ideologies. According to Althusser (1985), ideology materializes in the actions that are carried out by subjects under its influence and in the context of a given social practice. Therefore, in addition to understanding scientific knowledge, its nature and recognizing its impacts on society, the SL also implies that the subject apprehends elements of scientific philosophy in the set of its ideological influences, as a requirement for the realization of scientific culture in practical life, civic and sociocultural, since that is its objective.

A close look at the repertoire of indicators in the affective/attitudinal domain reveals that most are focused on individual skills and not on attitudes of responsibility with a collective bias. A large part indicates the subject's interest and views on science and on their own scientific capabilities, such as self-management and evaluation. Ritchie, Tomas and Tones (2010) refer to scientific self-efficacy as a subject's belief in their own ability to perform actions necessary to produce certain achievements.

The focus solely on the subject's individual abilities may not meet the main objective of the SL, which is the collective reaction to the problems of our time, but only direct the subject's ability to adapt to the scientific and technological labor market and the global consumption chain. When we think about the central objective of the SL, which concerns a change in political, social and ecological behavior, taking into account scientific knowledge, we believe that the validity of these affective/attitudinal indicators is correlated to the effective implementation of the SL in an applied sense, in actions driven by the scientific knowledge and philosophy, generating and disseminating scientific culture.

Aware that only a small part of the indicators of the Affective/Attitudinal domain turn to the behavior and social vision of the subjects, we aim for future research to investigate possible interactions between the ideological baggage, the apprehension of the scientific culture and its attitudinal response to confront situations linked to the global humanitarian challenges of the 21st century.

Conclusions

We started this article by asking how the cultural and ideological face of the SL has been treated in the categorizations proposed for the term, in the pedagogical approaches carried out in the context of science teaching and what are its indicators. We verified that the cultural, affective and attitudinal elements of scientific knowledge are considered by several authors as an important part of the SL, constituting what we call here the affective/attitudinal domain. We also verified that there are already indicators and methods of approaching these elements in the literature. However, they are a minority in the pedagogical interventions proposed for basic education.

We observed that the SL proposals in basic education can depart from the critical character present in their theoretical conceptualization, when the emphasis of intervention is given to the elements of scientific production to the detriment of socio-cultural elements.

Nonetheless, even indicators of the affective/attitudinal domain may reflect a liberal ideology in science teaching, if they only reflect individual skills in the subject's daily practice. We suggest that, due to the relationship between attitude, culture and ideologies, indicators that reflect the latter can contribute to the evaluation of scientific literacy, in the context of the subjects' practical and daily life. Thus, it is recommended that when planning an approach to SL, teachers and researchers are clear about the following questions: what is the objective of scientifically literate a specific public and for whose benefit; which SL domains are targeted; which indicators will be used and how they will be collected. This clarity is essential for a good pedagogical structuring of the approach, for the harmony of the work with the final objectives and with the very visions of education, science and society adopted by the authors.

References

Allchin, D. (2020). From nature of science to social justice: The political power of epistemic lessons. In H. A. Yacoubian and L. Hansson (Eds.), *Nature of science for social justice* (pp. 1-21). Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-47260-3_2

Althusser, L. (1985). *Aparelhos ideológicos de Estado: nota sobre os aparelhos ideológicos de Estado*. Rio de Janeiro: Edições Graal.

Araújo, J. L., Morais, C. and Paiva, J. C. (2021). Students' Attitudes towards Science: The Contribution of a Citizen Science Project for Monitoring Coastal Water Quality and (Micro) Plastics. *Journal of Baltic Science Education, 20*(6), 881-893. DOI: https://doi.org/10.33225/jbse/21.20.881

Cachapuz, A. F. (2016). Cultura científica e defesa da cidadania. *Revista de Educación, 35*(1), 3-12. Retrieved from: https://dehesa.unex.es/handle/10662/6826

Chen, S. Y. and Liu, S. Y. (2018). Reinforcement of scientific literacy through effective argumentation on an energy-related environmental issue. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(12), 1625. DOI: https://doi.org/10.29333/ejmste/95171

Choi, K., Lee, H., Shin, N., Kim, S.W. and Krajcik, J. (2011). Re-conceptualization of scientific literacy in South Korea for the 21st century. *Journal of research in science teaching, 48*(6), 670-697. DOI: https://doi.org/10.1002/tea.20424

Conforto, E. C., Amaral, D. C. and Silva, S. L. (2011). Roteiro para revisão bibliográfica sistemática: aplicação no desenvolvimento de produtos e gerenciamento de projetos. Presented in *8º Congresso Brasileiro de Gestão de Desenvolvimento de Produto*. CBGDP: Porto Alegre. Retrieved from: https://scholar.google.com/scholar?cluster=5359791953328325829&hl=en&as_sdt=0,5

Drummond, C. and Fischhoff, B. (2017). Individuals with greater science literacy and education have more polarized beliefs on controversial science topics. *Proceedings of the National Academy of Sciences, 114*,(36), 9587-9592. DOI: https://doi.org/10.1073/pnas.1704882114

Fives, H., Huebner, W., Birnbaum, A. S. and Nicolich, M. (2014). Developing a measure of scientific literacy for middle school students. *Science Education, 98*(4), 549-580. DOI: https://doi.org/10.1002/sce.21115

Hansson, L. and Yacoubian, H. A. (2020). Nature of Science for Social Justice: Why, What and How? In H. A. Yacoubian and L. Hansson (Eds.), *Nature of science for social justice* (pp. 1-21). Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-47260-3_1

Laugksch, R. C. and Spargo, P. E. (1996). Construction of a paper-and-pencil test of basic scientific literacy based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science, 5*(4), 331. DOI: 10.1088/0963-6625/5/4/003

Lee, H., Yoo, J., Choi, K., Kim, S.W., Krajcik, J., Herman, B.C. and Zeidler, D.L.. (2013). Socioscientific issues as a vehicle for promoting character and values for global citizens. *International Journal of Science Education, 35*(12), 2079-2113. DOI: https://doi.org/10.1080/09500693.2012.749546

Libâneo, J. C. (2005). As teorias pedagógicas modernas revisitadas pelo debate contemporâneo na educação. In J. C. Libâneo and A. Santos (Eds), *Educação na era do conhecimento em rede e transdisciplinaridade* (pp.19-62). Campinas: Alínea.

Libâneo, J. C. (2006). *Democratização da escola pública: a pedagogia crítico-social dos conteúdos*. São Paulo: Loyola.

Moraes, R. (2003). Uma tempestade de luz: a compreensão possibilitada pela análise textual discursiva. *Ciência & Educação, 9*(2), 191-211. DOI: https://doi.org/10.1590/S1516-73132003000200004

Mun, K., Shin, N., Lee, H., Kim, S.W., Choi, K., Choi, S.Y. and Krajcik, J.S. (2015). Korean secondary students' perception of scientific literacy as global citizens: Using global scientific literacy questionnaire. *International Journal of Science Education, 37*(11), 1739-1766. DOI: https://doi.org/10.1080/09500693.2015.1045956

Norris, S. P. and Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science education, 87*(2), 224-240. DOI: https://doi.org/10.1002/sce.10066

OECD (Organization for Economic Co-operation and Development). (2006). *Assessing scientific, reading and mathematical literacy – A framework for PISA 2006*. Paris, France: Author. DOI: https://doi.org/https://doi.org/10.1787/9789264026407-en

Ricardo, E. C. (2003). A problematização e a contextualização no ensino das ciências: acerca das ideias de Paulo Freire e Gérard Fourez. Presented in *IV encontro nacional de pesquisa em educação em ciências*. Bauru: ABRAPEC. Retrieved from: https://scholar.google.com/scholar?cluster=3168219158730092114&hl=en&as_sdt=0,5

Ritchie, S. M., Tomas, L. and Tones, M. (2011). Writing stories to enhance scientific literacy. *International Journal of Science Education, 33*(5), 685-707. DOI: https://doi.org/10.1080/09500691003728039

Rios, T. A. (2011). *Ética e competência*. São Paulo: Cortez.

Rodrigues, V. A. B. and de Quadros, A. L. (2020). O ensino de ciências a partir de temas com relevância social contribui para o desenvolvimento do letramento científico dos estudantes? *Revista Electrónica de Enseñanza de las Ciencias, v. 19*(1), 1-25. Retrieved from: http://revistas.educacioneditora.net/index.php/REEC/article/view/437

Roth, W. M. and Lee, S. (2004). Science education as/for participation in the community. *Science education, 88*(2), 263-291. DOI: https://doi.org/10.1002/sce.10113

Santos, W. L. P. (2009). Scientific literacy: A Freirean perspective as a radical view of humanistic science education. *Science Education, 93*(2), 361-382. DOI: https://doi.org/10.1002/sce.20301

Saviani, D. (2017). Fundamentos filosóficos e pedagógicos das Metodologias de Ensino. *Série Acadêmica, 35,* 7-19. Retrieved from: https://periodicos.puc-campinas.edu.br/serieacademica/article/view/5702

Saviani, D. (2018). *Escola e democracia*. Campinas: Autores associados.

Shen, B. S. (1975). Science literacy and the public understanding of science. In *Communication of scientific information* (pp. 44-52). Karger Publishers. Retrieved from: https://www.karger.com/Article/Abstract/398072

Teixeira, P. M. M. (2003). Educação científica e movimento CTS no quadro das tendências pedagógicas no Brasil. *Revista Brasileira de Pesquisa em Educação em Ciências, 3*(1), 88-102. Retrieved from: https://periodicos.ufmg.br/index.php/rbpec/article/view/4114

Vieira, R. M. and Tenreiro-vieira, C. (2014). Fostering scientific literacy and critical thinking in elementary science education. *International Journal of science and mathematics education, 14*(4), 659-680. Retrieved from: https://link.springer.com/article/10.1007/s10763-014-9605-2