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education sciences

Article

Reconceptualizing Scientific Literacy: The Role of Students' Epistemological Profiles

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Abstract: In this theoretical article we construct an argument for a pedagogical perspective based on the notion of epistemological profiles for scientific literacy for primary and secondary education. Concurrently, we offer a discussion of the implications of this proposal to the preparation of teachers and the development of their pedagogical skills. Underlining cultural practices in the construction, communication and validation of knowledge—called epistemic practices which are informed by an ideological perspective on science, are implied in the notion of epistemological profiles in the context of science teaching, particularly physics. Using the concept of *mass* in the context of science education, we discuss how different ideological perspectives on science reflect distinct aspects of reality. Thus, in this paper we propose an 'order' and 'direction' to scientific literacy and education in science, emphasizing the construction of a clear empirical perspective for primary school and a rationalistic ideological perspective for secondary school. We complement our argument with resources from activity theory and discourse studies, alongside a discussion of issues and challenges. In concluding this paper, we point out that such proposal requires a change in the classroom teaching culture.

Keywords: science education; epistemological profile; ideological perspective on science; model for learning; philosophy models; culture; activity theory; discourse

1. Introduction

The field of science education acknowledges the importance of scientific literacy for effective citizenship and conscious actions in today's world [1–3]. The concept of scientific literacy was first introduced by Hurd [4] in 1958 and has been used in the literature for more than 50 years [5]. According to Hurd [4] science and technology are the most prominent characteristics of the modern world, which suggests that scientific literacy is a requirement for contemporary citizenship.

While a goal for education in science, scientific literacy is still a polysemous term, as its definitions do not necessarily converge. Also, the methods on how scientific literacy can be acquired still lack convergence, as we can see from inspections of the situation of many countries that use the term in their official documents, but in practice such a literacy is still not a reality in these cases. In paper we raise the following question: *is there no consensus about what scientific literacy is or how it can be achieved* [2,6]?

As Roberts [7] argued, there is no scientific literacy (SL) if students do not know any subject content:

> "there is no consensus about the meaning, or even the parts, of SL—with one exception: everyone agrees that students can't be scientifically literate if they don't know any subject matter. The literature contains many expressions of frustrations about the implications of the lack of consensus for research and practice" [7] (p. 13).

In his review of SL, DeBoer [8] expresses the following:

> "instead of defining SL in terms of specifically prescribed learning outcomes, SL should be conceptualized broadly enough for local school districts and individual classroom teachers to pursue the goals that are most suitable for their particular situations" [8] (p. 582).

McEneaney [9] argues that there is no consensus in defining the specifics of SL. She describes it as a "worldwide catcher" in terms of a "scientific literacy approach" that, in her view, enjoys worldwide attention as a science education goal. In her analysis she provides examples from curricular statements, textbooks, and assessments materials in a variety of countries.

Despite such issues in defining SL and how to acquire it, the National Science Educational Standards [10] consider scientific literacy necessary for all students. In this case, it is related to equity and excellence, so science in schools must be available to all students, regardless age, sex, cultural background, and so on. Also, The Standards defines levels of understanding and abilities that all should develop.

According to The Standards: "Excellence in science education embodies the ideal that all students can achieve understanding of science if they are given the opportunities. Students will achieve the outcomes at different rates, some sooner than others. But all should have opportunities in the form of multiple experiences over several years to develop the understanding associated with the Standards." Our point of interest is the problem of the time-scale and its implications for life in society. If all students should acquire such competences, they inevitably will acquire at different times along life, which makes the work of teachers even more difficult. However, as studies have showed even teachers in many countries, including Brazil, are not scientific literate. Given this issue, the question then becomes one of, *how can we expect that students to be scientific literate if their teachers are not*?

Also, SL can be considered as the domain of methods and language of science. From this perspective, a student is SL if she/he is capable of serial, compare, contrast, deduce, induce, communicate, associate and interpret variables and so on. Of course, these procedures are part of the work of scientists, but they are not capable, alone, to assure if a person or a group of people are scientific literate, even because the definition for SL still weak in these cases, and lack of a structure that gives meaning to levels of SL, what, in our vision, needs to be more compatible with the reality of schools and the work of teachers.

In order to address this problem, it is necessary to ensure that teachers themselves are scientific literate and this is a problem in many countries in which teachers lack interesting in teaching due to low pay, bad teaching conditions, lack of students motivation and interest, among others [11–13]. Aligned with this problem, there is the definition problem: *what exactly does it mean to be scientific literate*? Such a question lead us again to the problem of demarcation, cleared posed by Roberts [7] and mentioned above. Furthermore, is SL possible in basic education or even in fundamental education?

Another trend in SL is the socio-scientific approach [14,15] and eco-reflective approach [16] which are used for framing the responsibility of individuals towards global sustainability. However, these approaches carry a strong sense of enforcement given that in order to critically debate, one needs to have a strong understanding of the scientific subject. Lee, Sohn & No [17] have shown that the socio-scientific debates still show that students awareness of contemporary world problems are weak and they are not pro-active in solving and discussing these problems.

In this paper, we argue that the socio-scientific approach provides a means for SL, but much work has to be done to integrate socio-scientific discussions in the curriculum. In this sense, we consider we need a model for scientific literacy that encompass such convergence areas at the same time avoid some of the mentioned problems.

Other issues related to this discussion are the logical operations students take when they are considered scientific literate [18,19]. The operations the authors describe are embodied in the daily interactions among people and in our vision they are not capable, alone, to distinguish if one is or is not SL, We consider that SL could be more than that in any given group or society. That is, SL encompasses it but in some sense it is much more than the domain of these operations (induction, deduction, analogy, causality, definition, consistency, and so on). As Piaget [20] proposed, humans pass for well-defined stages of development and this shall not be confused with SL, which, in turn, can take advantage of these stages to promote the literacy. Therefore, one would argue that an individual can "deduce" from naive realism, as well "deduce" from empiricist, and "deduce" from rationalistic perspectives and so on, and this makes the whole difference for the type of literacy we are proposing in this article and for life in society as a whole. We will explain such perspective in details further.

At this point, we briefly present a synthesis of the discussion: on the one hand, scientific literacy is a goal and a condition to be achieved. On the other hand, there is no consensus about the meaning of scientific literacy and how it can be achieved in the teaching of science (for contrasts see Holbrook & Rannikmae [21]). The incoherence is clear. It is important to have a theoretically based and established definition of literacy that incorporates the cultural practices of the students and, at the same time, the work of teachers.

It is important to note that we conceptualize culture as the historical process of accumulation and transmission of knowledge, meanings, values, rituals, expectations and norms, which are distributed in the systems of activities of a society [22]. We share the idea that culture began jointly with the emergence of discursive practices among humans, which enabled the construction and transmission to each new generation of the achievements of the previous ones. Furthermore, the culture is constantly changing given the urges of creation of new motives to constantly new human needs [23] emergent from the daily human-machine-environment interactions; science, by its turns, is the privileged form of knowledge to overcome the difficulties that arise from such rapid evolvement of technology-society-environment dimensions [24].

Building upon these theoretical perspectives, in this article we propose a theoretical alternative to the understanding of scientific literacy derived from the notion of *epistemological profile* proposed by Bachelard [25] and resources from *activity theory* [22,23,26] and *discourse studies* (sociolinguistics and textual linguistics).

2. The Notion of Epistemological Profile

Bachelard [25] proposes the notion of epistemological profile to conceptualize different forms individuals understand and deal with reality. The epistemological profile consists of "zones", called 'philosophies' and 'levels' by Bachelard. They range from the most common in the daily culture, like animism and naive realism, to empiricism, which is related to techniques of measurement with instruments, and rationalism, made of abstract models and concepts that impose an order of theoretical causality in the comprehension of reality. Each "zone" is epistemologically and ontologically characterized. Each 'zone' is different and a new zone cannot be achieved by adding knowledge but by ruptures, as Bachelard explains.

Bachelard uses as an example different ways of conceptualizing the definition of mass from his own epistemological profile. He proposes an auto-analysis of his profile for conceptualizing mass. Different "zones" interact, such as naive realism, empiricism, Newtonian rationalism, complete rationalism and discursive rationalism (dialectical). We will call these "zones" as "ideological perspectives on science" as we will explain further.

While our proposal does not encompass all "zones" available in the culture of basic education, we will comment all presented by Bachelard to clarify the notion of epistemological profile. Like Bachelard, we will use the concept of mass to exemplify his proposal. We will explain Bachelard's perspective and enrich it with perspectives from the field of education.

For the naive realism, mass is something large, with volume, something that becomes quantity if it is large enough. Most people work under this perspective when they think and talk about mass. This is the common sense that guides previous concepts of students, as documented in works on conceptual change [27–36]. The culture of daily life operates in the construction of such "zone". Cultural differences imply differences in the comprehension and usage of the same concept or idea. Despite the differences, this "zone" is characterized by immediatism in the construction of affirmations, visual appreciation, inconsistent usage of fragmented theories—non-systematic and locals—and an almost complete lack of generalization.

The next "zone" (ideological perspective on science according to our usage) in Bachelard's evolutionary line is the empiricism, characterized by certain measurement standards and techniques. Bachelard's evolutionary line coincides with the historical line of science, in which the "zones" posteriorly developed are located at the right of the epistemological profile, establishing a hierarchy of philosophies. The transition to this new zone of the profile overcomes epistemological obstacles from the previous zone, the naive realism. The transition presupposes the abandonment of the sensitive immediatism of naive realism and follows systematization and use of controlled techniques and methods of comparison, mediated by instruments that presuppose usage orientated by theories and ideas, even when those theories are unknown to the individuals operating them. Mass is understood here as something that can be measured and connected to an instrumental objectivity: mass can be compared to other mass using scales calibrated in a systematic standard. The prototypical image of this "zone" is the work of technicians making measurements according to certain standards and using available techniques to make such measurements even when technicians themselves do not know the theories that constitute, orientate and give meaning and purpose to the instruments and techniques.

The "zone" of rationalism derives from works in science that culminated with the first rationalist synthesis in science: Isaac Newton's classical mechanics. Individuals under rationalism use abstract models, rational and generals, to understand and explain the world. An example is the expression F=ma, which relates mass, force and acceleration in an abstract and rational way. Each variable is discriminatory, formal and general as they can be any mass, any acceleration and any force, regardless how the variables were measured or obtained. The knowledge of one variable is immediately deduced from the knowledge of the other two. Rationalism creates a formal and apodictic order of the world. The variables are understood and structured as a rational relation and only acquire full meaning in this relation. Synthesis and generality are characteristics of rationalism which is also aligned with knowledge of theories that give meaning to entities and exercises of the constant conceptual thought (action and thoughts mediated by concepts).

The founding of the constant $\pi = 3.14$, is another instance of how rationalism operates. In the case, 'π' (Pi) is the inclination of the straight line of a graph of the diameter vs. perimeter of a circumference, which is given by the tangent of the angle of both cathetus. As this constant number (Pi) was modeled to be achieved, it reveals the nature of rationalism, which is the usage of elements of nature and their relation through formal mathematics expressions, which imposes an order of causality and then provides previsions and more control to humans in the world. Thus, with rationalism, humans come to control more and more nature.

The next step in the hierarchical scale of the epistemological profile is the complete rationalism, in which mass is a complex function of velocity. The mass of a body can increase and decrease according to its speed. The notion of mass acquires an internal functional structure. This is the realm of relativistic mechanics, which inaugurated the complete rationalism. Einstein questioned: (1) the problem of non-invariance in Maxwell's equations of electromagnetism when submitted to Galileo's transformation, leading to the questioning of the principle of relativity; (2) the asymmetry in the explanation of electromagnetic phenomena when analyzed under different inertial references. Based on the knowledge available at the time, Einstein decided that the principle of relativity could be extended to electromagnetism, which turned out to be correct, and in this case the transformations of Galileo and Newtonian mechanics would not be correct in certain circumstances, requiring the modifications established by the theory of relativity. In this new perspective, light becomes constant and independent of the framework used to measure it, time and space are not absolute anymore, and the mass of a body becomes a complex function of velocity. It is important to observe that the theory of relativity derived from the clash between theories from the mechanics and electromagnetism, inaugurating the complete rationalism in the epistemological profile hierarchy.

Bachelard proposes a last philosophy or "zone": the discursive or dialectical rationalism. The status of this philosophy derives from the notions of dialectics and discourse, in which the object is not determined once and for all but it is instead constructed in the discursive and dialectical relations humankind creates and (re)creates continually, marking historical and ideological phases in the various levels discourse and counter-discourse operate.

Based on the knowledge he had at his time, Bachelard raises the possibility of asking: 'can mass be negative?'. The individual answers: 'why not?'. This is a dialectical step that looks for an entirely new concept, detached from common reality. Bachelard takes as an example Dirac's mechanics, in which the propagation determines what is propagated. Bachelard says about the concept of mass:

> Calculation yields up this notion to us along with the others, the magnetic and electric moments, the spins, respecting to the very end the fundamental syncretism which is so characteristic of complete rationalism. But now comes the surprise, now comes the discovery. At the end of the calculation, the notion of mass is delivered up to us strangely dialectized. One mass was all we needed. Calculation gives us two, two masses for a single object. One of these masses sums up perfectly everything that was known about mass in the four antecedent philosophies: naive realism, clear empiricism, Newtonian rationalism, full Einsteinian rationalism. But the other mass, the dialectic of the first, is a negative mass. That is a concept which cannot be assimilated at all in the four antecedent philosophies. (Bachelard [25], p. 29)

In this quotation, Bachelard [25] (p. 30) proposes that reality is preceded by "realization" (the equations and calculations). In his own words "Thus, realization takes precedence over reality. By so doing it demotes reality".

It is important to emphasize that each philosophy (according to Bachelard's usage) establishes itself in relation to underlying cultural practices. These cultural practices create possibilities that might reinforce or hinder the construction of the philosophy at stake. Discursive practices in the classroom should reflect different aspects of scientific culture, encompassing knowledge, procedures, attitudes, meta-knowledge and the scientists' discursive practices of construction and validation of knowledge, which are based on the dominant scientific paradigm, as mentioned by Kuhn [37]. We can say that each "zone" or philosophy in the epistemological profile is constituted by multiple paradigms, we just have to remember the case of rationalism, which encompasses the paradigms of classical mechanics and electromagnetism.

The knowledge of the philosophies of the epistemological profile related to sciences can inform and contribute to consistent discursive and practical changes in the work of teaching professionals. The new discursive practices and the classroom culture need to be aligned with a "zone" of the epistemological profile that will be centered on the construction and strengthening of the teacher's knowledge. The requirements for the formation of teaching professionals in this proposal are new but feasible. However, a dialogue between the tradition and the vanguard in the science education is vital to inform and move it forward.

Having presented the notion of epistemological profile, in the next section we offer a discussion of how this perspective provides an alternative for the understanding of scientific literacy.

3. Scientific Literacy and Epistemological Profile

As discussed earlier, scientific literacy can be understood as the strengthening and construction of new zones in the epistemological profile of individuals based on practices and knowledge of science.

Such practices are cultural. Therefore, it does not make sense to talk about an acting zone without relating it to the cultural and discursive practice that constructs and validates it.

The naive realism is both the result and component of practices kept between individuals in a certain culture. Those practices are always presented in the daily interactions between individuals sharing meanings when they act and talk. This is the zone in the epistemological profile that most people have in common and the education in science needs to take into consideration modes of acting and knowledge related to this zone of the epistemological profile. The naive realism mediates the type of knowledge students usually bring to science classes. Research on students' previous conceptions and conceptual change have documented the nature and operational mode of the naive realism in the conceptualization of acceleration, force, heat, optics, electrical circuits, chemical balance, among others [27–35] .Teachers are again central. They must be able to operate within the naive realism and aim at overcoming it. Teachers need to master at some level the language of their students and the implicit assumptions to be overcame by the construction of a scientific zone in the epistemological profile of their students.

It is neither desirable nor possible to eliminate this mode of producing and reproducing knowledge. Put in another way, it is not possible to eliminate the subtract of that zone in the epistemological profile, which are cultural practices uniting most people and allowing them to undertake daily discursive exchanges aimed at giving meaning to immediate and apparent experience, even though when they have no scientific basis.

Primary school students are curious but have not yet developed abstract thinking completely, which will be done in adolescence [20,38,39]. Individuals are born under certain biological circumstances and this is framed, as Vygotsky circle as shown, by the culture and speech of adults surrounding them. The main problem to be posed is: How to cross both perspectives to develop personalities akin to a better world and to themselves? Under this circumstance, this level of basic education can counteract naive realism brought by students to clear empiricism brought by teachers, in which students gradually come to realize, recognize and operate under control variables and the technique and domain of standard procedures. In such perspective, students compare, classify and put in order the empirical reality. The procedures are constructed and repeated. In turn, the measurement and comparison become more precise, and also become the axis of this practice, through which the students can explore the natural world, realizing empirical correlation between the entities and measures, recognizing patterns and elaborating a certain degree of the empirical reality. In this process, the material tools acquire a central importance. They allow the classification and identification of measures and relations, which in turn allows the measurement of those relations and contribute as means for the students actions.

In that level, it is clearly possible to use some rationalist concepts to explain the theoretical causality of certain phenomena measured and realized empirically. What is in question is the priority: in that level priority is given to the construction of the empiricism, making it, for the students, clear and distinct from naive realism. The construction of a new zone in the epistemological profile of the students would be a goal in the scientific literacy of primary students.

The establishment of correlations, the comparison, the measurement, the identification of empirical patterns and the technique are means of action of an individual that acts under the clear empiricism and should, therefore, be privileged in the practice of teaching science education at primary level. Natural sciences offer several modes to achieve that objective, from the use of control variables to the measurement and establishment of correlations, such as the relations between a shadow in relation to the position of bulkhead of the object and light source.

The construction of that also presupposes a discussion and teaching of questions related to science, technology, environment [2,3,40,41] as well as the exercise of argumentation as a scientific practice in the establishment of statements empirically and theoretically based, and in the effective citizenship in today's democratic societies [42–44]. The construction benefits from those perspectives and at the same re-signify a new epistemological order distinct and more advanced than naive realism.

In secondary school, physiological, psychological, social and cultural aspects and the students' ability to abstract evolve quickly [20,38,39], allowing the construction and strengthening of rationalism, which contributes to the structuration and consistency of the evolving abstract thought. At this level, causality, the laws, theories and meta-knowledge are privileged. They are based on the construction of models used to understand empirical relations established at primary school. It is not a collection of knowledge, but the construction of a new epistemological order in the action and thought, based on conceptual, abstract and theoretical parameters.

The construction of the rationalism supports the development of the students' cognitive abstraction, becoming a requirement for action, thought, speech and rationalization of the world, in which ideas are based on other ideas and concepts are defined in a structured and organized conceptual net. The teaching of Newtonian mechanics clearly supports the construction and development of rationalism, and can be taken as a prototype theory of it. Concepts are defined by the type of relation they have with other concepts. Understanding and operating according to such logic is radically different from operating with the logic of naive realism, in which the epistemological obstacles need to be overcome and understood, supporting the acquisition of a larger understanding of zones of the epistemological profile that influence the students' actions.

Questions related to science, technology, society, environment, discussions of socio-scientific issues and the use of argumentation in effective citizenship [2,3,10,40–48] are suggested at primary school. At secondary school, such approach can be re-signified and elaborated again taking into consideration the rationalism that is being constructed and strengthened.

From this perspective, students are faced with questions and problems that require modeling, construction and synthesis of concepts, and abstraction. They in turn are the means to discuss, problematize and use of argumentation, making arguments widen in scope and in meaning. Reciprocally, the questions and problems benefit from argumentation, which enlarge their scope, generality and consistency.

4. A New Proposal for Reconceptualizing Scientific Literacy

In our proposal, scientific literacy develops within the creation and strengthening of 'zones', what we will call for the sake of clarity, "ideological perspectives on science" in the epistemological profile of the students, which will in turn make it possible for them to act and think scientifically. This identification is no accident and for a clearer definition of what we are calling "ideological perspectives on science", we will discuss some of the resemblances of the Aristotelian philosophy and modern Science, in such a way that both are synthesis of reality, and how they differ from each other on the basis that sustain their "zones" (ideological perspectives), which in turn will lead us to discuss the notion of epistemological profile.

4.1. Aristotelian Philosophy and Modern Science: Their Main Differences and Implications for the Notion of Epistemological Profile

Modern science resembles Aristotelian philosophy in using models to explain phenomena. The difference between these ideological perspectives of knowledge chronologically separated relies on the bases which sustain their models. In the case of the Aristotelian philosophy, by basing its statements on observations, immediately sensations and immediate impressions; in modern science, the models are based in other models, in experiences and observations, which are mediated by instruments, available technology and by the particular scientific community. Thus, this is a clear difference of "ideological perspectives" among these two models to explain reality. Both sustain on the real and have had the authority and the right to claim about it. The main difference between them and common sense resides in the antinomy: synthesis and syncretism/fragmentation and unsystematic.

Common sense is based on immediate impressions, like Aristotelian philosophy, but, unlike it, the common sense does not provide a model and synthesis of reality. In few words, the common sense knowledge is noticeable unsystematic and disperse, although it serves to construct localized explanations which are incorporated in the discursive memory of a culture or micro-culture, constituting and reproducing the common sense.

The notion of epistemological profile proposed by Bachelard [25] is useful to this discussion, as it clarifies the "ideological perspectives on science" behind the zones of the epistemological profile of individuals. For instance, the epistemological profile of a professional physicist generally covers various zones, as is the case for Newtonian mechanics, the relativity and quantum mechanics, just to stay in examples from physics. The transition among the zones of the profile does not happen by continuity, but by the overcoming of the epistemological obstacles. Thus, between the common sense and the Sciences there are epistemological obstacles that are not overcome simply by experience or accumulation of more information and quotidian thoughts. Science Education is decisively one via for the overcoming and for the construction of scientific zones in the students' epistemological profiles.

The zones of the epistemological profile are representations of the different ideological perspectives on science of knowledge that influence the individual who acts. These ideological perspectives encompass cultural practices in the classroom in the construction and validation of the new ways to deal to knowledge of content and in relation to meta-knowledge, that is, knowledge about other forms of knowledge (for example, knowledge about the nature and history of science [49–53]). Additionally, as Carvalho [54] have suggested, it is also necessary to create conditions for the development of the students' conceptual, procedural and attitudinal dimensions and their understanding of Science, Technology, Society, Environment and socio-scientific issues [55–58].

The conceptual dimension is related to the learning of a given field; the procedural dimension has to do with doing well established operations (procedures) to accomplish a determined goal of an action. Finally, the attitudinal refers to the feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves [59]. In addition, of course, these three types of dimensions are interrelated since a type of attitude can evoke a set of procedural dimensions (operations), which in turn can affect the learning outcomes of a given subject.

Individuals need to be careful and sensitive to global issues, respect each other and take responsibility for their actions to solve current problems [40,60]. And this encompass the three related dimensions: attitudinal, procedural and subject matter (conceptual), what in turn, are (re)conceptualized in terms of the ideological perspective on science at stake of the epistemological profile of the interactors.

In our view, these outcomes would be difficult to achieve with individuals discussing under different ideological perspectives of the epistemological profile, because they will not enter in agreement since the basis that sustain their knowledge bases are epistemologically different. We consider the epistemological profile approach is a fruitful mean to join people together of different backgrounds in conversations with the same dominant ideological perspective on science, which enable them to have "fruitful debates", as instance, about socio-scientific issues in terms of SL with the support of the teacher, who mobilizes the perspectives underpinning the discussions.

4.2. Middle Point

The knowledge of the ideological perspectives of the epistemological profile related to sciences can inform and contribute to consistent discursive and practical changes in the work of teaching professionals. The new discursive practices and the classroom culture need to be aligned with a knowledge of such perspectives that will be centered on the construction and strengthening of the teacher's.

However, the question is how students and teachers can acquire such skills? It does not rests only on acquire competency in using one or another concept in typified assessment activities, but mainly of the student be able to act and operate according to determined ideological perspectives on science in problem-situations, and know how to evaluate the product of his/her actions in terms of the mobilized ideological perspective; in our case, we are interested in science—that is—the ideological perspectives on science.

From this perspective, the learning of sciences acquires a fundamental importance, since it presupposes the passage from common sense to new ideological perspectives—that of sciences (more general, theoretical and systematized than the common sense). In this passage (i.e., along the teaching and learning) the students move forward and backward between the ideological perspectives, mobilizing different concepts depending of the situational demands, including as a way to deal and understand the particular demands posed by teaching. Thus, the classrooms are privileged spaces to students gradually acquire resourcefulness with ideological perspectives distinct from the common sense, mainly the scientific ones. This, however, leads us to a demarcation problem: what is scientific?

The sciences have common assumptions, such the empirical nature, the rationality principle and the mediation of knowledge by models, instruments and theories. The methods, approaches and theories used, however, varies between the sciences and among fields of the same science, depending of the scientific community, the problems of study, the counter positions erased and active, of the accepted argumentations, of the available techniques and of the cultural-historical collection of its time. One central process for the individual to domain the paradigms, theories and methods of one determined scientific field is his/her acculturation in this field.

From this point of view, the gradually acculturation of the students in the epistemic practices in the classroom can bring them opportunities to collectively develop competency in talk, write, read and produce science [61]. One important step in this process is the understanding by the student that science is a privileged form to understand and possess knowledge of the world. In appropriating and producing science the student gradually acquire competence in talk and think under scientific perspectives. Regarding the epistemic practices, Sandoval [62] poses a clear definition on learning:

> [in the model of cognitive apprenticeship] learning science entails the appropriation of discipline-specific modes of discourse and action. These ways of talking, thinking, and acting include often tacit epistemological commitments, commitments to the kinds of questions worth asking, the kinds of answers worth having, and acceptable methods for making them. Developing an apprentice-oriented science pedagogy thus requires an epistemic focus, an effort to understand how knowledge is made within a discipline.

Our position is that learning science does not have to do only with "equip", but mostly in "empowering" intellectually the students with scientific resources of our era and history. The demand this conception of teaching and learning implies is urge, however, in Brazil there is a lack of teachers in their specific areas of teaching, more specifically in science. In the physics teaching, unfortunately this index is alarming. It is necessary to overcome the older problems of teacher education [63] and advance, in the teacher education and continue education, the modeling of the practices, what presupposes reflections and dialogue among universities, schools, government and community attended.

This perspective implies changes and investments in the teacher education programs. It is essential to inform the understanding of teachers about science and its value to the contemporary citizen. The visions of science of teachers and students needs to be questioned and widen, aiming to an approach that implies the introduction of the processes of science into the classroom, and the development of the conceptual, procedural and attitudinal skills of the students.

According to Kelly [61], discursive and ethnographic investigations of the epistemic practices of daily life in the classroom evince how science is "performed" moment-by-moment in these scenarios by students and teachers. Such an analytical approach studies how the epistemic practices of classrooms offer possibilities and constraints to what counts as science, who can participate and how science is accomplished among the members of the group.

Kelly [61] claims that the focus on epistemic practices situates the learning of science in social contexts and insert a new set of demands to research. The analysis should include the multiple actors, the modes how roles of the individuals are established, the norms and expectations, the mediators' artifacts and the local histories of sociocultural practices.

According to the author, the discursive investigations of the epistemic practices in the classroom benefit of more widen analysis, which include the school, the media, university, parents, and cultural practices of daily life of the students. The crossing of these perspectives informs the research and the practice and propitiates opportunities to more critically analysis by the part of researches, students and teachers.

The study of discourse is a strong theoretical and analytical perspective to deal with issues and demands of science education for democracy, well-being and consequent decision makings. Under this perceptive, we will discuss in the next sections the perspective of activity theory and cross this perspective with resources from the discourse studies and of the epistemological profile, and then discuss their contributions to inform and widen the problem developed until this point.

5. Activity Theory and Discourse Studies

Activity theory has its roots in soviet psychology in the beginning of the 20th century. Such a theory emerged from the shared works of Vygotsky, Luria and Leont'ev, and it was systematized and articulated by Alexei Leont'ev [23,26]. The historical, dialectical and material components of human development based on a Marxist ideology had a great influence in the formulation of activity theory. According to this perspective, cognition and human development are interrelated to practical activities, which provide structure and content to individuals' inner activities.

The development and continuity of the human activity systems succeeds at the light of processes of acculturation created by society, in which individuals appropriate of knowledge historically accumulated by previous generations [22]. This phenomenon implies mediation, the use of instruments (both material and ideal), rules, division of labor, situated identities and, evidently, discourse. These processes are constitutive of, and constituted by, the structure of human activity. In this structure, the level of action emerged with the division of labor among humans engaged in social activities. This is a conscious level and regards what must be done which not necessarily converge directly to the motive of the collective activity. We will explain this point of view.

According to Leont'ev [23,26] and validated by the academic community [22], any human activity can be analyzed by means of its structure in levels, each one representing an authentic and particular reality: Activity, action, and operation. Each level has its own characteristics and objects and will be discussed. We begin by the activity level.

5.1. Activity: Originated in a Need/Motive

Human activity has origins in a need, whether biological or cultural. The needs are the departure point to an activity beginning, but alone they cannot give them a start and orientation. It only happens when the need meets one determined object (ideal or material) that can satisfy it, and this object is called the motive of one's activity, Leont'ev call this process an "objectification of a need", which is the "filling" of a need with content of the objective world.

We highlight that the motive is the "motor" for the development of all actions that unfold from the activity. As instance, we have in school activities, extra-school activities and leisure activities distinct motives that characterize and determine these activities.

We recognize that teachers must be capable to manage different motives for their classes, considering the curriculum, the teaching planning, feedbacks from students and contextualized clues from previous classes. This is an alternative perspective for teachers' motives approach, which generally are imposed mostly exclusively by the didactic textbook, inflicting one unique motive to all of their classes—seek uncritically the didactic textbook and, as a consequence, the deflation of the teaching activity and its image upon society

The discourse, and its domain by the part of teachers can offer opportunities for them to consciously domain and manage their motives according to contextualized clues they are able to recognize and understand from their classes. The students, by their turn, and usually, are not initially conscious of the class' motive. They are, actually, conscious of the object of their actions, constructed and transferred gradually and discursively to them by their teachers, as we will explain next.

5.2. Action: Related to the Satisfaction of a Conscious Goal

With the advent of the division of labor, for one single activity the individuals may appeal to different processes, obtaining different and partial results; the articulation of these processes may result in a common product that may satisfy one individual's need or a group of individuals. Leont'ev calls "actions" these processes, which are related to the individual's representations of a product or result, that is, a conscious goal. Thus, each action is oriented to a previous or emergent goal. This perspective is evident in the classroom, since in these learning spaces the teacher's didactic intentionality cannot lost sight of; his/her intentionality manages the students' actions and manages the discursive rhythm that is oriented to the motive (or the "main teacher's goal") for that class.

Again, the discursive perspective is crucial for teachers understand the conscious goals that must pass by ideological formations and negotiations of group of teachers that gradually transfer this responsibility to their students, making them the objective of their actions, which are related to various discursive components, as is the case for the linguistic-structural components, among them the discursive orientations (e.g., Vieira, Kelly & Nascimento [64]; Vieira & Kelly [65], as for narrations, explanations, argumentations, descriptions, injunctions, and dialogues). Such discursive orientations are derived from the notion of "sequence" from studies on textual linguistics [66,67], and are dominant modes of language structuring that transcend the phrasal level of analysis. Each discursive orientation can allow or restrict the satisfaction of a determined didactic goal. Thus, is evident how the discursive-linguistic-structural and activity theory work together to inform the teaching practice in the classroom. As instance, narrations, explanations and injunctions can help the satisfaction of more authoritative goals, while argumentation and dialogues are related to more open-ended goals.

Besides its intentional aspect (what must be done or obtained), every action also presents an operational aspect (how and by which means the goal can be satisfied). This operational aspect is determined by the material and symbolic conditions available to the goal satisfaction. These considerations lead us to the level of operation, which will be the next point to be discussed.

5.3. Operation, Related to Conditions and Methods

As we mentioned before, any action develops according to certain objective conditions, which determine the methods for accomplishment of the action. Leont'ev calls "operations" these methods.

Operations are usually unconscious and are subordinated to the goal of the action they contribute to realize. An individual may form operations through conscious processes. With time, they begin to structure more complex chain of actions, losing their intentional aspect, which is no longer recognized by the individual, but keeping their operational aspect, which becomes automated in the form of an operation. To execute an operation the individual needs to know how to make it and this is the reason why an operation is generally automatic, that is, without the need of intentional effort to be realized.

Again, the discursive perspective allows us to understand how operations help to establish patterns at the action level by means of what we have called "Discursive Didactic Procedures", which are the means arising from the conjunction of the teacher's propositions with convergent meanings (propositions are the less units of meaning of discourse, as can be found in Vieira, Kelly & Nascimento [64]; and Vieira & Kelly [65]). The delimitation of propositions, taking into account the cultural or micro-cultural character of the classroom, are established by sociolinguistics criteria [68], such as pauses, intonation, eye gaze, etc., and verbs of change (run, jump, etc.) which often co-varies and mark changes in the content and direction of the established discourse. This evinces the historical-cultural nature of the discursive perspective informed by activity theory.

Activity theory places the human being as an agent in the historical-cultural processes of knowledge, ideology and work. It is in the advent of division of labor that arises the fundamental differentiation of animal and human activities: the level of action. That is, this difference is born in the concerted relations between humans.

In a few words, the division and articulation of actions and activity were historically elaborated with the advent of division of labor concomitantly with the use, production and accumulation of material and symbolic instruments. Such a division of labor was mediated by, and constitutive of, language in labor activities, what enabled the negotiation and establishment of meanings, reassembling then the emergence of the culture as a discursive practice and the human consciousness as the product of the appropriation of the systems of meanings cultural-historically constructed and construed by humans.

6. Implications for Science Education in School Science Activities

As an example on how such perspectives can improve science education, in school science activities the students have the opportunities to learn in discursive dynamics in which a concept or subject may be initially a motive of the shared activity, with coordinated actions that may not be necessarily directed to the definition of the concept or subject, but helping in circumscribe and contextualizing it, and, as a consequence, passing to the conscious action of the students in another activity, until arrive to the level of the operation, assuming then the status of condition or method for the realization of other actions, and, finally, turning again the motive of a new shared activity, at this time with a meta-reflexive motive. Such a meta-reflexive activity presupposes the reflection of the students regarding the fields and limits of applicability of the concept, whether a concept of common sense, fragmented and with little generality, whether a concept under the paradigm of Newtonian mechanics, more general, systematized and rational. Metacognition serves as an important component to people as they encounter various problems that relate to personal, societal, and global issues [69].

This dynamic of the concept or subject in transiting between the motivational, the intentional and the conditional is afforded by the engagement of the students in the discursive practices in the classroom mediated and managed by the teacher (for a discourse perspective in science classrooms see Kelly [70]). In turn, the students begin to domain concepts and their fields of application, beginning to construct zones of their epistemological profile related to science, as instance, domain the ideological perspective of classic mechanics. It is important to stress that in the passage of the common sense to the scientific ideological perspectives there are epistemological ruptures that the individuals need to be conscious.

Furthermore, the implicit assumptions, so common in discursive activity [66], initially operate "naturally", but with the advance of these activities the implicit assumptions come to turn to explicit, even because of the results of the ideological power of explanations that the epistemological profiles have to offer. Also, the interplay of discursive implicit-explicit [66] affords the emergence of various constructions and interpretations performed by the individuals who interact in the considered group [70]. The control of the teacher over these interpretations passes precisely by his/her knowledge of the psychology of humans (activity theory), of the discourse features that constitutes the school activities, and finally, of the ideological aspects that give meanings to the science constructed and construed in the classroom. It is in this last step the epistemological profile approach acquires a fundamental function, since it is recognizable a new instance for the comprehension of scientific concepts and meanings that the automatization of teaching darkens.

We consider that the provided theoretical perspectives can inform the consciousness of the teachers about the structural, discursive and epistemological components of their activities, and of their students'. Our point of view is that the relation and interpretation the individuals have of their discursive memories present a qualitative change when they pass to have the "lens" and consciousness of the structure of their activities and that of their peers. As we mentioned earlier, such a lens articulates the motivational, intentional and circumstantial spheres of human activity and its appropriation by the individual, along the appropriation of discursive and ideological perspectives resulted by the uses and application of discourse analysis and of the epistemological profile approach produce new effects of sense regarding their memories, constructed in and by the discursive interactions. These changes influence the way the individual sees the world, how sees him or herself and how actively lives and act in the world, what can collaborate or no to a (re)production of a model of society.

7. Scientific Literacy and Epistemological Profile

As evident in the discussion so far, scientific literacy can be understood as the construction and strengthening of new ideological perspectives in the epistemological profile of individuals based on practices and knowledge of science. Such practices are cultural. Therefore, it would not be wise to offer a discussion about an acting ideological perspective without relating it to the cultural and discursive practice that constructs and validates it.

The naive realism is both the result and component of daily practices kept between individuals in a certain culture. Those practices are always presented in the daily interactions between individuals sharing meanings when they act and talk. This is the ideological perspective that most of people have in common and the education in science needs to take into consideration the modes of acting and knowledge related to this zone of the epistemological profile. The naive realism mediates the type of knowledge students usually bring to science classes. Teachers are again central. They must be able to operate within the naive realism and aim at overcoming it. Teachers need to master at some level the language of their students and the implicit assumptions to be overcome by the construction of a scientific ideological perspective.

It is neither desirable nor possible to eliminate this mode of producing and reproducing knowledge. Put in another way, it is not possible to eliminate the subtract of naive realism, which are cultural practices uniting most of people and allowing them to take daily discursive exchanges that give meaning to immediate and apparent experience, even though when they have no scientific basis.

Primary school students are curious but have not yet developed abstract thinking completely, which will be done in adolescence [20]. Under this circumstance, this level of education can counteract naive realism brought by students to clear empiricism, in which students gradually come to realize, recognize and operate under control variables and the technique and domain of standard procedures, thus acquiring familiarity with the natural world. In such perspective, students compare, classify and put in order the empirical reality. The procedures are constructed and repeated. In turn, the measurement and comparison become more precise, and also become the axis of this practice, through which the students can explore the natural world, realizing empirical correlations, recognizing patterns and elaborating a certain degree of the empirical reality. In this process, the material tools acquire a central importance. They allow the classification and identification of relations, which in turn allows the measurement of those relations and contribute as means for the students' actions.

In that level, it is clearly possible to use some rationalist concepts to explain the theoretical causality of certain phenomena measured and realized empirically. What is in question is the priority: in that level priority is given to the construction of the empiricist ideological perspective, making it, for the students, clear and distinct from naive realism. The construction of a new ideological perspective on science in the epistemological profile of the students would be a goal for the scientific literacy of primary students. Their control of the knowledge, procedures, attitudes and meta-knowledge related to this new ideological perspective, once added, orientates and restructure all these processes of knowledge in the action and operation in course.

The establishment of correlations, the comparison, the measurement, the pattern and the technique are means of action of an individual that acts under the ideological perspective of clear empiricism and should, therefore, be privileged in the practice of teaching science education at primary level. Natural sciences offer several modes to achieve that objective.

The construction of that ideological perspective also presupposes a discussion and teaching of questions related to science, technology, environment [1,10,45,46,71]. As well as the exercise of argumentation as a scientific practice in the establishment of statements empirically and theoretically based, and in the effective citizenship in today's democratic societies [43,44]. The construction of an empiricist ideological perspective benefits from those perspectives and at the same time re-signify a new epistemological order distinct and more advanced than naive realism.

In secondary school, physiological, psychological, social and cultural aspects and the students' ability to abstract evolve quickly [1,10,20,39,45,46,71] allowing the construction and strengthening of the rationalistic ideological perspective, which contributes to the structuration and consistency of the evolving abstract thought. At this level, causality, the laws, theories and meta-knowledge are privileged. They are based on the construction of models used to understand empirical relations established at primary school. It is not a collection of knowledge, but the construction of a new epistemological order in the action and thought, based on conceptual, abstract and theoretical parameters. At this stage the concepts are part of a net that weaves the web of a system, a conceptual system that can integrate and explain phenomena from different orders, making this ideological perspective highly general.

The construction of the rationalistic ideological perspective supports the development of the students' abstraction, becoming a requirement for action, thought, speech and rationalization of the world, in which ideas are based on other ideas and concepts are defined in a structured and organized epistemological net. In physics education, the teaching of Newtonian mechanics clearly supports the construction and development of this perspective, and can be taken as a prototype theory of the rationalistic ideological perspective on science.

8. Discussion and Final Remarks

Several reform documents report that students need to learn the practices and processes of science, including the understanding of the role of argumentation in the accomplishment of science [1,10,45,46,71,72]. Students are asked to engage in more active activities and investigations open to rational discussions, including the consideration and debate of socio-scientific issues and the learning about nature and history of science. There is a clear tendency in contemporary science education in promoting the learning of "science as argument" [73–75]. However, science teachers and future teachers still lack specific orientations about the new recommendations for the teaching of sciences. According to Duschl & Osborne [76] (p. 1), "An examination of recent policy reports [...] strongly suggest that classroom and school environments and teaching practices, for all intents and purposes, remain essentially unchanged during this 50 year period".

The problem of the preparation of teachers for science education in the 21st Century becomes even more complex in light of the theoretical perspectives recommended in this article. The point that we bring forward is: students should engage in argument, but argumentation should follow a set of paradigms in an epistemological and conceptual evolution, in which elaborating ideological perspectives on science support the improvement of discussion of fundamental and diverse issues, including socio-scientific ones [2,3,16,41,43].

Thus, this article proposes a perspective for scientific literacy based on epistemological profile that privileges the construction of the clear empiricism in the teaching of primary school and rationalism in secondary school. The proposal establishes a re-conceptualization of scientific literacy that provides means for ideological science paradigms evolving into a human being, at a certain moment and under certain conditions. The demand for ideological perspectives on science is given by the development of individuals in the activity systems of society, such as the complete rationalism (for those studying physics at university) or the strengthening and enlargement of ideological perspectives previously established, like the clear empiricism (for whose studying chemistry in a technical course, for example).

According to Wickman & Ostman [77] (p. 1):

> Research in science teaching is currently dominated by constructivism. This school of thought rests on the legacy of Piaget, and learning is seen a change of cognitive structures that interacts with the environment [78]. The central aim of this research has been to describe people's ideas about different concepts and phenomena and to explain "conceptual change" [79,80]. Originally it had an epistemological stance, where people's naive ideas about nature were compared with scientific theories or paradigms. [29,34]

In our proposal, we have not eliminated such a research trend, but instead it was integrated into a larger scope framework, in which the teachers consider and identify the ideological perspectives on science that the students have and show their inconsistency. By doing so, the students gradually, through adequate discursive practices in the classroom and other spaces of learning, construct and strengthen a new ideological perspective on science. It does not mean the students will abandon the previous one, as they will have a new option to understand and deal with reality. The consciousness individuals have of their profiles and their consciousness of contemporary questions and problems of their societies under a determined ideological perspective on science are other aspects privileged by teachers and need more clarification.

Such consciousness depends on the ideological perspective under which the reality is understood and reflected. Rationalism's understanding of reality or of a phenomenon is quite distinct from the naive realism. In this sense, as Lundqvist, Almvist & Östman [81] argued, a question is raised: "How often do we as teachers or students act as a direct result of an epistemological belief in a philosophical sense?" The differences have implications for life in society and effective citizenship aimed at the well-being of the individual and society at large. It also encompasses mutual respect and a deeper consciousness and engagement in the physical and social reality that constitutes the "subtract" of activities and personalities of human beings.

Several questions regarding the difficulty to implement our proposal may arise. For example, we can immediately recognize the distance between the satisfaction of the proposal and the reality of science teaching, in which students finish secondary school without knowing basic scientific concepts. They also have reading and writing challenges and do not present even a minimum empiricist zone in their epistemological profile. Unfortunately, this is the reality of most schools in which students finish basic education almost totally under the domain of the naive realism, not having, therefore, an informed and deep understanding of fundamentals questions about contemporary issues. Such perspective unfortunately worsens what is already bad in the world and is reflected in the official documents of many countries, which aim to reverse this situation in the schools by means of a new science education approach [1,10,23,45,46,71,72].

Despite the difficulties, the proposal is justified by the suggestion of a "perspective" and, in a certain way, "a goal" for scientific literacy. The goal is still far from being full-filled but this does not eliminate its value as a goal and its contribution to the process of reformulation of science education where such reformulations are needed. Such a goal requires changes in today's culture in science classrooms and in the activity of the teachers. A better understanding of the structure and discourse of the students' activities and the structure of scientific ideological perspectives can inform the dialogue between researchers and teachers. Such a dialogue could provide new means for allowing discursive practices and the ideological perspectives on science to be constructed and strengthened in the classroom more coherent and consistent. Framed within these theoretical constructs, this article proposes a re-conceptualization of scientific literacy by placing at the heart of its account students' epistemological profiles.

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