Opinion and knowledge: epistemological positioning and didactic issues

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Introduction

Bernadette Bensaude-Vincent (2003) uses an anecdote from Plato's *Theaetetus* to present the "*two ways of being-in-the-world*" which, for Plato, characterize the relationships between science (episteme) and opinion (doxa) which he distinguishes by the difference of objects which are specific to each (Bensaude-Vincent, 2003, p. 15). For her, this is the event which is at the origin of a separation between science and opinion[1]. Before proceeding further with the examination of the relationships between knowledge and opinion, it is worth specifying the different meanings of the term opinion such as they appear in the *Dictionnaire historique de la langue française*: "*in French, opinion designates the*

[1] This anecdote concerns Thales of Miletus known as the founder of mathematics and physics: "I will illustrate my meaning by the jest of the witty maid-servant, who saw Thales tumbling into a well, and said of him, that he was so eager to know what was going on in heaven, that he could not see what was before his feet." (Plato, Theaetetus, 174a-b). Bensaude-Vincent notes that "by her laughter, the maid-servant marks the distance that separates her from the scholar-philosopher. The anecdote expresses the distance, the incomprehension which separates science (episteme) from opinion (doxa)" (2003, p. 14).

feeling that one has of a thing, more particularly the intellectual position adopted in a given field (v. 1283). *It signified "hypothesis, theory" (1314) before being excluded from the scientific field. The initial meaning having acquired a collective value, the word, while conserving its individual psychological meaning, entered the modern syntagms* liberté d'opinion *(1936) and* journal d'opinion *(20th century). Current usage also gives it the meaning of "value judgement that one has of someone, of something" (v 1265) […]In a second group of uses, from the 16th century, opinion refers to a set of ideas, of judgements shared by several people (1563), by a social group, notably in expressions such as public opinion (1590), then absolutely (1762). It is used in sociology to designate the type of social thought which consists in taking position on problems of general interest (1580) and, currently, the set of dominant attitudes of the spirit in a society"* (Rey, 2000, p. 2467). This historical analysis of the word "opinion" illustrates the possible polysemy of this term and therefore the diversity of relationships between opinion and knowledge. This may explain the diversity of contributions which comprise this first survey of the new journal, *Recherches en didactique des sciences et des technologies*, which is reflected in the highly diverse bibliographical references in the articles of this issue of RDST.

As for the definition of the word knowledge, we also use it with several meanings. It is used in works referring to historical epistemology with a Popper-inspired meaning, that is, as the inhabitants of Popper's world 3 (Popper, 1991/1998, p. 182-183), the world of the objective content of thoughts. With this theory of the three worlds, Popper insists on the objectivity of knowledge. Thus "objective knowing "*without knowing subject*" (*ibid*., p. 185) is opposed to a theory of subjective knowing, "*which rests upon subjective dispositions to psychologically and passively integrate the content through sensorial experiences identified as the content of beliefs*" (Robillard, 2004, p. 6). In relation to this objectivity of knowledge, knowing is understood as the subjective facet of knowledge (Fabre, 1996, p. 70). Within the framework of the study of socially sensitive issues or the socio-scientific issues[2], it appears rather difficult to define in a few lines the numerous specifics of the scientific knowledge and practices retained[3], all the more as, as Albe (2009) puts it: "*the epistemological foundations are, more often than not, implicit even if the idea of considering science as social constructions is widely present*" (p.

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[2] The use of these terms is explained in the second part of this article.

[3] We will, however, define several meanings in paragraph 1.2. For further information on this subject, see Pestre (2003).

103). Finally, other meanings of the term seem pertinent, even if they have not been called upon by the authors. This, for example, is the case for local nature knowledge which, since the Rio Agreement on bio-diversity (1992), is the object of particular attention and for which specific didactic questions are posed within the framework of the transmission of this "local knowledge" from one generation to the next.

The ambition of this introduction is to provide some signposts to facilitate the epistemological positioning of the various articles of this thematic survey and the different didactic questions which they pose. We also present other possible meanings of opinion and knowledge for which no articles were submitted.

1. From epistemological positions …

1.1. Opinion and knowledge within the framework of a historical epistemology

The epistemology of Gaston Bachelard: rupture and obstacle

The authors of several articles in this issue of RDST (Jean-Yves Cariou, Patricia Crépin-Obert, Michel Fabre, and Julie Gobert) refer to a psychological and individual conception[4] of the term opinion and situate their reflection within the historical epistemology of Bachelard in order to envisage the relationships between opinion and knowledge.

Bachelard's work *La formation de l'esprit scientifique* (1938), which is seen by Dominique Lecourt to constitute "*an essentially pedagogical work*" (1974, p. 57), is quoted in five of the eight articles in this survey. In this work, Bachelard (1938), uses the term opinion for "*first idea*", "*intuition*", "*shared knowing*" which drives scientists confronted with the quest for explanations. Therefore, in the writings of Bachelard, the term opinion must not be confused with the term public opinion. This first point can specify the problem tackled by Bachelard, a problem which will be taken up, in a different way, by Canguilhem and his numerous pupils: Dominique Lecourt, François Dagognet, etc.

The epistemological work of Bachelard developed in a specific

[4] The term "opinion" refers to an individual dimension insofar as it refers to the opinions mobilized by an individual confronted with the learning of an element of knowledge, even if there is recurrence of the same opinions which can be found when different individuals tackle a same element of knowledge. It is still an individual opinion nevertheless that does not mean that there is no recurrence or regularity, since this is related to the ways of thinking that are available in the cultures (the sharing in "*shared knowledge*"). Accordingly, in Bachelard's work, opinion has a psycho-sociological dimension since there is some entity constructed by the history of the individual.

historical context: the development of non-Euclidean geometries, the development of the non-Newtonian theory of relativity, the beginnings of microphysics, etc. The beginning of the 20th century seemed to him to be a break in the history of science. It was upon these intuitions that Bachelard would build "*an original philosophical category*" (Lecourt, 1974, p. 21): the category of the "*non*" (Bachelard, 1934/1940), which led him to oppose both a conception of the history of science based on continuity and a unitary or monolithic conception of knowledge: "*the contemporary scientific mind could not be put into continuity with simple common sense*" (Bachelard, 1953/2000, p. 207)[5]. On this point, he is radically opposed to the realist theses of Meyerson, which, postulating the identity of the human mind, sought "*to deduce*" Einstein from Newton[6]. Bachelard refuted Meyerson's *Déduction relativiste* (Meyerson, 1925), with his own *La valeur inductive de la relativité* (1929): "*one does not go from the first to the second by amassing knowledge, by intensifying the care [taken] in measurements, by slightly rectifying principles. On the contrary, an effort of total newness is needed*" (Bachelard, 1934/1984, p. 46).

This double historical and epistemological basis is essential to the understanding of the notion of *rupture* in the work of Bachelard (Lecourt, 1974, p. 23), this stance enabled him to distance himself form the dispute between Meyerson and Comte[7] "*by refusing the continuity of the intellectual approaches of common sense and scientific reason*" (Canguilhem, 1968, p. 179). The introduction of the concept of rupture enabled Bachelard to construct an epistemology which refuses positivism, since the concept of rupture "*destroys the linear image of scientific progress by challenging a postulated property of the straight line of admitting only a parallel drawn through any point outside of itself*" (Canguilhem, 1987, p. 444). This concept of rupture enabled Bachelard to envisage the relationships between opinion and knowledge. Therefore the opposition, which Bachelard ceaselessly referred to, between science and opinion, must be understood as the refusal of "*homogeneity of the forms of knowledge – common and scientific*" (Lecourt, 1974, p. 23). Thus, Bachelard does not oppose science with a capital S to public opinion, but

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[5] One must not take Bachelard's "philosophy of the non" to be a philosophy of negation. Bachelard himself points this out: "'the philosophy of the non […] is not a philosophy of negation. It destroys nothing. Quite the contrary, it consolidates what it overwhelms. Newtonian mechanics remains valid within its clearly designated sphere of application. Its basis was experimentally too narrow; its rationalism now seems to be a simplification. Ultra-precise experiments have demanded a de-simplification of rationalism" (1972, p. 95-96).

[6] Similarly, Newton cannot be put into continuity with common sense.

[7] Although Meyerson also opposes the positivism of Comte.

rather common, ordinary, immediate knowledge to scientific knowledge: "*scientific progress always manifests a rupture, perpetual ruptures between common knowledge and scientific knowledge*" (Bachelard, 1953/2000, p. 207). This enabled him to highlight the difference in nature between common knowledge and scientific knowledge: where common knowledge isolates and naturalizes things and objects, scientific knowledge is a process which enables the construction of a system within which scientific concepts are linked one to the other: "*in every circumstance, the immediate must give way to the construct*" (Bachelard, 1940/2005, p. 144). There is, therefore, for Bachelard, a rupture between scientific knowledge and common knowledge: scientific knowledge has a necessary character since it is founded on reason through a permanent process of repetition and rectification[8]. This reason is not the reason of fact but polemic reason; concerning Bachelard's rationalism, Canguilhem talks of "*a commitment to the rationality of reason against his own tradition*" (Canguilhem, 1972, p. 5). Therefore, in the words of Rumelhard, scientific knowledge "*has a polemic function since it ousts metaphysical, moral, religious and political beliefs which presented themselves as being true explanations*" (1997, p. 14). Bachelard ceaselessly repeated that one must not ignore but rather re-work opinions and that one must necessarily use them as a basis in order to rectify them. This difference in nature between knowledge and opinion is studied in the articles written by Patricia Crépin-Obert who seeks to understand how pupils can construct an item of "*reasoned paleontological knowledge*" and by Julie Gobert who analyses the passage from an opinion to scientific knowledge as observed with upper secondary pupils majoring in science (*Première S*) tackling the concept of embryo development.

The construction of scientific knowledge is seen by Bachelard as a process of rectification and re-organization[9] from the base to the summit which implies the "*theoretical primacy of the error*" (Canguilhem, 1957): "*there can be no first truths, there are only first errors*" (Bachelard, 1970). Bachelard considers this work of rectification and re-organization to be a component of scientific work; logically, he concludes that opinion or common knowledge "*in law is always wrong*" (Bachelard, 1938/1996, p. 14) and this is the meaning which must be given to this quote used by Grégoire Molinatti in his article. The concept of epistemological obstacle is linked to this axiom. The function of the epistemological axiom is to

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[8] "Rationalist thought does not "start". It rectifies. It regulates. It standardizes" (Bachelard, 1949/1998, p. 112).

[9] "One only organizes rationally what one re-organizes" (Bachelard, 1972, p. 50).

"*overcome the rupture between common knowledge and scientific knowledge*", and thus "*it functions in reverse to the Non*" and "*re-establishes the continuity threatened by the progress of scientific knowledge*" (Lecourt, 1974, p. 27). Therefore, epistemological obstacles are not difficulties external to knowledge which should be overcome, but their source is in thought itself. Opinions are generally profoundly stabilized by the obstacles; this implies that during the construction of scientific knowledge "*something of thought has to be destroyed, or at least dismantled after the psychoanalytical fashion, for this to occur*" (Peterfalvi, 2001, p. 32). Bachelard indicates that the place of the obstacle in the process of knowledge is variable: either it springs out "*at the moment of the construction of [the element of] knowledge, or at a later stage in the development, once it has already been constituted as scientific knowledge. In the first case, one shall say that it is a 'counter-thought', in the second case a 'stopping of thought'*" (*ibid*.). The identifying of the workings of epistemological obstacles in the learning process is at the heart of the didactic investigations presented in this volume by Jean Yves Cariou, Patricia Crépin-Obert and Julie Gobert.

Bachelard describes the process of the construction of an element of scientific knowledge which puts opinions and obstacles to work as a dialectic (a new conception of dialectics) between an applied rationalism and a rational materialism[10], or, in other words, as a "*process of reciprocal adjustment of the theory and the experiment*", an "*adjustment not as formal adequacy, but as a historical process*" (Lecourt, 1974, p. 29). The introduction of the dialectic between theory and experience was the means used by Bachelard of mobilizing the concept of phenomenotechnique by showing that modern science is a science which creates phenomena (the Zeeman Effect[11], the Stark Effect, etc.) which do not exist outside the instruments which enable them to appear. This accounts for the importance of scientific instrumentation which constitutes "*the new organs which intelligence gives itself in order to take the sensory*

[10] "No matter the point of departure of scientific activity, the activity can only fully convince by leaving the base domain: if it experiments it must reason; if it reasons it must experiment." (Bachelard, 1934/1984, p. 4).

[11] When one excites a low-density atomic gas (using strong heat or electrical discharges), the electrons can reach states of higher energy than their when they are in their rest (or fundamental) state. By returning to their fundamental state, the excited electrons lose this energy by emitting light of a wavelength exactly corresponding to the difference in energy of the levels. The emission spectrum of a gas thus respects the range of levels of energy available to the electrons of the atoms. When a magnetic field is present, the rays of the spectrum and therefore of the levels of energy subdivide: this is the Zeeman Effect. Sébastien Descotes-Genon, Université Paris-Sud 11. Available online at: <http://www.cnrs.fr/sciencespourtous/abecedaire/pages/zeeman.htm>.

organs, as receptors, out of the scientific circuit" (Canguilhem, 1968, p. 191). And so "*the true scientific phenomenology is therefore essentially a phenomenotechnique. […] It learns because it builds*" (Bachelard, 1934/1984, p. 17). The determining role of instruments in scientific activity enables Bachelard to show the need to take into account the state of the technical (and its history) in order to envisage the history of a science. As a consequence, scientific activity has an eminently social character: "*pure science is a science which is nevertheless socialized. It belongs to the psychology of what I call […] a scientific estate: the scientific society within our present societies*" (Bachelard, 1972, p. 54). Thanks to the introduction of a social dimension to scientific activity one may progress, within the framework of a historical epistemology, from the individual and psychological dimension of the opinion to a collective dimension (public opinion). Therefore, as we shall make clear in the lines which follow, the opinion/knowledge relationship refers also to the links between sciences and societies.

Concerning the social dimension of scientific activity presented by Bachelard, the movement towards a sociological approach to sciences underlines a limit to his epistemology, particularly when it comes to understanding the relationships between sciences and societies. Such criticism is explicitly expressed by Bensaude-Vincent who denounces the invention by Bachelard of a society which science needs, a society "*on the margins of social society, […] a collective of well-formed, purified, sanitized minds emptied of all traces of opinion, interests and affectivity. Two heterogeneous worlds, face to face, incommensurable*" (2003, p. 178). It should, however, be made clear that Bachelard did not position himself as a sociologist of knowledge, but described, in epistemology, the "*ideal*" functioning of the scientific estate, that is, what distinguishes it from the other human communities with their ploys for power, search for funding… Bachelard thus attempts to define the epistemological specifics of the scientific estate, why there is production of knowledge and not just power and ideology, and to this end he insists on its creative dynamism and the importance of adopting a normative point of view (see note [3]). It is worth underlining the interest of this epistemological perspective, which the sociology of sciences contests, yet which it cannot do without, if only to mark the distance between effective and ideal functioning. We find here an approach which is developed in the RDST survey by Michel Fabre when he proposes an "*education in discernment*".

Although this limit to Bachelard's epistemology is shared by those who continue in his footsteps (Canguilhem, Lecourt and Foucault), these latter take a different route to that followed by the science studies movement which we present in section 1.2. Following Canguilhem[12], Lecourt postulates "*the necessity in order to construct the concept of a history of sciences, to refer to a theory of ideologies and their history*" (1974, p. 35). This is the avenue of research which Canguilhem and Foucault will take to extend and develop the epistemology of Bachelard.

Canguilhem, philosopher and historian of medicine and the biological sciences

The work of Georges Canguilhem continues, in the area of life sciences, the work of Bachelard[13]. Under his impetus, Bachelard's work is not only continued but also evolves, particularly concerning the taking into account of the history of ideologies in order to understand the functioning of obstacles in the construction of a scientific concept. This might explain why Canguilhem is the most quoted source in the articles of this RDST[14] survey.

In *La connaissance de la vie*, Canguilhem (1965) uses the construction of cellular theory to show how the term cell can transport sociological and political values: "*social and affective values float over the development of cellular theory*" (Canguilhem, 1965, P. 62). Canguilhem explains how 19th century French political thinking (France was in latent conflict with Germany at the time) became an obstacle to the French vitalist movement of the school of Montpellier; this vitalism was in harmony with the German romantic tradition (*ibid*., p. 63). From a generalization of this example, Lecourt indicates that "*in the final analysis, the transformations-deformations of a concept are only the index of the constant reformulation of the problem in different theoretical areas, under the influence of various ideological determinations, even contradictions*" (1974, p. 81). Canguilhem talks of cultural supervision or of a social status of science, to show that scientific activity is not the product of a pure logic, but that it is inscribed within social training which is itself traversed by ideological values and the tensions between these values (*ibid*., p. 73). One can thus understand how, following on from Bachelard, Canguilhem's epistemological tools (condition of possibility, ideology, norm and normativity) will enable the refining of the comprehension of the relationships between opinion

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[12] "The history of the sciences should include a history of scientific ideologies recognized as such" (Canguilhem, 1981, p. 38).

[13] Canguilhem's doctoral thesis – *La formation du concept de réflexe au XIIe et XVIIIe siècle* – was directed by Bachelard.

[14] There are fifteen references to Canguilhem in six articles (out of eight) four of which refer to *Idéologie et rationalité dans l'histoire des sciences de la vie.*

(understood in its collective dimension) and knowledge. The historical epistemology movement has constructed concepts enabling the analysis of the relationships between sciences and societies (particularly through the intermediary of the technical, see below) within a different framework to that used by the sociology of sciences movement. We shall specify these contributions while attempting to show how they enable the comprehension of the relationships between opinion and knowledge using the relationships between sciences and societies.

The intrication of science and ideology is at the core of Guy Rumelhard's article in this issue of RDST, an article which develops numerous aspects of his previous contributions to the journal *Aster* (Rumelhard, 1998, 2000, 2005). He enquires into the different functions of scientific ideologies in the treatment of questions, such as that of eugenics, the relationships between genetics and racism, or the concept of reflex in school. Guy Rumelhard states that "*scientific teaching should include an analysis of the ideologies in order not to degrade itself, not to dogmatize, transform itself into an ideology*". In their article, Castéra and Clément also look into the interaction between knowledge and values in the conceptions of French teachers concerning the genetic determinism of human behaviour. They use the work of Canguilhem as a basis for defining as an ideology the fact that, in life sciences, complex phenomena are reduced to mere genetic or molecular determinism.

From the epistemological point of view, one of Canguilhem's contributions concerns the notion of the "*condition of possibility*" of construction of certain scientific concepts, a notion taken up in this issue of RDST by Julie Gobert. Even if he never provided a precise definition of the notion, Canguilhem refers to it in his first major epistemological work: "*one is rather led to wonder what a theory of muscular movement and nerve action should enclose so that a notion, such as that of reflex movement, covering the assimilation of a biological phenomenon to an optical phenomenon, may find a sense of truth, that is firstly a sense of logical coherence with other concepts*" (1955, p. 5-6). Thus conditions of possibility can cover intellectual conditions (which in Foucault refer to epistemics) and/or the technical[15] which enable the emergence of new concepts[16]. In Foucault, Canguilhem's work can be seen as a conducting

[15] Canguilhem thus indicates three conditions of possibility for chemotherapy: "a new symbolization of the chemical entities, a new technique substituting the extraction of substances for the production of products" and the discovery of serotherapy (1981, p. 72). Two belong to the implementation of new techniques and the other to the availability of certain intellectual tools.

[16] We should note that, for these two authors, the conditions of possibility are not necessarily the

thread, a thread which enables one to "*focus on the conditions of appearance of concepts, that is, in the final analysis, on the conditions which render the problem formulatable*" (Lecourt, 1974, p. 78-79). This leads to a second determining clarification of the contribution of Canguilhem to Bachelard's epistemology concerning the very close relationship constructed by Canguilhem between the concept and the problem. As Macherey reminds us, "*defining the concept is formulating a problem*" (1964/2009, p. 54), the important element being the recognition of "*the persistence of the problem within a solution which one believes one has given to it*" (Canguilhem, 1966/2005, p. 40). This close concept-problem relationship is a major element of the theoretical framework developed by Jean-Yves Cariou. This relationship is constitutive of the problematization framework developed by Michel Fabre (2009) and Christian Orange (2002, 2005), which is used in the research presented in this issue of RDST by Michel Fabre, Patricia Crépin-Obert and Julie Gobert.

Another contribution of Canguilhem's work should be mentioned in order to position certain articles of this issue which deal with the relationships between sciences and society. Several articles in this issue of RDST examine the issue of opinion/knowledge through the sciences/society tandem, something made possible by the polysemy of the term opinion. Canguilhem envisages the relationships between sciences and societies through the scientific – technical relationship and the concept of the norm mainly investigated in *Le normal et le pathologique*. As Jean-François Braunstein reminds us: "*the theme of the technical is at the heart of Canguilhem's first works*" (2000, p. 18), he would extend this reflection in his work on medicine which constitutes "*a technique or an art at the crossroads of several sciences, rather than a science in its own right*" (Canguilhem, 1966/2005, p. 7). Countering the positivist maxim "*from science comes foresight, from foresight comes action*" (Comte, 1830, vol. I, p. 50), Canguilhem envisages a development of science and the technical on different planes. Sciences and techniques establish between each other dialectical relationships which cannot be simplified to reductionist applicationism: sciences and techniques are "*two types of activity, which cannot be grafted onto each other, but which each reciprocally borrows from the other alternatively solutions or problems*" (Canguilhem, 1965, p. 125). Basing his reflection on several examples, Lecourt develops Canguilhem's reasoning and shows that "*in reality, the*

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prerequisites for the emergence of concepts, since they may appear at the same time as the scientific concept is forged.

technical is foremost before science" (2008, p. 71), "*science intervenes afterwards. Having taken as its object the technical difficulties encountered by the engineers, it could account for them theoretically, and then serve to develop the power of the machines*" (Lecourt, 1997, p. 88)[17]. According to Lecourt, this "*erroneous conception*" of the relationships between science and the technical, one of the consequences of which is the formation of the concept of techno-sciences[18], only serves "*to indict science*" (Lecourt, 2003, p. 84)[19]. Ignoring the conflicts between bio-catastrophists and techno-prophets (with their positivist and scientistic conceptions), Lecourt develops the thesis of a "*rooting of technical activity in the debate between the living and its milieu*" (*ibid*., p. 85). This enables him to show that the technical plays a determining role in the process of the individuation of each individual. Following in the footsteps of Canguilhem, Lecourt continues to "*wager that philosophy […] can encourage us to refuse both the platitude of thought without temporal depth and the fascination for the metaphysics of the abyss*" (2009, p. 14). In this issue of RDST, Michel Fabre adopts this perspective when he proposes a "*good use of the controversial subjects which are there to wake us from our dogmatic slumber*". To achieve this, he recommends the development of the discerning mind which must pass through learning to distinguish between the different sets of language mixed together in the social practices linked to scientific and technological issues, in order to "*assign to them, their area of validity*". In this issue of RDST, Virginie Albe and Adel Bouras tackle this problematic concerning the relationships between science and the technical, focusing on the issue of nano-technologies, but using a different theoretical framework. Using the work of Larochelle, Désaultels, Pépin (1994) as their starting point, these authors attempt to expose the evolution of trends (before and after teaching nano-technologies), trends in the epistemological points of view about the relationships between sciences and technology of six students studying for a Masters in mechanical and electrical engineering in Tunisia.

The concept of the norm is the last point we would like to broach from the Canguilhem perspective in the relationships between science and the technical. Canguilhem elaborates the concept of the normal in response to the problem of the relationships between the history of therapeutics and

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[17] Science "*is the work of reducing provoked by the failures of the creating power*" that is the technical (Canguilhem & Planet, 1939, p. 175-176).

[18] Concept introduced by Jürgen Habermas (1973).

[19] Dominique Lecourt and Michel Foucault attribute a political dimension to obstacles, which leads them to denounce the government of men and the false sciences of man.

the history of physiology. In opposition to a positivist quantitative conception according to which the normal would correspond to a statistical average which should be restored in pathological situations, Canguilhem establishes that the characteristic of the normal is to be normative, that is the promoter of its own norms. Macherey summarizes the principal thesis of *Le normal et le pathologique* as follows: "*it is not life which is subjected to norms, these [norms] act upon it from the exterior, but norms, in a completely immanent manner, are produced by the very movement of life*" (Macherey, 1993, p. 288). On resuming his work, Canguilhem uses this property of the living at a starting point, which enables him to revise the notion of health and illness, to ask if the fact "*of thinking the norm against a background of normativity rather than against a background of normality, can be extended from the vital to the social*" (*ibid*., p. 292). This is the perspective which Grégoire Molinatti adopts, in this issue of RDST, to investigate the interactions between "*scientific norms*" and social norms in the discourse of researchers participating in debates with high school pupils concerning the use of human embryo stem cells. This issue brings us back to the starting point of this section, that is, the intrication of the relationships between science and society.

Conclusion

With Bachelard, Canguilhem and Foucault, we are dealing with the epistemology of the concept, and seeking to understand the way in which scientific concepts have been historically built. From a didactic point of view this can provide us with directions to reflect on the conditions of possibility for enabling pupils to construct scientific concepts from their representations which update, in the school context, certain opinions or common knowledge.

It can be seen that, starting from the inaugural Bachelard rupture, the employment of the concepts of historical epistemology enables the conceiving of didactics between rupture and continuity: Scientific knowledge is a rupture from opinion or common knowledge, yet a continuity of problematics exists. Similarly, the relationships between science and society are also envisaged within a didactic conception of independence and interdependence. This enables the continuators of Bachelard and Canguilhem, such as Dominique Lecourt, to apply the concepts of historical epistemology to socially sensitive scientific issues (Lecourt, 1990, 2009).

As Anne-Marie Moulin reminds us, it is in relation to the didactics of rupture and continuity that "*the sociology of sciences appears to be both insufficient and indispensable*" (1993, p. 126). Moulin (*ibid.)* then clarifies the position of Canguilhem who refuses both a strictly internalist approach to science and an exclusively externalist approach (science seen as yet one more product of society).

The science studies movement develops a different epistemological position which we shall present below. This approach will lead to the construction of the problem of the relationships between sciences, societies and knowledge from a different perspective, enabling the development of another theoretical framework to envisage these relationships.

1.2. Opinion and knowledge in the social sciences

The researchers developing this approach note a profound modification in the status of sciences in the 19th century and take this as their starting point: "*The idea of an objective Science founded on the ideal of the excluded outsider, the "scholar" who cuts himself off from the object of his study, was shattered at least at the beginning of the 20th century, particularly with quantum physics and Heisenberg's principle of uncertainty. The implication of the scientist (whether he claims it or not) in his object also means that the knowledge produced is located, intersubjective and results also from compromises between its authors and between these [authors] and the institutions which finance them*"[20]. Dominique Pestre defends the idea that "*the last three decades have seen the implementation of a new regime of production, appropriation and regulation of sciences in society, a regime that has strongly broken with the history of the preceding century and a half*"[21]. The consequence of this is the overturning of the relationships between sciences and societies. In order to better understand the evolution of these relationships, on the one hand, and the relationships between researchers and the public, on the other, we shall review several important stages in the evolution of the Public Understanding of Science (PUS) movement.

The contribution of the Public Understanding of Science (PUS) movement

In his "Launch perspective" to the first issue of the journal, *Public Understanding of Science*, John D. Miller (1992) provided a brief survey of thirty years of research into PUS. He first refers to a survey entrusted to Davis by the National Association of Science Writers and the Rockefeller Foundation[22] (Davis, 1958). The objective was to use a sample of 1300 American adults to ascertain the nature of the public's expectations concerning scientific popularization. The questions, which mainly dealt

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[20] Claude Vautier (2007).

[21] <http://erstu.ens-lsh.fr/spip.php?article192>

[22] See also on this subject: Lewenstein (1992).

with attitudes towards science and technology, were supplemented with tests of knowledge on the understanding of the principle of vaccination.

The first of the biennial survey reports, the Science Indicators, destined for Congress, was published in 1972. A chapter of these reports deals with the attitudes of the public towards science and technology. Perceiving misgivings in certain sections of the population towards scientific research policies and thus their funding, and subsequent to certain methodological criticisms formulated by The Social Science Research Council (SSRC), from 1979, the National Science Board, in its role as the scientific committee of the National Science Foundation (NFS) in the United States, promoted a second series of statistical inquiries in order to gain better knowledge of how the public perceived science: interest and attitude towards science and the nature of controversies, particularly concerning nuclear energy[23]. Miller would propose the concept of "*issue attentiveness*", which comes from political science and proposes a typology of publics according to their interest in scientific and technological policy and whether the individuals consider themselves to be well-informed on these issues or not. 1979 was also the year of the introduction of items concerning the acquisition of specific knowledge. This enabled Miller (1983) to evaluate "*scientific literacy*", that is, the quality of scientific popularization[24]. This first study enabled him to define what he meant by the expression "*scientific literacy*". There are three aspects covered by this term:

– The appropriation of scientific vocabulary and concepts;
– The comprehension of the processes of science;
– The consciousness of the impacts of science on individuals and society.

These aspects were evaluated in the studies which followed in 1985, 1988 and 1990 as well as in other countries: England (1988)[25], Canada (1989), Europe (1989) and New Zealand (1990). From 1992, following the initial impetus imparted by John Miller, this method was widely developed in Europe with the Eurobarometers, then in the USSR (1996), China and

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[23] According to this study, in 1979 approximately 20 % of the adult American population was very interested in science and technology, 20 % had a certain interest, and the remaining 60 % had no interest in this subject.

[24] John D. Miller is a central actor in PUS research and the scientific literacy movement, in particular. His message is based on the numerous publications and concepts which he has proposed. Globally, his work is to be found in the "current agenda", an approach which is based on the knowledge deficit model. See, in particular: Miller, J.D. (1983 a, b) (2003).

[25] As early as 1985, the British Association for the Advancement of Science in collaboration with the Royal Society and the Royal Institution created the Committee for the Public Understanding of Science.

Japan (2001), India and Malaysia (2004), Canada (2005) and Korea (2006).

These studies have been the object of numerous methodological criticisms: closed questions, restricted choice of subjects reflecting certain concerns and dominant conceptions among the experts and the public authorities behind these inquiries (Irwin, 2001). Although one of the major interests of such inquiries is their realization on a very large scale, when they are carried out in countries with different languages and cultures, one may consider that there is a major fault linked to the difficulties of translation and/or interpretation of certain terms which vary from one language to the next (Cheveigné, 2004). On a methodological level, although the authors do not completely espouse this view, we find very similar aspects in the contribution by Jérémy Castéra and Pierre Clément. Their work is part of a vast research project (BIOHEAD-Citizen) which applies a comparative approach to 19 countries (from the north of the European Union to North Africa as well as Lebanon and Senegal) in order to discover how sensitive topics, such as health education, evolution and environmental education[26] are taught. More specifically, this article makes reference to the study of the interactions between scientific knowledge and values in the conceptions of 732 French teachers concerning the genetic determinism of human behaviour. The work presented in this article is based on a questionnaire made up of 168 items but exploits the replies to the 31 items related to the "human genetics" theme, replies which are sometimes cross-referenced to individual parameters.

Another criticism of the Science Indicators is formulated by Wynne (1992) who deplores the fact that certain contributions of Science and Technology Studies (STS) are not sufficiently taken into account within scientific literacy, particularly the understanding of scientific processes and the consciousness of the impacts of science on individuals and society[27]. He concludes that the Science Indicators focus too often on one point: the

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[26] In their article, Jérémy Castéra and Pierre Clément state that "the questionnaire was constructed through two years of collective work, taking the necessary methodological precautions for its validation: pre-test, test of the stability of replies, complementary interviews, analysis of the replies to a pilot test then choice of the discriminating questions".

[27] Albe (2009) provides this clarification: "Particularly in the 1980s, the Sciences-Technologies-Sociétés (sciences technologies societies) movement later renamed SciencesTechnologies-Sociétés-Environnement (sciences technologies societies environment) proposed that the teaching of sciences should be inserted into a context which was wider than the strictly school one. But the efforts to implement science curricula inspired by the STS perspective were undermined in favour of the re-introduction of traditional teaching (Jenkings 2002). On this topic, certain authors have shown how scientists organized themselves so that these innovative aspects were removed from the curricula (Blades 1997)".

appropriation of scientific vocabulary and concepts.

Finally, from an epistemological point of view, it should be specified that these inquiries find their coherence in the PUS approach, based on the deficit model which opposes scientific knowledge obtained by researchers and/or experts to what the general public knows, fraught as it is with beliefs and superstitions[28]. The supporters of this model think that the deficit in scientific knowledge of the public leads it to adhere to irrational discourse which sometimes tends to reject any scientific approach[29]. For the researchers of this movement – mostly North Americans – educating the public is the recommended solution. This is the context in which the American Association for the Advancement of Science (AAAS)[30] developed the scientific literacy movement which subsequently became known as *Alphabétisation scientifique et technique* (AST)[31] in the French-speaking world. According to Fourez (2002), AST aimed above all at training the citizen to the detriment of training the future scientist "*courses aimed at a scientific career are declined into physics, chemistry and biology. Those aimed at training the citizen talk of environment, pollution technology, medicine, space conquest, history of the universe and the living*" (Fourez, 2002, p. 111). This led him to propose that "*the perspective of the scientific literacy [training] can be expressed in terms of humanistic, social and economic finalities*" (*ibid.).* This point of view on the finalities of AST was shared by Johsua (1994) who, without making explicit reference to the deficit model, stated that "*the relative distance from the level which needs to be reached to escape from the dictatorship of the "scientific experts" so as to ensure the strict minimum of control by the citizens required for democracy is without substance, this distance is ceaselessly increasing*" (Johsua, 1994, p. 42). In the same article, he explained that, given that there is technical skill pertaining to scientific and technological knowledge to be mastered over the long term, only school

[28] Callon M. (1999).

[29] Bensaude Vincent (2003) very clearly opposes this point of view. She claims that the critical attitudes of the public are not dependent upon the deficit model but much more upon the public's critical representation of the sciences/expertise relationship. This point of view is shared by Pestre, who thinks it too simple to talk of public mistrust towards sciences and even less of the emergence of a new irrationalism. He defends the idea that there is, on the contrary, a strong link between the expectations of the public concerning sciences and their means of production and regulation. Text available online at: <http://erstu.ens-lsh.fr/spip.php?article192>.

[30] The role of the American Association for the Advancement of Science (AAAS) is to promote the teaching of sciences at an international level.

[31] This theme, *Alphabétisation scientifique et technique*, was the object of the *XVIe Journées internationales sur la communication, l'éducation et la culture scientifiques et industrielles* in 1994. It was also analyzed in the work of Fourez (1994).

could provide the nodal point for the reflection on this acculturation "*because, as Vygorski has already indicated (undoubtedly exaggerating a little), this knowledge, in distinguishing itself from everyday knowledge through a strong demand for coherence and the reduction of polysemy of the terms employed, subsequently rendered intentional learning, that is school [learning],unavoidable*" (Johsua, 1994, p. 39).

Within this framework, the AAAS proposed an ambitious program entitled, Science for All Americans, the objective of which is to specify what each student should know on scientific thematics[32].

From the Public Understanding of Sciences to Science and Technology Studies (STS)

Jean-Marc Lévy-Leblond (1992) clearly opposed this knowledge deficit model stating, first of all, that, given the high degree of specialization of present sciences, scientists, who do not belong to a given area, find themselves in the same position as non-scientists when confronted with the issues and stakes of this area. To illustrate this point of view, he takes the example of the short-term and long-term health risks associated with the nuclear industry. He explains that an exact understanding of the situation necessitates technical, medical and economic knowledge. Confronted with the complexity of these issues, sometimes even with the uncertainty of some of the answers formulated by scientists, and, therefore, with the impossibility of possessing an individual mastery of societal problems, Levy-Leblond claims that there can thus be no rift between scientists and non-scientists. In this issue of RDST, Grégoire Molinatti reaches the same conclusion by analysing the communication discourse of researchers expressing the relationships between scientific knowledge and opinion concerning the status of the embryo. He shows that "*researchers make little mention of the scientific norms, under construction, which could be liable to "mark the boundaries" of the definition of the embryo*", even though "*the area of neurosciences is structured by a paradigm of reduction of mental states, conscience, rational thought and thus individuation to their physiological correlates*". Levy-Leblond is opposed to the paradigm of rupture between scientists and non-scientists concerning issues raised by opinion and so he expressed the desire to abandon the project of the Age of Enlightenment to ultimately accept a relative ignorance of all the actors of society, a prerequisite, according to him, to a more democratic practice of scientific activity.

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[32] For more information, consult the online resource: <http://www.project2061.org/publications/sfaa/>.

Within PUS, inspired by Wynne (1992), in particular, certain researchers reacted to the deficit model by favouring the taking into account of the context of social interactions. This leads them to propose another approach belonging to Science and Technology Studies (STS). Wynne (1992) considers that studies which attempt to evaluate the nature of knowledge and ignorance of both laymen and scientists are not relevant. He proposes a focus on the apprehension of the contexts of social interactions in which this knowledge is employed, followed by an integration of these contexts into the process of evaluating the scientific knowledge of the public. To illustrate this point, he relates the example of workers employed at a nuclear reprocessing plant at Sellafield in England. He justifies the fact that if these workers do not seem to be particularly aware of notions of radiation it is because, within their company, they consider this to be incompatible with the implementation of a chain of confidence uniting the different actors of this plant – engineers, technicians and workers. Wynne introduces the concept of active ignorance to designate this ignorance assumed by certain actors implicated in a complex social construction of interdependence, particularly at the level of the continuity of their employment. This most definitely does not mean that these workers do not elaborate their own knowledge of this subject. Wynne therefore proposes going beyond the deficit model since what, from a strictly cognitive point of view, scientists consider to be incomprehension of science by the public, can indeed represent a de-contextualized evaluation of knowledge.

Callon (1999) proposes three models to present the role of laymen in the elaboration and the dissemination of scientific knowledge:

– The model of public instruction (deficit model) within which scientific knowledge is opposed to the irrational beliefs of a public which must be educated
– The public debate model: laymen are invited to give their points of view and to communicate their experiences
– The coproduction of knowledge model: laymen participate directly in the elaboration of knowledge which concerns them and upon which their well-being and identity often depend.

At the end of the article Callon suggests that the third model should be generalized, thus offering an exit from the crisis of public confidence towards experts.

These two movements of thinking on the diffusion of sciences, as they were defined in 1992, have contributed to structuring the area of scientific communication at the international level. The deficit model thus organizes the rupture paradigm[33] which dissociates scientific knowledge from non-scientific knowledge whereas, within the STS movement, Jacobi (1984) proposed the continuum paradigm, or the paradigm of the socio-diffusion of sciences. Francophone research into socially sensitive issues (quite close to the Anglophone socio-scientific issues) developed within this same movement (Simoneaux & Jacobi, 1997; Simoneaux, 2001; Simoneaux & Simoneaux, 2009; Albe, 2009). The contributions to this issue of RDST by Virginie Albe and Adel Bouras, on the one hand, and Molinatti, on the other hand, can be totally integrated into this movement of PUS.

Public Understanding of Research (PUR)

Following on from this work, while remaining within the PUS movement, a Public Understanding of Research (PUR) movement developed. This was initiated at the end of the 1990s by Hyman Field, Director of Informal Education at the National Science Foundation. Field & Powell (2001, p. 63) defined PUR "*as public education that helps laypeople understand what current research is being conducted; helps them consider what the social, ethical, and Policy implications of new findings might be; and helps them to recognize the importance of continued support for both basic and applied research*". There also exists a second definition of PUR, which has been less formalized by researchers but which has definitely been more often acted upon: this aims at helping the public understand the processes of research. Finally, Field and Powell explain that, within the framework of PUR, one must insist much more on what is not known than on the presentation of known knowledge.

Shapin (1992) proposes a similar approach entitled "science in the making" which consists in explaining to the public not only what scientists know but also and above all how they came to know it and with which degree of certainty. In order to achieve this end he proposes to show:

– That scientific knowledge is the fruit of collaboration among researchers who each possess a portion of the knowledge
– That scientific subjects, like all other subjects, are under the influence of unknown quantities, luck and mistakes, in short, that science is not infallible
– That scientific conclusions are the consequence of the interpretation of results and that they are thus just as subjective as other elements of knowledge, etc.

[33] The word "rupture" is used here with to signify a rift between researchers and the public. It does not refer to "rupture" as used by Bachelard which was defined in the first part of this presentation.

Using the greenhouse effect as his example, Shapin supports his point of view by asking the following question: how could people lacking scientific competences decide which position they wished to adopt when they are presented with diverging expert opinions without an explanation of why they diverge? He pursues this line of reasoning by explaining that there would be a major risk if the public were to think that one of the formulated opinions was the opinion of scientists who were incompetent and/or who refused to tell the truth for partisan interests.

In this survey Virginie Albe and Adel Bouras propose a contribution close to this movement. These authors seek to identify the knowledge mobilized by students who, once they have analysed a file of documents about the controversy over the peak in petroleum production which was compiled by student engineers of the *École des Mines de Paris*, are asked to write a study of the controversies arising from nanotechnologies. While Shapin (1992) defends his viewpoint by explaining that: "*Some fairy-tales would have the public believe there is a universal efficacious scientific method which sorts out good from bad data and confirms or disconfirms scientific theories*", Virginie Albe and Adel Bouras explain that "*the issue of access to a diversity of knowledge in our mediatised societies is also raised, particularly when individuals or groups are confronted with socio-scientific controversies, for which different actors elaborate argumentation and in which no one is in a situation to pronounce the 'truth' which would close the debate*".

This bias has undeniable consequences upon the implementation of educational policies, even within natural history museums and science centres. A study carried out in Australia (Rennie & William, 2002) shows that when adult visitors leave a science centre they are more inclined to claim that scientists always agree with their colleagues, that scientific knowledge is certain and immutable and, finally, that science has an answer to every problem of society. Durant (1992, 2004) explains that, until the 1990s, natural history museums and science centres presented stabilized scientific knowledge, which he calls "finished science". Since the early 1990s[34] and, above all, since the first decade of this century, certain museums have started presenting debated scientific knowledge or "unfinished science" (Durant, 2004), a term which is close to Shapin's "Science-in-the-making" the expression used by Legardez & Simonneaux

[34] Take, for example, the exhibitions presented during the 1990s at the London Science Museum, or the Science Museum in Boston, then the opening in 2000 of the Wellcome Wing (Science Museum in London). More globally, one should note the first colloquium: "Museums, Media, and the Public Understanding of Research" held at the Science Museum in Minnesota in September 2002.

(2006) “socially sensitive issues”. The taking into account of these aspects necessarily leads to profound changes in the practices of museums which can no longer claim to present the truth, nor to have the answers to all the questions. As an illustration of this aspect, we shall use a small temporary exhibition held in the London Science Museum in the 1990s. This exhibition dealt with the effects of passive smoking on people’s health, an issue which was subject to much debate within the research community. The organizers were most explicit in stating that these effects were the object of research, that the experts were in total disagreement over the conclusions which could be reached from the experiments which had been realized and that there were also numerous pressure groups defending various conflicting points of view (Durant, 2004). It should be noted that the organizers chose to state that, in preparing the exhibition, they had been led to favour one of the points of view, and thus adopted the committed impartiality stance of Kelly (1986), that is, encouraging the expression and confrontation of varied points of view while stating one’s own opinion.

We shall now focus our attention upon another problematic, that of the recent awareness among the international community of the relevance of local nature knowledge which has proved to be efficient, particularly in the management of the environment. This knowledge is often associated with identity-related, political and legal demands but has changed status, becoming heritage knowledge, in the cultural or immaterial sense, which gives rights to property and thus rules of access[35] which are a first obstacle to transmission. This patrimonial specificity of this knowledge has other consequences on the learning methods which are sometimes based on the observation of the members of the group and sometimes on observations involving strong ritual constraints, rendering their presentation within the school framework impossible.

1.3. Local natural knowledge

Recently, the natural knowledge of local populations has been attracting a lot of interest. Previously this local knowledge relating to nature was denigrated and considered to be esoteric or amalgamated with shamanism. More often than not defined as popular knowledge, it has been celebrated by various authors under a host of names since the 1980s. In some cases, the means of transmission and the strong insertion within tradition are stressed; this is the Traditional Ecological Knowledge

[35] Some define this knowledge as “collective cultural heritage” which implies that one must belong to a community in order to hold and/or use this knowledge or know-how, as is the case for the Aymara

(TEK). Other authors focus on the influence upon the status of the knowledge holders and thus refer to Indigenous Knowledge (IK). Yet others underline the geographical implications of this knowledge and talk of local natural knowledge.

The entire set of knowledge types "are the expressions which are most often used to designate a disparate set of popular knowledge about nature (agricultural and pastoral knowledge and know-how, local varieties and races, medicinal practices, etc.)" (Roussel, 2005, p. 83). This knowledge has been the subject of particular attention since the Rio Conference (UNCED, Rio de Janeiro, 1992) and the subsequent 1995 Jakarta Conference, as is stipulated in Article 8 of the Convention on Biological Diversity: "Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices" (Article 8 J of the CBD, Rio de Janeiro, 5th June 1992).

We shall use an example to clarify the nature of this local knowledge. In ethno-botanical research conducted among the Jotï and Piaros Indian populations of Venezuelan Amazonia, Stanford (2009) stressed that the Piaros use at least 75 suffixes to categorize and determine the plants which they use and to which they attribute the characteristics of habitat and ecological associations. Zent (2001) showed that the Piaros possess knowledge of this primal forest enabling them to identify 220 vegetal taxa of which 180 have medicinal uses[36]. To identify these taxa, they employ anatomical characteristics such as the bearing of the tree, the nature and colour of the bark, the odours of the roots, barks, leaves, flowers and/or the resins produced by certain plants. All this contextualized knowledge, which is based on very acute observation of the cycles of the seasons, the cycles of the moon, marine currents, winds etc. (Stanford, 2009, p. 75), is efficient knowledge which has enabled numerous populations, in specific contexts, to live harmoniously with their environment while respecting their own representation of the workings of the world or even in relation to a cosmogony (Dugast 2009).

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in Peru.

[36] We use the term taxon which has a wider meaning than species.

This knowledge has sometimes been likened to magic thinking or "a timid and stuttering form of science". However according to Levi-Straus (1962, p. 26)[37], "Magical thought is not to be regarded as a beginning, a rudiment, a sketch, a part of a whole which has not yet materialized. It forms a well-articulated system, and is in this respect independent of that other system which constitutes science, except for the purely formal analogy which brings together and makes the former a sort of metaphorical expression of the latter. It is therefore better, instead of contrasting magic and science, to compare them as two parallel modes of acquiring knowledge. Their theoretical and practical results differ in value, for it is true that science is more successful than magic from this point of view, although magic foreshadows science in that it is sometimes also successful. Both science and magic however require the same sort of mental operations and they differ not so much in kind as in the different types of phenomena to which they are applied". Levi-Strauss clarifies his position (p. 24) stating that "the first difference between magic and science is therefore that magic postulates a complete and all-embracing determinism. Science on the other hand is based on a distinction between levels: only some of these admit forms of determinism; on others the same forms of determinism are held not to apply". To illustrate this point Levi-Strauss (Levi-Strauss, 1962, p. 23) quotes Hubert and Mauss (1950) who provide the example of a man who slept in a wheat loft undermined by termites only to be buried under it, when it collapsed; he explains that the Azande say that the collapse of the wheat loft is a cause which combines with witchcraft to kill the man. In this case, witchcraft is not responsible for the collapse, but is the reason it happened when a particular individual was inside the wheat loft. Magical thought "can be distinguished from science not so much by any ignorance or contempt of determinism but by a more imperious and uncompromising demand for it which can at the most be regarded as unreasonable and precipitate from the scientific point of view" (Levi Strauss, 1962 p. 23). The means of constituting this knowledge is also different and, concerning this topic, Albe (2009), Jimenez-Aleixandre & Pereiro Munoz (2002), and Kolstø (2000) explain that scientific knowledge is established through consensus following phases of critical examination, argumentation, discursive practices and questioning, phases which ultimately lead to peer evaluation. Another major difference between scientific and local knowledge may also be noted: the former claims a universal vocation whereas the latter is self-

[37] See the first chapter (particularly p. 11-13 of the Chicago University Press, paperback edition) of the English translation: *The Savage Mind*.

contained and often proposes explanations which are far removed from current academic knowledge[38]. However, unlike the latter, it takes shape within the framework of an inclusive explanation. This can be seen in the theory of the genesis of colours amongst the Bwaba of Burkina Faso which are "elaborated from elements drawn from different registers: the vegetal universe and the animal kingdom (the chameleon) are amply solicited, but the representations at work in matters concerning cosmogony, the origin of the world, are equally called upon. Shared by all members of society, such symbolical elaborations are nevertheless above all produced by one of its components, the blacksmith cast" (Dugast, 2009)[39].

1.4. Conclusions

We have highlighted different epistemological positions in order to account for the relationships between knowledge and opinion:

– A rationalist epistemology which enables one to understand, from a historical point of view, how scientific concepts are constructed. This epistemology is based upon the idea of a rupture between scientific knowledge and opinion, taken in a psychological and individual sense, even if, behind this rupture, there may be a continuity of problematics as is shown in *La Formation du concept de réflexe* by Canguilhem;

– An epistemology which uses science studies in order to understand the relationships between knowledge and opinion and which aims to clarify the opposition between, on the one hand, the paradigm of rupture, which dissociates scientific knowledge from lay knowledge, and, on the other hand, the paradigm of the *continuum* or the socio-diffusion of sciences;

– A rehabilitation of popular knowledge, Traditional Ecological Knowledge or Indigenous Knowledge which form a well-articulated system which, although it is independent of science, is no less relevant for the management of the environment.

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[38] In reality it is much more complicated since one could talk of constructing hybrid knowledge, the fruit "of a dialogue" between scientific and local knowledge which is not fixed in time.

[39] "Bwa society has long been characterized by the strong community aspect of its social organization […] the vast Bwa village communities are not less affected by fierce non-egalitarian relationships, which are just as fundamental in their social structure and the construction of their cultural representations: those which arise from the cast system which divide society into three endogamous socio-professional groups – the casts – between which there is a powerful hierarchy based on the attribution to each specialized professional activity of esteemed or on the contrary despised qualities. Such a division, which ranks groups according to their dominant professional activity, is naturally propitious for the elaboration of quite learned discourse on the theme of colours by the group whose members are the most engaged in a constant relationship with the matter: the blacksmiths" (Dugast, 2009, p. 246-247).

These different positions have direct consequences on didactic problematics, some of which are dealt with in the articles appearing in this issue of RDST.

2. … to didactic problematics

According to the epistemological positions adopted by the authors of the articles in this issue of RDST, the didactic issues tackled vary widely.

In order to maintain a modicum of continuity, we shall return to the topic of local knowledge and its transmission.

2.1. The transmission of local knowledge: which possible transmission?

In the context of globalization, although the question of the conservation of local knowledge and thus of its teaching seems crucial, it also raises issues of methodology. "*How can one be sure of maintaining it in contexts of modernization, often accompanied by rapid acculturation? How can one evaluate its relevance, its efficiency in managing and conserving bio-diversity? How can one ensure its transfer, transmission and application?*" (Chouvin *et al*., 2004, p. 11). Should it and can it be integrated into curricula? In certain communities, projects have been initiated to incorporate the content of indigenous knowledge into the school curriculum. However, are things that easy? Within these communities the principal method of learning is based on the observation of one's surroundings (Katz, 1986; Zarger, 2002) and the young freely choose the activities which they wish to undertake. This process is so diffuse that it is often not perceived as learning by the learners themselves (UNESCO, 2009, p. 6). This highlights different modes of acquisition/transmission: the school mode, which implies sitting in a class to listen and learn knowledge structured into subjects, and the immersive mode based on the experience acquired through daily contact with the environment and conducted by parents, or occasionally, grand parents (Zent, 2009, p. 52). Despite the difficulties mentioned earlier, the recent taking into account of these ethno-sciences by the international community, that is, giving equal treatment to the acquisition of local knowledge and to the acquisition of scientific knowledge, has sometimes enabled their joint transmission within curricula. In the context of Burkina Faso, Lewandowski (2007) highlights a certain number of obstacles to this teaching. Overly large classes (sometimes more than 100 pupils in primary classes) dictate frontal teaching which does not enable pupils to express their own ideas: "*in the ordinary school, in the daily class routine,* *local knowledge is rarely evoked, and when it is, it is essentially in order to de-construct that knowledge which is judged obsolete*". The tales which constitute the privileged tools of community pedagogy and which can be understood on several levels — narrative, philosophical and esoteric — are used in school textbooks in a denatured way: "*this is linked to the transfer into writing, but also to the pedagogical use to which they are put: tales are classified in numerous rubrics such as "school and family", "hygiene and health", which present texts of different inspirations in order to raise the child's awareness of behaviour which is judged positive*" (Barry *et al*., 1996). However, Lewandowski, showed in his thesis that "*the new culture which seeks to associate local knowledge and school knowledge is today presided over by the developmental norms which are partially variable according to the fund providers*" (Lewandowski, 2007)[40].

The "*Proyecto Ninez y Diversidad Cultural*" program implemented since 2002 by PRATEC (*Proyecto Andino de Tecnologías Campesinas*) can provide an example of the intrication of scientific and local knowledge within a curriculum. According to the program leaders, pupils should acquire both local nature knowledge and the basics of scientific and technical information, both at school and within the community they live in. The finality of this program is to teach reading and writing as well as to reassert the value of local traditional knowledge of ecological, social and spiritual aspects. From a list of seven objectives we have retained four which are close to our concerns:

A - To engage in the conservation of bio-diversity by re-creating the ecological equilibria and the agro-bio-diversity though the implementation of school vegetable gardens.

B - To improve the diet of pupils by privileging the use of local products cultivated in school or family gardens. This favours the taking into account of social, ecological and spiritual aspects.

C - To enable exchanges between modern knowledge and local knowledge within the curricula. This dialogue between types of knowledge should be carried out with the participation of the community within which the pupils live.

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[40] The author refers to a system of production of educational knowledge in numerous countries from the South, particularly in African countries which, given the difficulties they have in providing education for very rapidly rising numbers of children, form ties with infra- and supra-national technical and financial partners belonging to the development milieu. The author explains that these institutions develop and seek to diffuse developmentalist discourse and norms which are referenced against a desired social change in the countries from the South. Finally, she explains that one can follow the historical variation of these norms (for instance, in the ways of apprehending local knowledge or bio-diversity by examining the institutional texts of these partners and their traces in the curricula and textbooks).

D - To organize periods for the young boys and girls but also for teachers and peasants in community properties so that they may have other experiences. These periods should improve the agro-bio-diversity which exists in the peasants' gardens both through the acquisition of new agricultural practices and through the exchange of seeds and peasant know-how linked to their use.

These objectives underline the strong integration of this bio-diversity teaching program within the pupils'community. This educational project adopts an intercultural approach, as defined by Rengifo (2005, p. 3-46), based on the transmission of knowledge by the elders, on the one hand, and upon the overcoming of the duality of local and scientific knowledge, on the other.

For all this, it should not be considered that the problematics of local knowledge only concern the Southern countries. In the context of the management of bio-diversity, in particular, very similar aspects can be found in the Northern countries. Currently, within the framework of an ANR[41] project, research is being undertaken into the transfer in agricultural education of the modelling of multi-agent systems developed by the ComMod research network. The process which is based upon the modelling of not only the scientific but also the local knowledge of the different actors is followed by a simulation with these different actors (farmers, environmentalists, foresters, hunters, elected representatives, etc). The ComMod group has applied its approach to varied problematics (allocation of agricultural land, water management, conservation of bio-diversity, fire prevention) and in very diverse environments (the Grands Causses steppe-like grasslands, Mediterranean forest, large cereal-producing plains, Mediterranean reed-marshes, peri-urban areas etc)[42].

2.2. The transmission of scientific knowledge in the school context

The function of school is to transmit knowledge to the new generations of pupils. However although there is transmission of knowledge from one generation to the next, most research shows that this cannot be the transmission of one element of knowledge to one individual. Herein lies the key psychological dimension of constructivism which "*stresses the fact that it is the subject who is learning who constructs her/his knowledge*" (Astolfi, 2008, p. 127). This psychological constructivism augments the

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[41] ANR ED2AO. The ANR is a French national research funding agency.

[42] <http://cormas.cirad.fr/ComMod/ Collectif ComMod>. 2006. Modélisation d'accompagnement. In Amblard F. and Phan D . *Modélisation et simulation multi-agents: applications aux sciences de l'homme et de la société*. London, Hermes sciences, p. 217-222.

constructed dimension of scientific knowledge revealed by the historical epistemology of Bachelard and Canguilhem. Since scientific knowledge is constructed outside the area of the pupils' daily life experience, the function of school consists in ensuring the transmission of this knowledge, that is, enabling pupils "to *appropriate cultural content through sorts of "didactic shortcuts"*" (Brossard, 1998, p. 39). The articles by Jean-Yves Cariou, Patricia Crépin-Obert and Julie Gobert attempt to answer this question by confronting this doubly constructive dimension with a third constructivism: a pedagogical constructivism (Astolfi, 2008, p. 129-131).

Before examining the didactic strategies developed by the authors of this issue of RDST, we shall attempt to cast some light on the articulation between epistemological and psychological constructivism which subtends pedagogical constructivism. To this end, we shall present a possible articulation between the epistemological positions of Bachelard and the work of Vygotski (Lhoste, 2008).

For Vygotski, the distinction between scientific concepts and daily life concepts (or scientific knowledge and opinions or common knowledge) resides in different levels of generalization (scientific concepts are organized into systems) which leads to dialectic relationships between them (Vygotski, 1937/1998). The rupture between common knowledge and scientific knowledge at the epistemological level can thus intersect with the rupture, at the psychological level, between scientific concepts and daily life concepts. Vygotski explains this by the fact that scientific concepts are, on the one hand, organized into systems and, on the other, the product of a culture and thus shaped outside the pupils' area of experience[43]. In contrast, where Bachelard sees a rupture: "*popular knowledge cannot evolve*" (1949/1998, p. 107) and a definitive cohabitation of common and scientific knowledge, even within the researcher who is "*ultimately a man provided with two behaviours*" (*ibid*., p. 104), Vygotski envisages a dialectical relationship (rupture and continuity) between scientific and daily life concepts which do not represent themselves as static states but as two dynamic poles (Vygotski, 1937/1998). Therefore both daily life and scientific concepts develop and school learning plays a determining role in this development (*ibid.).* This relationship allows us to talk of continuity between scientific and daily life concepts.

Therefore, the epistemological and psychological contributions demonstrate that school learning is clearly placed within a

[43] Even if no trace of the idea of an epistemological rupture is to be found in Vygotski.

rupture/continuity dialectic at both the epistemological and psychological levels. This rupture/continuity dialectic which is at work in scientific learning in school is examined in the articles by Jean-Yves Cariou, Patricia Crépin-Obert and Julie Gobert featured in this RDST survey.

Jean-Yves Cariou uses the aphorism of Giordan & De Vecchi (1987) concerning the initial representations of pupils, "*making do with to go against*", to present the tool, DiPHTeRIC, which modelizes a scientific approach for school aims. He follows the evolution of pupils' answers before and after a year's learning using the DiPHTeRIC approach. Even if, following the reasoning of Canguilhem who declared that "*the idea of experimental method is an intellectual monster*" [44], one might have epistemological suspicions about a "*universal*" [45] scientific approach, Jean-Yves Cariou's proposition provides teachers with a framework which enables them to lead pupils to set their initial conception to work for learning purposes. This proposition attempts to present a model which is neither linear nor unique: "*the plan of the core of PhyTe clearly shows its absence of linearity which definitely does not lead to claiming that there is a single approach in science*". By proposing the DiPHTeRIC, tool, Jean-Yves Cariou poses the question of pedagogical approaches in the science class in a new way[46].

The research of Patricia Crépin-Obert and Julie Gobert can be seen as the pursuit of a line of research into scientific learning processes which has been presented in the journal *Aster* since 1985. At the centre of the investigation carried out by these two authors one finds the concept of the obstacle (following on from the work of Jean-Pierre Astolfi and Brigitte Peterfalvi, 1993, 1997) and the concept of problematization (following on from the work of Fabre and Orange, 1997; Orange; 2003). They are thus in direct continuity of the research published in the following issues of *Aster* 20 (Representations and obstacles in geology), 24 (Obstacles: didactic work), 25 (Teachers and pupils faced with obstacles), 40 (Problem and problematization), and 44 (Sciences and narrative). The reasoning of pupils, during moments of scientific controversy in class, is analyzed in order to identify how certain daily life reasoning of common knowledge can become obstacles for the construction of scientific concepts (problems) targeted by teachers. In

[44] Canguilhem said this during an interview with Charles Mazières, professor at the *Faculté des sciences* of Paris-Orsay, director of the mineral chemistry laboratory of the *École nationale supérieure de chimie*.

[45] Thom states that "the experimental method is a myth" (1983).

[46] This criticism of school scientific approaches has given rise to research into the didactics of

so doing, these two authors place their research within the framework of recent studies into the function of scientific debates in learning (Buty & Plantin, 2008; Schneeberger & Vérin, 2009).

Using a comparative study of historical and school controversies[47], Patricia Crépin-Obert shows that although the obstacle of artificialism intervenes in both controversies it does not have the same function in them.

Julie Gobert uses an epistemological analysis of the concept of biological development, which is being completely reshaped at a scientific level (Kupiec, 2008), to endeavour to understand the intrication between the obstacle of the "*molecular preformationism*" and the process of problematization of the concept of development by senior high school pupils majoring in sciences (*Première S*). This enables her to pose (following Lhoste & Peterfalvi, 2009), the question of the relationships between problematization, obstacle and problem.

It is worth noting that these studies are from the field of life and Earth sciences and that no article was submitted from the field of physics and chemistry although the first research into both the role of daily life reasoning in scientific learning (Viennot, 1979) and into scientific debates in class (Johsua & Dupin, 1989) came from this latter field.

The last two articles presented seek to understand under which conditions pupils can construct scientific concepts in the school situation. This constitutes a necessary stage in precise reflection concerning the construction of teaching scenarios in relation to Astolfi's third constructivism, the pedagogical constructivism: "*The function of teachers is to propose facilitating but non substitutive mediations. They have to elaborate constructed devices and calculated situations, which are adapted to the cognitive structures of pupils which they simultaneously transform*" (2008, p. 131). However, for the devices to be adapted (processes and approaches in the context of current curriculum re-shaping) and their mediation to be facilitating (work on the professional acts of teachers, didactic analyses of the teachers' activity) exact knowledge of learning processes (referred to norms) seems a prerequisite. It is even a decisive stake in training within the framework of the implementation of Masters in Teaching in the universities.

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sciences (Astolfi et al., 1978).

[47] Along a line of research which will be developed in the survey to appear in issue 3 of RDST (2011) which deals with the relationships between didactics and the history of sciences (issue coordinated by Cécile de Hosson and Patricia Schneeberger).

2.3. Between knowledge and opinion, dealing with socio-scientific issues at school

The introduction of teaching to deal with socio-scientific issues has taken place progressively, initially in the Anglo-Saxon countries from the 1980s or thereabouts (Zeidler, 1984; Driver *et al*., 2000; Kolstø, 2000). The typology established by Kelly (1986) concerning the stances of teachers (from exclusive neutrality to committed impartiality) underlines the acuteness of the issues raised in the 1980s and which remain pertinent today since, even in the context of education related to the environment and/or sustainable development, teachers find it difficult to tackle non stabilized knowledge. This is highlighted by Audigier (2001) and what he terms the model of the 4 Rs (Realism, teaching the Results only, according to a consensual Referent, and Refusal of the political).

However, socio-scientific issues which according to Albe (2009, p. 28) "*favour the emotional, moral and ethnic dimensions*" or the socially sensitive issues "*which have more recourse to the notion of debates bearing interests and values*" (*ibid.)* are, by their nature, issues which refer to non stabilized knowledge, knowledge which is the object of debate among researchers and within society. This should induce a reflection on the nature of this activity within school. These socially sensitive issues are most often linked to the choices of societies (energy, food, lifestyle, etc.) and refer to cost-benefit analyses thus implying a pluri-disciplinary approach and the understanding of uncertain future decision-making models (Girault & Girault, 2004). Astolfi (2008) explains: "*here, the difficulty is in knowing what should be debated and what should not. Kuhn would say that one must define the stable paradigm within which the controversies take on meaning if one does not wish to see non democratic ideologies dive into the breach of absolute relativism*". Given both the relevance of dealing with these issues in class and the great difficulty of doing so, more and more researchers have been investigating these subjects. Sadler (2004) proposed a first typology of this research along four structuring axes:

A - Research which questions the influence of the acquisition of scientific concepts on the reasoning of pupils.

B - Research which focuses more on the way in which pupils are capable or not of evaluating the relevance of information within a set of diverse and sometimes contradictory information.

C - Research which analyzes the links between the representations of science which the pupils or learners have when involved or engaged in making various socio-scientific decisions.

D - Research which investigates more the way in which pupils justify their opinions relating to a socio-scientific issue.

Like all typologies, this one can be criticized, in that much research, including some very recent work, deals with several aspects, particularly C and D. Other studies broaden the scope of Sadler's axes. In his thesis, Benoit Urgelli (2009), for example, shows how the opinions of teachers on climate warming can influence the logic underlying their didactic commitment concerning this socially sensitive issue within an avowed perspective of education for citizenship.

Albe (2009, p. 102) also explains that "some of this research explicitly refers to constructivism or socio-constructivism" […] "other research positions itself as a complement to the STS movement" […], finally other studies "refer to or mobilize the theoretical framework of situated cognition".

Finally, we should point out that research into Science and Technology Studies fires investigations in the areas of both environmental education (Girault 2005; Girault *et al.*, 2007; Girault & Sauvé, 2008; Lange, 2007, 2008; Simonneaux & Simonneaux, 2009b and 2009c) and in citizenship education (Debart & Girault, 2009) which particularly implies "*the development of values and skilfulness relative to decision-making concerning the use of science and technology with regards to a certain quality of society*" (Sauvé, 1997, p. 66). If further persuasion is needed, it can be found in the work of Kolstø who instigated the transposition of consensus conferences to teaching (2000). Finally we could say that Simonneaux (1995) introduced to France the question of socially sensitive issues when dealing with biotechnology[48], this theme still has strong current relevance given the research into topics such as nanotechnologies which are at the crossroads of approaches drawn from chemistry, physics and biology. The contribution to this issue of RDST by Virginie Albe and Adel Bouras is a case in point.

Conclusion

The call for contributions to this first issue of RDST was very/too ambitious and obviously the selected articles do not cover the entire "Opinion and Knowledge" problematic. With no intention of evoking the totality of the thematics which might have been tackled, it would appear to us that two essential aspects have not been dealt with by the authors who responded to our call. First of all, we would like to evoke the extreme

[48] Simonneaux (1995).

diversity of contemporary modes of appropriation/co-construction of knowledge which go well beyond the spheres of formal and informal teaching. This is the case for associations and/or NGOs which enable their members to acquire sometimes very specialized knowledge and also to share values and to forge opinions on thematics linked to agriculture, energy, the environment, public health, etc. Finally, we would like to refer to the very great possibilities for the diffusion and exchange of knowledge offered by internet forums which, in all likelihood, will contribute to profoundly modifying their users' relationship to knowledge, users who are capable of finding and diffusing a multitude of sometimes very contradictory information. This is most certainly the place to find new avenues to develop research into the teaching of sciences and the relationship between opinion and knowledge.

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