

Scientific Culture, Epistemology and Pedagogy

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ABSTRACT

The author proposes a revision of the epistemology as a key to understanding not only science but also the consequences of educating a scientific attitude that contributes to the formation of citizens with well-established criteria. Epistemology is not an exercise of thought aseptic, but entails criteria and reasons that humanize the scientific culture and promote the development of society.

Key-words: epistemology, philosophy, scientific culture, transdisciplinarity, pedagogy.

Although quite in use, Epistemology is not well known. You may discuss with friends about the latest progress in molecular biology, human cloning and the importance of research in these fields... You are epistemologizing. A scientific vulgarizer wonders on the value of medical discovery. He too is doing epistemology. A physicist proposes to reflect on the limits of our human knowledge, on the latest extent of development in his field, its impact on the vision of the world... He is still doing epistemology, like *good old Mr. Jourdain* used to prose without knowing it. So most of us use epistemology, but what is epistemology precisely? and why consider it here?

Scientific Culture and Epistemology

Before offering a definition let us try to give it its proper place and justify its usage. Nowadays scientific culture has grown into a prioritized necessity for many governments throughout the world and private organizations as well. This concern is translated into diverse public activities such as radio, TV programs and even exhibitions in museums entirely earmarked for this purpose. If we analyze the content of these manifestations, we notice the three dimensions applying to scientific culture are those that have been studied in depth by researchers for more than a century. In fact, scientific activity can be considered under three general aspects. The first one is its *cognitive dimension*: destined to increase knowledge, it constitutes its trade mark. This is the epistemological part. Next, science is not a readymade entity from day one, but it was born at a

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precise time, fluctuating with ups and downs and even disappearing during certain periods². It was an activity which developed progressively, a complex evolution offering several avenues. This is its *historical dimension*³. Finally there is a *practical dimension* offering varied social consequences; this part is called the *Science-Technology-Society* relations (the famous STS relations)⁴. To carry on a serious reflection on scientific activities, one must take into consideration these three distinctive though complementary dimensions. Furthermore, most of the time, the cognitive dimension of science, its evolution and the STS relations are closely interconnected. As I had the opportunity in a previous work to treat the historical aspect of science,⁵ I would now like to consider briefly the cognitive aspect and the discipline called epistemology.

Preliminary Approach to Epistemology

When studying epistemology for the first time, one must take into consideration the different variations of the term. For the Anglo-Saxons the wording *epistemology* refers in general to a special branch of philosophy, the *theory of knowledge*. In France, it rather indicates the *study of scientific theories*. Both approaches could be reconciled with little ado in a general term, if one thinks of epistemology as *the theory of scientific knowledge*. In this way the following will keep closer to the French trend of thought.

Epistemology has as its object the study of science; being analytical and reflective, it constitutes in this way a motion of the second degree examining a primal activity. In other words, "It ascertains to observe a total abstraction of any things that are aimed at by science and keeps only for its domain, not what science is about in exclusivity but what it talks about".⁶ It does not aim at improving our scientific knowledge nor exploring new fields such as observation of stars, some mollusks or new social behavior. Instead, epistemology studies the formation and structure of scientific concepts and theories. It also cares for the procedures and methodologies followed by those practicing as scientists. To be more precise, one could say that it proposes four well delineated fields for analyses and reflection, each one dealing with specific problems.

1/ Sometimes called the *syntax of theories*, the first field deals with the nature and the structure of scientific concepts and theories. It investigates the logic of sciences and identifies and analyses possible problems (problems of validity).

2/The second one deals with the object, the extent and the meaning of scientific concepts and theories; it is sometimes called the *semantic of theories*. It analyses and evaluates the concepts of representation, of reference and of meaning that apply to the theoretical tools of scientific research (problems of significance and truth).

² It was so during the Roman Empire and also during the Barbarian invasions which gave birth to Middle Age.

³ More and more universities are offering new courses of History of Sciences, less often of Technology, an official recognition by academic institutions all the more welcome, as it took much time before being acknowledged.

⁴For the STS relations one can notice institutional recognition, with the difference that the courses are specialized Ethics courses often offered as prerequisite for the students opting for scientific carriers such as medicine.

⁵Cf. 'Histoire des sciences et pédagogie au niveau collégial', *Pédagogie collégiale*, vol. 16, no 2, déc. 2002, p. 4-12.

⁶BLANCHE, R., *L'épistémologie*, Paris, PUF, coll. « Que sais-je ? », n° 1475, 1972, p. 120.

3/ The third one studies the *methodology of sciences*, i.e. the scientific method in general as well as the question of the existence of such eventual methodologies or techniques specific to some sciences, for example human or social sciences (problem of method).

4/ Finally the fourth field examines the *theory of scientific knowledge*, i.e. the status of this type of knowledge and the question of demarcation between science and non-science (problems of limitation and of value of scientific enterprise).

On the whole one can say in a broad sense that "epistemology studies scientific research and its product, scientific knowledge."⁷

Some Examples of Treated Problems

Given this fourfold delimitation it follows that epistemology covers *grosso modo* four kinds of questionings tied up with each field of analyses and reflection. It is rare if one selection does not mix up with another field so that each questioning interpenetrates other ones. Here are a few examples showing interconnection.

1) *Problems of logic and the validity of science and problems related to the structure of scientific theories*

How to formalize a theory? and is it always useful? What is the status of mathematical entities: are they only formal objects, constructions of the human mind or are they instead "real" objects? What is the status of evolutionary theory: has it the same value than a physics theory such as general relativity? What type of logic suits the amazing results of quantum mechanics: is it still classical logic? What is the relation between a law and a theory? Furthermore is a law always mathematical in nature? Can we speak of real laws in matter of human or social sciences?

2) *Problems of significance and truth*

What is the field of application of such concept or such theory? What is for example the precise object of evolution: individuals, populations or species? And what is it when one speaks of species in biology? What relation can we establish between observation and theory? Does the second one really derive from the first one? How to interpret statistics? What is the real object of quantum mechanics?

⁷BUNGE, M., *L'épistémologie*, Paris, Malouine, 1983, p. 13.

3) *Problems of method*

Are there one or several methods in science?⁸ From the start is there a standard scientific method or only diverse empirical procedures?⁹ Can one method associate with different techniques? Do human and social sciences have ONE rigorous method, and is it the same as one uses for the so-called exact sciences? What is a qualitative methodology about?¹⁰ Can we confirm an isolate hypothesis, or do we confirm only a scientific theory taken in its globality, or even a whole scientific field (the famous Duhem-Quine thesis)? Has such confirmation any degrees? Can we measure the degree of confirmation of a hypothesis or a system of hypotheses? What is the relevance of induction in science?

4) *The problems of limits and value of scientific enterprise*

What is scientific or not? Are there false sciences? Do human and social sciences have the same value than natural sciences? How to detect frauds in science? Can a scientist be really neutral or objective or is it an inaccessible ideal? Does our knowledge progress ceaselessly, or are there limitations registered in our instruments of observation and measurement, or even in nature itself?¹¹ When can we rightly use the system of probability: only by lack of sufficient information or data?

Science, “Metascience” and Internal or External Epistemologies

Questions raised through epistemological reflection are numerous, difficult and they could not be more up-to-date. Besides, the overlapping of epistemology and science is such that it is hard to deal with the first one without infringing on the field of the second one. To overcome these hurdles, logicians propose a hierarchy of languages which differentiate carefully the objective language of science from the *metalanguage* of epistemology (a language dealing over another language). In this optic, science is considered as an enterprise intended to describe and analyze an empirical determined field which uses a kind of language such as Mathematics. If one accepts Mathematics as a formal language, *metalanguage* will question their foundations and the nature of logic-mathematic notions themselves. For instance, are the transfinite numbers of Cantor just a practical formalism or do they correspond to some kind of reality?¹²

⁸We will come back on this difficult question, related to the ticklish problem of unity in science.

⁹One should not forget that someone like Feyerabend defends the position called epistemological anarchism, which holds that there is no such thing as a scientific method. Cf. *Against Method*, London, New Left Books, 1975.

¹⁰For more than a century, a debate has been going on in human and social sciences on the relative value of qualitative and quantitative methodologies.

¹¹For sure, one thinks right away of Heisenberg’s famous indeterminacy relations, later transformed in an uncertainty principle.

¹²The partisans of the intuitionist school – started by Brouwer and his disciple Heyting – and the constructivist movement that stemmed from it, consider the notion of actual infinite or transfinite a dangerous illusion. For instance, Kronecker reproached Cantor to have corrupted Mathematics, in a way that reminded the accusations long ago formulated against Socrates.

Thus the work of epistemology is found at the crossroad between philosophy and science; if epistemology is usually practiced by philosophers, it is however often the fact of scientists themselves. Indeed, many scientists tend to extend their works in two directions: first downstream in vulgarizing and transmitting their knowledge to the public at large, then upstream, as a kind of personal reflection which goes beyond the scope of their results, which is generally called internal epistemology of science, to be distinguished from external epistemology used mostly by people having a sound philosophical background. Thus "internal epistemology becomes the work of scientists while remaining however a philosophical work".¹³ When Hubert Reeves wrote in 1981 *Patience dans l'azur*, he intended to show that contemporary fusion of high energy physics with a venerable branch of science, astronomy, has produced, thanks to the birth of scientific cosmology, a new vision of the universe, of its origins, and that such a new opportunity allows untold perceptions on its birth and its evolution. This is high level vulgarization in the scope of a recent outgrowth in the tree of sciences, astrophysics. However, when Bernard d'Espagnat publishes *À la Recherche du Réel* (1979), he offers instead a sharp reflection on the attainments and dilemmas of physics, questioning himself about the limits of our knowledge and our abilities of access to reality itself, keeping in mind the means of our observation and of the instruments we have at hand. It is no more giving an account of some attainments or transmitting to a public athirst of knowledge the latest developments in his specialization, but questioning the foundations of our knowledge and also, maybe, their unsurpassable limits. This is epistemology internal to the present quantum physics. These two types of extensions of science do not have the same status. Although useful, vulgarization aims only at offering results of science accessible to a public at large. It does not give any clarification on the concepts, the methods or the extension of any field of research. No doubt it increases the notoriety of the researcher while improving public understanding, but it adds nothing to the scientific enterprise itself. Its value is therefore pedagogical rather than academic. On the other hand, although hardly accessible to the public at large, the epistemological work carried on by d'Espagnat aims at offering the researchers themselves a reflection in depth on their own discipline and its limits.

Epistemology of Science or Epistemology of the Sciences?

Occasionally, what makes contemporary epistemology unsettled is its pronounced oscillation between the general aspects of the theories of knowledge (the Anglo-Saxon meaning of the term) and highly specialized scientific considerations (the Francophone one). In fact, "the problems of epistemology extend rather naturally in two sets: those having general characteristics covering all sciences and those proper to only one group of sciences, more or less extensive"¹⁴. This brings the difficult question of knowing if science and its method are one – what G.-G. Granger calls "the presumption of unity (or generality)" – or if there is in fact a "singularity, even an irreducibility of different domains of Science"¹⁵. This indeed is one of the most discussed problems, today. As for

¹³ BARREAU, H., *L'épistémologie*, Paris, PUF, coll. « Que sais-je ? », no 1475, 1990, p. 11.

¹⁴ BLANCHE, *op. cit.*, p. 46.

¹⁵ GRANGER, G.-G. (« Épistémologie », *Encyclopædia Universalis*, 1988, vol. 7, p. 61), quoted by P. Jacob, *L'épistémologie – L'âge de la science*, Paris, Odile Jacob, 1989, p. 11. Such questioning brings back to the third series of questions, the problems linked to method.

the human and social sciences, there were hot debates at the end of XIX c. in Germany. Several practitioners were defending the methodological dualism, a thesis which makes a sharp distinction between, on one side, the explanation (*Erklärung*) which would be related to the science of nature more inclined to the research of causality, and on the other side, the comprehension (*Verständnis*), which, more specific to human and social sciences, would rather seize the motivations of the actors in action in the diverse fields of study. If we adopt this position which is far from being unanimous, the sciences of nature would be rather analytical while the human and social sciences would be more synthetic¹⁶. Such division, enabling to justify the fact that it is more difficult to formalize human and social sciences, is based on the difference of objects – human realities are more complex for they are endowed of conscience – but also on a scientific truth: analysts and objects of study have the same nature – both are human¹⁷. These also render more problematic the objectivity of the results as well as the neutrality of its practitioners. All this has a direct impact on the status of these disciplines and consequently on the hypothetical general unity of sciences. One must also note that even in the sciences of nature, the same question divides the present epistemologists. The unitarian stand will be defended by the logicians. As an example, Karl Popper (1902-1994), in his splendid *Logic of Scientific Discovery*, has modified in depth the way of understanding the work of verification in science. The tenants of the pluralist stand will rather make use of the history of scientific enterprise, and analyze in detail one or several particular disciplines. This approach has been strengthened through the work of Thomas Kuhn, whose *Structure of Scientific Revolutions* (1962) marked a decisive turn in understanding men of science, their practice and the validity of their work. “Conceptual analysis encourages to scrutinize the general aspects of the scientific move; on the contrary, historical move helps in the research of ‘regional’ particularities proper to special scientific branches as well as their historical background eras”¹⁸. In human and social sciences as well as in sciences of nature, the acceptance or rejection of methodological monism depends a lot on the way the epistemologists proceed to study the scientific enterprise and on the tools they use to this end.

Epistemology and Pedagogy

As one can see after these considerations, epistemology interests the philosopher as much as the scientist or the teacher of sciences. As it includes external and internal aspects, it becomes a cross-road discipline and it is opened in various degrees and in function of the programs to all those who teach philosophy and sciences. In Rimouski College¹⁹, where teachers of sciences of nature have been collaborating for several years with members of Philosophy department, this concern has developed a care for reflection over scientific enterprise which includes epistemology among others subjects. A section of scientific culture was developed for the totality of the specific courses of the program with the voluntary contribution of each teacher. Such collective enterprise among the staff of various disciplines is grounded in a reform of the program which took place

¹⁶ The philosopher who worked much to accredit this dualism was WILHELM DILTHEY. Cf. his *Introduction to the Human Sciences* (the famous German *Geisteswissenschaften*), Princeton, Princeton Univ. Press, 1989.

¹⁷ This is what epistemologists call *the hermeneutic circle*.

¹⁸ JACOB, *op. cit.*, p. 11.

¹⁹ Rimouski is a town located in Lower-St-Lawrence, in Quebec Province. It is the place where the author taught.

several years back. It introduced diverse broad objectives, three of which refer to aspects of scientific culture and therefore indirectly to epistemology:

- 1) Establish links between science, technology and the evolution of society.
- 2) Localize the context of emergence and elaboration of scientific concepts.
- 3) Define a system of value.

These three objectives fit well for a work of concertation between the content of the science courses and those of general formation²⁰. The third objective, for instance, is directly in line with the third course in philosophy which, adapted to the programs, includes Ethics and the construction by the students of a system of personal values. But the one I am most interested in is the second of these objectives. For the context of emergence and elaboration of scientific concepts refer to history and to a special social environment, Ancient Greece and the invention of Democracy. However, it is also closely linked to epistemology in the sense whereby it is difficult to present such context without, in the meantime, discussing scientific concepts, their eventual reach, their limitations, etc., which is dealt with in epistemology. Let us be more explicit. The first philosophy course deals with the apparition of rational thinking in Greece. By this, it is meant the twofold birth of philosophy and science, for the first philosophers, Thales of Miletus, Pythagoras, Democritus, etc. were also scientists. The birth of science means mainly astronomy and geometry, the first sciences which received solid basis at that time. So, during the first collegial semester, it is quite appropriate to bring new students of science of nature²¹ to reflect on the nature of these two disciplines, their methodology and the progressive separation from the purely descriptive geometry of the Egyptians²² (in case of Mathematics) or from the Babylonian astrology (in case of astronomy). As to Mathematics, one speaks of the appearance of the first theorems of geometry with Thales in VIth Century BC, of a philosophy unheard of in history, the Pythagorean realism which develops the first known demonstration using methodical reasoning, of the discovering of paradoxes and of the infinite in Zeno, of the nature of Mathematics according to Plato, etc. Regarding the specific courses of the first semester, it is easy to establish links with the history of sciences or epistemology. For example, in the differential calculus course, one can recall the paradox of Zeno about the divisibility of motion, paradox seen in philosophy, and make the link with the notions of limit and speed instantaneous observed in Mathematics. In the general Chemistry course which presents Bohr's probabilistic model, one can refer to the atomic theory of Democritus seen in Philosophy and take advantage of its ulterior evolution, while questioning about the exact reach of such a model²³.

²⁰ In Quebec, general formation comprises obligatory courses of French, Philosophy, English and Physical Education.

²¹ This presupposes ready agreement with the college administration in order to get a preferential grouping of science students.

²² The Greek etymology of the word *geometry*, *measure* (-metron) of the earth (*geo*-) recalls its empirical origin from the Egyptian people where it was used to establish anew the register of the lands after each flood of the Nile.

²³ In our college, the connection usually took place between sciences of nature and philosophy, but it could also proceed without much ado with the social and human sciences. As an example, it would be easy to connect the question of citizenship, so important nowadays in many debates throughout the whole world, with the growth of democracy often referred to in the courses of philosophy.

What are the advantages of such a program of scientific culture for the student? They are of different orders and affect as much the knowledge than the skills or the attitudes. Let us mention of few of them. On the cognitive level, this painless initiation allows him to perceive the possibilities, but also the limits of the method or of the scientific concepts, to recognize their extent of validity and perceive the close original link among science, philosophy and democratic environment in human experience. On the attitude level, it broadens his vision about the sciences and their origin and makes him aware that they are not far off from their pre or pseudoscientific ancestors. On the level of skills, the student develops on this occasion his ability of argumentation, his analytical competence and his critical sense.

Scientific Culture, Pedagogy and Conception of Philosophy

The conception of philosophy which emerges from these works, be it epistemological analyses or pedagogical experimentations, is more humble than the usual vision. In fact, philosophy has no longer the exclusive pretense to a broad view of all sets of sciences, it does not intend to throne at the summit or the base of “the tree of knowledge” (Descartes). The outstanding classic models are gone and the universal concepts they pretended to put into practice – matter, substance, form, causality, determinism, etc. –, have become inoperative²⁴. Each in his own way, the two philosophers, Quine and the last Popper proposed for our time a naturalization of epistemology, intending in this manner to emphasize the necessity to fix it on new bases, tied up to the comportment of living beings or onto the natural evolution of the systems of perception, joining among others domains cognitive psychology, evolutionary biology and paleoanthropology. In my mind, if one wants to be serious about such a program, one should abandon the anterior pretensions of philosophers in order to accompany the internal movement of diverse sciences towards self-reflection in the three natural fields of philosophy: the universe, society and man. In such perspective, the necessity of working in common for teachers in sciences and philosophy is obvious.

In a famous sally, which caused much writing and rancor, Heidegger stated: “Science does not think.” No doubt, he meant to stigmatize the scientist attitude,²⁵ who lightly uses naïve empiricism and believes in the linear and indefinite progress in knowledge,²⁶ while excluding *a priori* serious approaches of reality not referring to the scientific method. On the contrary, to deny science any value of truth as does Heidegger, is as bad and sterile as practicing scientism itself. In fact, contrary to what he believed, the role of a philosopher nowadays is not to think science, neither to think for it but to think from it. In this optic, his function consists, among others, in opening a dialog between diverse disciplines, giving them signification and causing exchange of meanings. On the

²⁴ Here are two brief illustrations: the classic concepts of causality and determinism have been strongly shaken by Quantum Mechanics, and the concept of form has been powerfully renewed by mathematicians René Thom (catastrophe theory) and Benoît Mandelbrot (fractals), the two of them spending most of their career in these fields.

²⁵ Scientism is quite different from scientific attitude, as it exaggerates the absence of critical sense, and easily falls in an ingenuous and self-satisfied optimism.

²⁶ In *Histoire des sciences et Pédagogie collégiale*, I tried to prove that linear development of sciences, purely internal and flatly cumulative, had become highly questionable during the last century.

whole, in my mind, he must fight against insularity in disciplines, sometimes so detrimental, to establish a nomadism of meanings, becoming a provider of significance, an operator of transdisciplinarity. 18

To do so, any teacher who opts for this way should have a minimal knowledge of history of sciences, but also some practice in epistemology²⁷, i.e. he should be at least familiar with methods and major results of diverse sciences, in order to be able finally to evaluate reasonably their place and their role in the present society or the future one. This is their way to contribute to situate sciences and technology in a more global context, the one of a world civilization in gestation. There may be no sense more stimulating for the expression *scientific culture* than this close relationship with the eventual future of the Occident, the origins of which are stamped by the conjoint birth of science, philosophy and democracy.

To attain this ambitious objective, there must be a will to harmonize the exigency of expertise supplied by specific formation and the need of meaning brought by general formation. Thus do we favor not only the success of students but offer a solid stake: forming for the future, citizens who prove themselves competent in their fields of specialization, and - we can hope for – are better enlightened. Thanks to the three aspects of an authentic scientific culture one can then avoid those related scourges, ideology and scientism, the first reducing the value of science and the second one exaggerating its virtue. In this way, one can encourage the student in science to take his own initiative to deepen his field of knowledge, as well as his own well-being and the well-being of the society in which he lives. Is there a better nobility for epistemology or scientific culture to bring their stones in building society, while contributing in forming well-balanced and harmonious persons?

²⁷ This recommendation is valid not only for philosophy but also for scientists and teachers of sciences.