Natural and Material Environments: Towards a Culture of Science Education

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The rapid changes in society that have accelerated over the past half-century have resulted in an upheaval in contemporary socio-cultural realities. The natural and material environments are becoming central issues where the new knowledge production regime of technoscience is linked more than ever before to the cultural, economic and political aspects of life in society. In this text, we will show how the breakthrough of this new regime has influenced scientific practices, which in turn influence the treatment of scientific issues in schools.

Keywords: natural physical and technical environments, knowledge production regime, techno-science, sociality of science, epistemological exceptionalism, science education

INTRODUCTION

Natural and material environments are at the level of learning in various curricula where human action is decisive. These environments are the basis of a culture for every citizen aware of the role of science and technology in building our material, intellectual and cultural environment (Albe and Orange, 2010; Orange Ravachol, 2018; Kalali, 2017b). The idea is to enable learners to construct a vision of the world that enables them to grasp current issues and the challenges facing contemporary society (Bader, 2004; Legardez and Simonneaux; 2006; Fabre, 2011; Kalali, 2017a). It is also about establishing a "space for negotiation" between the order of things taught and the "experiential" order of things (Larochelle, 2003). Putting this "unthinkable" into practice, according to the author, involves a hybridization of the world of scientists and the world of students, the latter often being declared invalid whereas students are often right to think what they think. Scientists' science and school science are again raising the questions of reference, content and activities, expertise, and citizen science education (Albe and Orange, 2010).

Appropriating the natural, physical and technical world, constructing a coherent representation of it, an evolving relationship is part of the school's mission (Legardez and Simonneaux, 2006; Martinand, 2000), and beyond the social project (Lange and Martinand, 2010) or the socio-political project that underpins our actions (Fourez, 1992). Nevertheless, according to some authors, the problem today is the lack of a culture and a worldview sufficiently shared by all the social actors involved (Hulin, 1987, 1992; Van der Leeuw (2016).

When curriculum unfolds the learning of these environments, it is in terms of domains to underline the globalizing aspect of a scientific and cultural education. This is the STEM domain (Science, Technology, Engineering, and Mathematics) in the Anglo-Saxon curriculum. In the French curriculum, the discovery of living, matter, and objects is taught from elementary school onwards. The reforms of “socle commun” (2013; 2015) define a domain of competences that is specific to it. This is competence domain 4, "natural systems and technical systems", which targets scientific, technological and mathematical learning by defining specific approaches to scientific investigation.

The Organisation for Economic Co-operation and Development (OECD) is not to be outdone. Through its surveys assessing the learning needs of citizens in the 21st century, it targets these same areas of science and mathematics to which it adds language learning. While the reasons put forward for their promotion are economic and the training of future workers, the cultural and social argument receives the same attention. As far as science education is concerned, the aim is to share with citizens the elements of the Western rationality of social and cultural interactions based on the language of science (Van der Leew, 2016). According to the author, this universalist language has made it possible to establish a conception of the world whose material benefits are undeniable.

Nevertheless, the irruption of risk issues in the public space and the influence of globalization soon showed the limits in the treatment of scientific issues, when they became social issues in the public space (Bonneuil, 2004, pp. 25-28). More than ever before, school science, with its aim of educating citizens, integrates controversial issues but is unable to offer an adequate treatment of them.

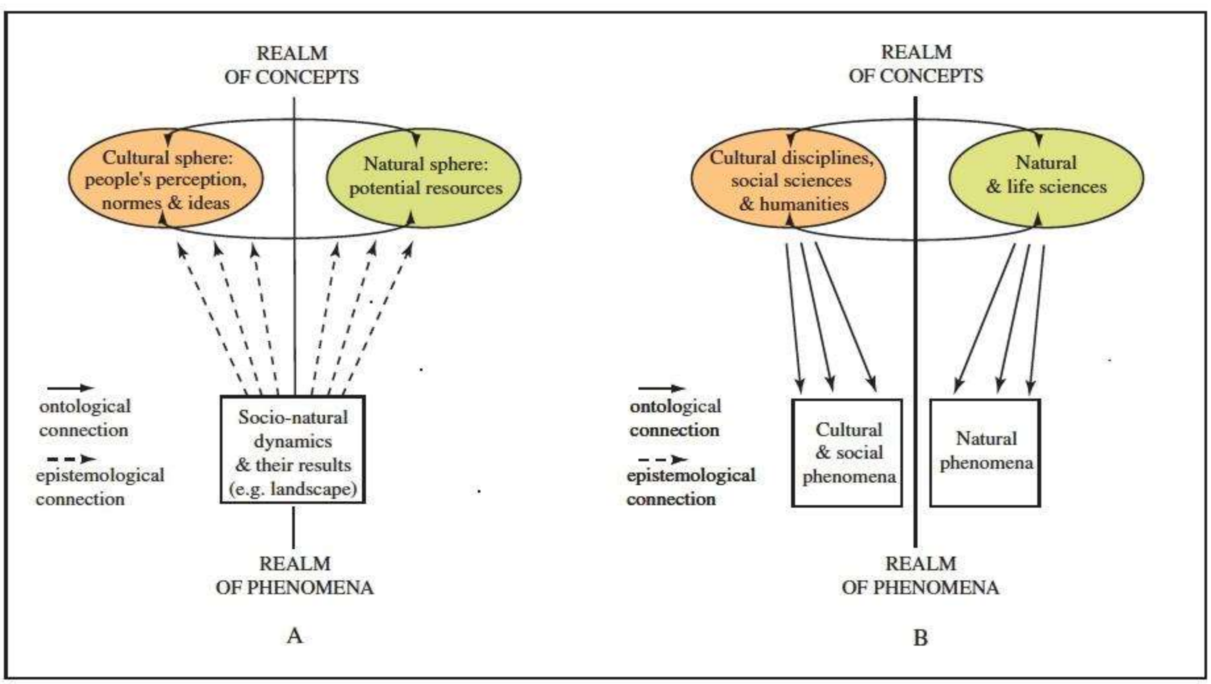
First of all, we will come back to the origins of some relationships to science, to show the evolution of research practices and types of labs. Then we will question the knowledge production regime of technoscience, the result of the pressure of changes in contemporary society, in order to discuss some issues related to contemporary scientific education. We will end with some reflections on what a culture of science education would be. For it is here that the decisive issue of our contemporary society lies.

The Origins of Some Relationships to Science

In the quest for a mapping of scientists' science and school science, we will examine studies of scientific practices in recent decades.

The history of scientific research practices and institutions provides clues and insights. The work of Van der Leeuw (2016) provides an example when he seeks to shed light on the changes that have occurred in the light of the emergence of disciplines.

FIGURE 1
LINKS BETWEEN CONCEPTS AND PHENOMENA



Source :Van der Leeuw, 2016

By examining the links between phenomena observed from a natural and physical environment and the concepts developed, the author considers that the emergence of disciplines has reversed the logic of science. Initially (Fig. 1, see on the left), the link between the domain of phenomena and that of concepts was an epistemological link, but when methods and techniques formed the basis of the disciplines, these links became ontological (Fig. 1, see on the right). Gradually, the acquired methods and techniques began to predominate in the choice of questions and challenges to investigate. This stimulated an increasingly narrow specialization, and led to difficulties in communication between disciplinary communities.

Diagram A thus shows a scientific practice open to phenomena of all kinds, exploiting questions without limits. The approach can be singular and without a systematic aim. According to the author, this scientific practice shows that the link between concepts and phenomena is an epistemological one: according to real-world observations, the phenomena studied were classified in various conceptual categories such as "social phenomena" or "natural phenomena". It is the observations that guide the work of analysis (Van der Leeuw, 2016, p. 163).

Figure B shows the emergence of disciplines and their institutionalization. The consequence, according to the author, is the specialization of scientists and their withdrawal from the public space, with a difficulty of communication between communities of disciplines. Each one limits its field of expertise to its field. Gradually, the acquired ideas determine the questions, phenomena and methods. It is then that theories, no longer observation, guide the process. It yields a worldview fragmented into disciplines and sectors.

We can nevertheless qualify the author's remarks. With the intrusiveness of the questions on risk that have shaken things up, the questions, or at least some of them, are being asked by society, which is expecting answers from scientists. The CNRS (French National Centre for Scientific Research), in its 2004 economic report, expresses its views on this issue[1]. The authors of the report speak of a moral contract between research that provides clear answers to the questions asked by society. The report emphasizes that the challenge lies in identifying the questions that science and scientists face. The social contract is to enable these issues to be debated with citizens. This new scientific communication (science in society) is a challenge for democratic societies and the "participation" of citizens is crucial through dialogue about important scientific issues that affect their lives and their future.

As a result, science, having become a source of innovation, acquires a value for the economic sector and becomes a criterion for justification in the political sphere and for the stakeholders in the decision-making and action processes. Van der Leeuw (2016) deplores society's disappointment in its expectations, whereas the main factor governing the role and perception of science is the public's trust in scientific institutions and the individuals who represent them (pp. 163-164).

In what follows, we will draw on some of studies. The challenge is to show that "knowledge is established because scientists have worked to stabilize it, to put it into circulation, to translate statements, to connect distinct worlds" (Albe and Orange, 2010, p. 21).

A New Regime of Knowledge Production

Many researchers have worked to identify and qualify the origins but also the transformations that have changed contemporary societies marked by complexity and uncertainty. The thesis of a radical change in the way science is carried out and knowledge is produced from which the profound changes affecting the institutions and practices of science are derived is shared by various authors (Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow, 1994; Nowotny, Scott and Gibbons, 2003; Pestre, 2003).

Science can no longer be considered as an autonomous space clearly distinct from other areas in the spheres of society, culture, and economy (pure science). The dominant viewpoint in the way these new relationships are viewed is that of society, in other words, the 'context' (Nowotny et al., 2003, pp. 14-17). This new mode of knowledge production is multidisciplinary, expands outside the strict framework of universities, around issues and operates in situations of uncertainty and urgency (Gibbons et al., 1994; Nowotny et al., 2003).

Nevertheless, according to Pestre (2003), the heterogeneity and interdependence of these fields have always been characteristics of science from the point of view of its social organization, but also in its epistemological and methodological aspects. He thus criticizes the contrast established by the authors

(Gibbons et al., 1994; Nowotny et al., 2003) between two modes of knowledge production (a "pure science" and a "science in context") that are not relevant from a historical point of view. Scientists"[2] have long been integrated into networks that go far beyond academic and university structures. The two modes proposed according to the author participate in the discourses that scholars themselves constitute and try to transform into normative systems (Western rationality; caesura and division between knowing object and subject; divisions between daily laboratory practices and the purified accounts that are proposed). Taking the mode of pure science as the historical form par excellence makes one forget, according to Pestre, the profoundly local and social nature of knowledge, minimizes the fact that any process of knowledge production is always-already situated; but without relativism, because it evades interactions with the world, and thus the effectiveness of knowledge. (Pestre, 2003, pp. 18-22).

Pestre (2003) then defines the notion of a knowledge regime that evokes a conception of scientific activity as a "collection of political and economic institutions and beliefs, practices and regulations that delimit the place and mode of being of science. Such a regime is heterogeneous in what determines it, it is the result of an always particular history: it is not necessarily a coherent system and it is not intended to be optimal" (p 36). The "knowledge regime of techno-science" that Pestre situates between 1870 and 1970 emerges thanks to a transformation of scientific practices and a recomposition of science (tendency towards generalized reductionism, pragmatic attitude under the influence of industrial laboratories, increased use of mathematics and processes of formalism, fundamentalization of applied research). It gives a better account (than the mode according to Gibbons et al.) of institutionalized compromises, of multiple logics with their own temporalities, and of the role of actors who deliberately or not modify the context.

Redefining Certain Issues in Networks

In contemporary techno-science, what is most important today is the redefinition in progress in the technical-scientific-industrial-social-political networks of certain issues such as those related to health, the environment, the major planetary balances, waste, nuclear power and GMOs. The urgency of these issues is due to the involvement of science in society but also to the changing nature of science, its new capacity to act on the world and transform it.

The effort to redefine it means that the issues are becoming political in society, which sees techno-science differently, especially the link to expertise and contestation (Pestre, 2003)[3]. Thus, educationally, we follow Pestre (2003) regarding the political dimension of the issue:

> "Techno-science, and the industrial world linked to it, have the capacity to transform the natural and social world so radically that the issue is becoming a political question in societies that are increasingly scientifically educated, increasingly eager to control their destiny - and that it is wise to respect democratically" (p. 16-17).

Formulated in this way, the question is stimulating for understanding the multiplicity of issues at stake in techno-science and thus for elucidating the links between science, society and politics. Science education according to Larochelle (2003) will have the task of questioning the re-socialisation of the world of objects as students do by connecting it to the interests, projects and networks from which it results. Désautels (2002) questions this sociality of techno-scientific knowledge that calls into question the regime of expertise. A regime in which competence is converted into authority.

> "It is not knowledge in itself that transforms our world, but knowledge that is taken in very specific forms of appropriation and development. What is new today is perhaps due to a certain efficiency inherent in knowledge, but is above all the invention of a new way of mobilizing[4] this knowledge in a different economic and political order" (Pestre 2003, pp. 106-107).

This statement by the author tends to clarify the notion of "knowledge societies" and the imperative of the industrial and economic argument. The transformation of the mode of production of knowledge today, partly because of the context of competition and then the evolution and reorganization of the spaces of production of science and technology with new forms of partnerships operating in a climate of neo-liberalism (patents, intellectual property, etc.), has meant that knowledge itself becomes at the heart of the creation of value and wealth - a fact that we are now in knowledge economies (Pestre, 2003, pp. 100-105).

We agree with Pestre's definition of knowledge and learning. When the author emphasizes that "it is not knowledge itself that transforms our world, but knowledge taken in very particular forms of appropriation and development," he is joined by Brossard (2012), for whom appropriation is the external, and therefore mediated, character of cultural objects produced and deposited out of the subject. The internalization of this world of external culture is done at the price of a construction by the internal activity of the subject. Appropriation and construction according to Brossard are done, in accordance with Vygotsky's historical-cultural theory, through structurally complex and meaningful activities. These "cultural activities" are historically elaborated and deposited (objectified) in the cultural environment.

In the case of scientific learning, the cultural activities would be those of problematization[5], production-comprehension of texts, relevant use of expertise to solve science/society questions, etc. Larochelle (2003) talks about making choices among various narratives about science. These choices are made according to the representation of science and its representation of students, the social project being pursued, and the expertise acquired.

Before showing how it is possible to develop an emancipatory relationship to knowledge and the world, because this is where the challenge lies, we will examine the conditions for the return of the figure of the amateur, which permeates all spheres of our society (culture, media, education, etc.).

The Return of the "Amateur"

One of the contributions of Sciences Studies, which we translate as "science studies" or "social studies on science", concerns the status of knowledge in our contemporary societies (Bonneuil and Joly, 2013). The authors question the return of the "amateur" at the dawn of the 1970s with regard to the production of knowledge. In their view, this figure is reminiscent of the figure of scientific amateurism, which embodied the Kantian philosophy of the Enlightenment, the search for knowledge being a right and duty of every citizen. Controversies such as AIDS and myopathies inaugurate a "citizen science". According to Callon et al. (2001), scientific research in such cases would have been impossible without the work of laymen, simply because of the lack of objects and the lack of problems. The families of the sick, for example, explore causal chains and make the existence of pollutants visible. They ask questions, seek information, meet with experts.

In the course of this redefinition of topical issues in networks, a "cooperation of parity" takes place, according to the authors, for a time[6] between researchers and laymen. For them, sociotechnical controversies on health or the environment are not the consequence of a lack of communication or information; they are an enrichment of democracy. Because they allow exploration through an inventory of actors, problems and solutions, they lead to learning by allowing confrontations between specialists and laymen and transforming for a time ordinary hierarchies and underlying conceptions. The idea of collective learning of a network of actors around collective projects is a real challenge, it allows compromise and alliances by overcoming the sharing of roles in which the citizen is confined by his legitimate representatives (Callon et al., 2001). It shapes the configuration of a citizen education with a real agenda. Faced with situations of uncertainty, according to the authors, it is a matter of proposing elucidation mechanisms with a gain on the epistemological level (elucidation of problems with their reformulation, elucidation of causal chains by accumulation of collections and search for regularities, proposal of new research with procedures...); at the citizen level (influencing political decisions through their democratisation); at the educational level (putting science and progress into debate, counterbalancing scepticism-fear-mistrust towards experts, questioning the universality of science) (Callon et al. , 2001, p. 30-60).

Science studies will make the imperative of involving the layman a dominant research object in 2000 for normative purposes: the problem becomes how to construct political/educational action that integrates in a reflexive and democratic way the role of objects (knowledge, spaces, means...) in science-society mediation (Bonneuil, Joly; 2013). What is the situation in the field of education?

Problems in the Field of Education

Epistemological Exceptionalism in Science and Science Education and Alternative Constructions

Cobern (1994) is interested in the cultural dimension of science education. Starting from the idea that educators have historically thought of science as something singular above culture, this epistemological exceptionalism of science[7] has led them at least implicitly to the idea that science education should also be a singularity[8]. The author's purpose is to suggest that alternative, culturally based constructions of science education that show various formats should be considered.

FIGURE 2
ALTERNATIVE CONSTRUCTIONS OF SCIENCE AND SCIENCE EDUCATION

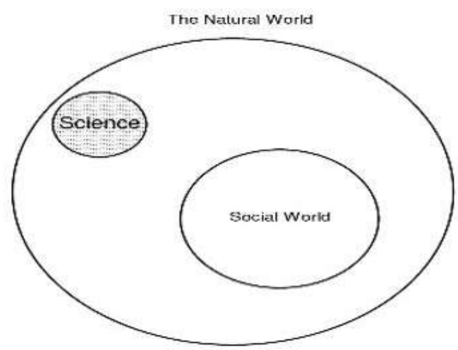
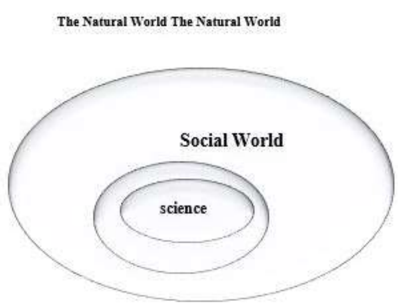


Figure 1. Strict Empiricist View of Science



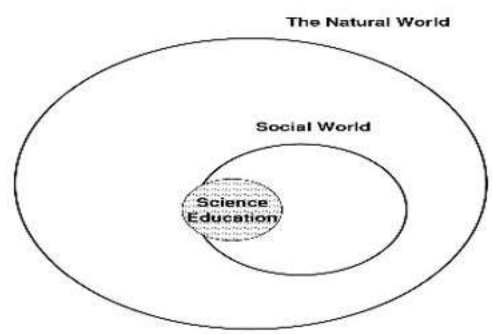


Figure 2. Social constructivist View of Science

Figure 3. Science Education

Source Cobern, 1999

In fact, according to the author, it is our personal understanding, the strict empiricalist vision (fig. 1) and the radical socioconstructivist vision of knowledge and methods (fig. 2) are similar to the epistemological exceptionalism of science. If he qualifies the empiricalist vision as preconceived ideas, -science is reflected in the natural world without any connection with the social world-, he finds (weak) critics to the socioconstructivist position -science is slightly affected by the natural world whereas it is a social construction. Thus, the author stresses that it is harmful to adopt the latter for any society trying to develop a community of scientists. Nevertheless, he sees no disadvantage in considering the model for scientific training and education (fig. 3), as long as alternative constructions are considered. His critique of science education as a scientific education that promotes a culture and worldview that unnecessarily alienates many students is shared by many authors. He rightly points out the gap between the reductionist representation of science promoted by the school and the holistic worldview possessed by students. This disciplinary power (Roth & McGinn, 1998; cited in Larochelle, 2003) that pervades science education in its various institutional, curricular and pedagogical components makes these particular forms of appropriation and valorisation of knowledge hazardous, according to Pestre (2003).

Nevertheless, one cannot but be disappointed by the alternative forms proposed by Cobern (1994). Let us take the example of classification. The author distinguishes between a scientific description established by research (this is a vision of the natural world only), and an alternative description that adds the natural, the social and the super-natural to the natural. It is impossible in such a short text to support criticism of the various dimensions of such a thesis. This paper will be as illustrative as it is demonstrative for lack of space. In this regard, we invite the reader to refer to works that have examined, discussed and developed avenues for classification (e.g., Gay Gould, 1993; Eco, 1999). Let's consider an example for illustration. Larochelle's (2003) review on the classification of a platypus troubled object shows that the research established actually tells a variety of stories about the classification of this object : platypus-ovipare, platypus viviparous, platypus ovoviviparous. Observation of the natural world alone was not decisive in bringing this object into the “scientific order of things”, in the author's words. It is in fact the dynamics of the epistemological conflict within the scientific community and negotiations that prove to be more decisive. Indeed, the observation of nature allows some people to favour eggs and ignore the udders (the defenders of the platypus). Those who defend the platypus ignore the issue of eggs. Does the object outside the mould lead to changing the mould? The outcome of the negotiations leads to the adoption of a new ovoviviparous order. The alternative forms presented by Larochelle are forms that are integral to scientific research itself. They differ from Cobern's categorization (natural, social, super-natural). Observation of the natural world is essential, yet the tensions and negotiations that have taken place within the scientific community as a social space have led to the scientific ordering of the object of discord. The idea of alternative constructions remains relevant. We will reveal in the rest of our text our avenues for taking it into account.

Re-socialising the World of Objects

The epistemological exceptionalism of the sciences raises the question of the place of the social within science and the articulation of different types of knowledge. Yet knowledge is nothing in itself; it is emancipatory or dominant depending on the use made of it, the situation and also the form of transmission in which it is transmitted (Develay, 2000). The representations of science, the relationships to scientific knowledge and its changes, the (practical) uses of science in situations of appropriation or operationalization make it possible to come out, according to Pestre's (2003) formula, of the "ready-to-think sciences" and their transmission. The problem of re-socializing the world of objects as students do through connections to interests, projects and networks that result in new questions about relationships to knowledge and didactic situations (Larochelle, 2003).

If there is an ideological character, as Pestre (2003) has formulated it, that participates in the discourses that scholars themselves elaborate and try to transform into normative systems, it is a question of the caesura and division between knowing object and knowing subject. Strong positions lead some people to denounce "a pedagogical readiness to think that it would be interesting to bring school situations closer to students' experiences" (Lhost, 2017, p. 48). We can denounce the radicality of this position, but the problem lies elsewhere. It is a question of changing the focus. The questioning of the relevance of school knowledge in terms of "relevant for whom" or "relevant for what" has often served to reinforce the hyphenation between knowing object and knowing subject, a division rightly denounced by Pestre (2003). Over time, despite the various waves of reconfigurations of science curricula, a kind of status quo about the organization of secondary school science as a practice that promotes the fundamental nature of science for the future academic success of a small number of students has been established. This orientation is even emerging as a priority for the education of the greatest number despite the initiatives and alternatives that may exist.

It is relevant to pose the question in terms of "who has the legitimacy to decide what is relevant...". The lack of consensus among those who refute this status quo by arguing for education for all does not help[9]. Re-socialising the object world that is the regime of students' everyday knowledge has been the basis for various innovative and alternative forms of science education (cf. note 11). The problem is that most operate without a clear consideration of how these modes of being combine or could combine.[10] The lack of consensus and fragmentation affecting these alternative forms has been highlighted above. Others wonder whether these evolutions are not a "means of summoning vernacular knowledge to make itself intelligible to scholarly knowledge, where state and top-down development models had failed to insert them into the market" (Bonneuil & Joly, 2013).

Contrasting Cultural Figures

As Cobern (1994) pointed out above, it can be said that science education is caught between two trends: one that is open to the natural world and questions it without limits and one that tends to make the answers given as references in this world of complexity and uncertainty. More concretely, Fensham (1998, 2002) and Gaskell (2003) explain that although the arguments on the educational research side are less favourable to formalism, the constraints on the political side make it more popular. Science education is mobilized at the highest levels of political and scientific decision-making based on economic arguments, often in a context of crisis, for the benefit of a certain elite. The cultural figure of the elite supports a phenomenon of self-referentiality of science and self-replication of scientists.

At the turn of the 1980s, researchers spoke of a "change of perspective". This is more of a "critique of the power relations that contaminate the production of knowledge". Science remains in the process of claiming its autonomy by putting forward "disinterested knowledge" in the face of social forces. This "critical" perspective, which contrasts with the previous "technocratic" perspective, highlights a "science in action" and promotes a new cultural figure, that of the pragmatic. While the former had emerged because of the upheavals of the post-war period, the latter emphasizes the upheavals of the end of the 20th century. Rapid economic development due to technological advances and globalization are advanced at the highest levels as creating a strong demand for skilled workers and a scientifically literate population.

Things are getting complicated. The civic argument is increasingly being mobilized at the level of scientific organizations seeking to give meaning to their missions, and the decision-making bodies that follow suit. On the research side, it is argued that young people are looking for more meaning in what they learn, a personal relevance to their daily lives. Both intrinsic dimensions and individual desires are thus highlighted as important (Layton et al., 1993; Irwin and Wynne, 1996). These challenge the knowledge deficit model and the adherence logic that accompanies it. The aim is a co-construction of knowledge in the service of action (Jenkins, 1999). The cultural figure of the citizen inaugurates this period both in terms of research policies (e.g., European Union Report, 2006), public understanding of science, and science education research.

CONCLUSION

Just as the content of science and technology education is unstable and conjunctural because of the missions assigned to it and dependent on political opinions (Martinand, 2007), it is important to recognize the contingent nature of the concepts, which does not mean that they are devoid of robustness or durability (Larochelle, 2003, p 59). The essence of a scientific education and culture is to identify issues, tensions, conflicts and negotiations (Legardez and Simonneaux, 2006). It means reconstructing with the students what has been established, with the consequences and risks attached to it, even if the school form favours decontextualized objects. Doesn't subjecting the world to tests represent an unavoidable condition for performing science (Larochelle, 2003), and educating for a problematic world (Fabre, 2011)?

ENDNOTES

1. We highlight two key sources: the 2004 Etats généraux de la recherche and the 2006 European Union report. Both sources have established the basis for orienting research at the CNRS or through EU framework programmes according to the model of science in society, a model that is neither technocratic nor top-down but participatory and involves citizens.
2. Emphasis added by the author.
3. This point of view is also underlined by Sterling (European Union report entitled "Science in Society", 2006) which inaugurates the new 7th framework for EU research in science.
4. Underlined in the text.
5. The world of life and culture is increasingly being problematized, but the character of the solutions provided remains questionable: : "Educating for a problematic world" (Fabre, 2011).
6. This is the time of emerging problems that scientists did not envision (e.g., AIDS, myopathies).
7. (Bimber and Guston, 1995 cited by Désautels, 2002).
8. The author supports this assertion by pointing out the remarkable similarity of science education around the world. This means that scientific culture is becoming more normalized (PISA) and internationalized.
9. For example: Science-Technique-Citizen (Kolsto); Nature-Technique-Society (Anderson); Science-Technique-Society-Environment (Hart; Dori and Tal); Science-Technique-Ethical-Society (Fourez).
10. Pestre (2003) makes the same criticism of various forms of participatory citizenship.

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