Unity of science against the rational construction of knowledge?

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Most scientists are confronted daily with the heterogeneity of scientific approaches and with the need to solve increasing difficulties in combining knowledge from various scientific areas. But these difficulties are ignored when the philosophy of science postulates the possibility of establishing a priori rational principles of a unified science. In so doing it logically considers that the problems encountered in integrating scientific knowledge from different sources result from institutional gaps or organisational failures, or from the lack of researchers' skills. The analysis of these problems is consequently handed over to the sociology of science. The debate on the unity of science may therefore conceal the heuristic value of approaches based on an epistemological regionalism to support the rational construction of knowledge.

Actually, for the scientist following the on-going building of scientific knowledge, the question of the ultimate state of science – unity *versus* disunity – does not matter so much. What is important is to acknowledge that here and now:

1) to deal with a similar phenomenon, theories based on distinct conceptual architectures –and sometimes contradictory hypotheses – coexist (for example Cartwright 1999);
2) each research programme has its own area of demonstration and builds knowledge through specific paths (Bachelard 1949);
3) the social sciences, natural sciences and technical disciplines may produce knowledge with distinct properties which generates different kinds of interactions with its environment (Hacking 2001, Hottois 1996).

If these statements are to be considered seriously – and so they are by most scientists – it is no more self-evident to put together different scientific areas: the integration of scientific knowledge is an epistemic situation that needs clarification to overcome difficulties encountered by researchers in getting an overview of the existing scientific knowledge, in integrating their approaches and in securing the recognition of the quality of their results.

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1 Breaking away from the ambiguity of the discipline

To observe science in progress in a perspective of epistemological regionalism, we need to account for the way in which the different 'regional rationalisms' pointed out by Bachelard (1949) are constituted. The first idea that comes to mind is to use the concept of a discipline. This is not a very good idea.

Debates on the evolution of science generally refer, more or less explicitly, to a 'vulgate' that defines the discipline as[2]: *' ... a set of rules and definitions, a domain of objects, a body of hypotheses considered to be true, theoretical and technical instruments, and a history (cf. M. Foucault). A discipline consists of a set of statements whose organization and coherence are regulated.' (Popelard and Vernan, 1997: 20)*[our translation]

But this definition of discipline is misleading for several reasons, especially because: (i) a discipline is also (even primarily, according to Toulmin (1972) a profession, with all its institutional dimensions; (ii) it is furthermore a material arrangement with its ad hoc instruments and material assets capitalized on over time (databases, model plants and model animals, long-term experimental devices, etc.), and (iii) a discipline does not necessarily correspond to a set of coherent statements; it usually groups together research programmes based on heterogeneous theories, which can have contradictory underlying hypotheses. This characteristic, described many times for the social sciences, also concerns the natural sciences, as N. Cartwright (1999) pointed out in the case of physics.

In other words, a discipline has to be defined as a complex set which necessarily comprises intellectual components (research programmes which can be based on contradictory hypotheses), institutional components (institutions that guarantee the validation and teaching of the knowledge produced) and material components (tools, databases, etc.). Its history (its historical background) has to be analysed from a threefold perspective since a discipline is based intellectually on a genealogy of problems, professionally on a series of institutional authorities, and materially on a set of technical devices (Laurent, 2003).

The cooperation between disciplines brings into play these different dimensions. Consequently, even if there is a relative consensus to consider that the classification of the terms *pluridisciplinarity*, *interdisciplinarity* and *transdisciplinarity*, in that order, tends to signify a growing integration of disciplinary approaches, as O. Pombo (2004) noted there is clearly no agreement on what the object of integration is. It is considered that what counts is above all the degree of conceptual integration (Berthelot, 1999) or the question of the sharing of a formalism between disciplines (Delattre), or else the questioning of the limits of scientific disciplines in all their dimensions (Stengers, 2000) or, finally, the transcending of the discipline-profession, through partnership with laypersons to distinguish 'interdisciplinarity' from 'transdisciplinarity' (Gibbons *et al.*, 1994).

This shows how much, when we analyse the question of the integration of knowledge in an internal perspective, the concept of a discipline can be a source of confusion rather than clarity. For example, what exactly does economy-ecology interdisciplinarity encompass? Which economic programmes (standard approach, economics of historical institutionalism, etc.) and ecological programmes (populations biology, landscape ecology, etc.) are linked? To undertake an internal analysis, this indeterminacy compels us to depart from the discipline and to adopt a perspective set in conceptually coherent entities.

But then, which concept can be used to account for the heterogeneity of the world of scientific knowledge? K. Popper (1959) maintained that everything ought to be related to 'problems'. D. Andler (2002) suggested, however, that if Popper was able to sacrifice the discipline, it was *'perhaps because he shared with his opponents of the Vienna Circle a unitary conception of science: if basically science is one, why worry so much about the technical division of tasks within it, a division that evolves and*

[2] This definition is taken from a manual designed to popularize the philosophy of science, and the authors themselves repeatedly point out the incompleteness of a manual of this type.

affects neither the foundations nor the goals of the scientific enterprise? If at least he professes realism, the contemporary philosopher can rightfully hesitate; depriving himself completely of disciplines could lead him, without a unitary science, to give up science itself.' (p. 695) [our translation]

Even if, in practice, those who study science in progress usually fall back on disciplines, there are alternatives. The concept of a 'paradigm' has been used in an attempt to account for the heterogeneity of scientific approaches over time (Kuhn, 1962) or at a particular stage (Berthelot, 2001). But actually, for the latter usage, the concept is rather fuzzy and provides little structure for undertaking an internal analysis, even a posteriori. The concept of a 'research programme', proposed by Lakatos (1970) seems more promising in so far as it offers a general framework to describe the different conceptual components of a research activity, irrespective of its institutional affiliation.

At a given point in time a research programme can be defined as a conceptual unit that coherently combines: (i) a permanent hard core of general theoretical hypotheses which are considered to be irrefutable by those in charge of the programme (e.g. hypotheses relative to the 'rationality' of human behaviours in the social sciences); (ii) ad hoc protective hypotheses intended to protect this hard core and research under way from the ‘anomalies' which they could encounter, that is, phenomena that are not consistent with the theory and that withstand observation (e.g. all the hypotheses that serve to define the domain of validity of results by adding a clause on everything that has to be covered by 'all things being equal'); and (iii) hypotheses to be tested, designed to expand the world of explainable facts. The concept of a research programme thus may serve to overcome several difficulties generated by that of a discipline for an internal analysis. It is a particularly useful tool for circulating within disciplines – and between them – and for comparing different approaches by clarifying the initial hypotheses on which they are based, by showing the approximations they entail, and by specifying the content of the ad hoc hypotheses that reduce the scope of their results.

We will now consider two examples to see how, by taking into account the heterogeneity of the regions of science, we can understand certain internal components of the difficulties encountered by researchers in getting a clear vision of existing scientific knowledge, in articulating their research programmes and in securing recognition of the quality of their results.

2 Exemple 1: Coexistence of research programmes with heterogeneous premises

21. Mapping science landscapes

It is possible to describe on the same bases research programmes which are affiliated with the same discipline but are grounded in contradictory hypotheses. For example, two research programmes in economics can be compared that way as Figure 1 shows. In this example we see that the hard cores of the two programmes under consideration[3] correspond to totally different domains of investigation and are based on contradictory hypotheses, for example as regards individuals' behaviour.

We thus observe that one case is an exploration of the heuristic value of a theory in terms of which individuals' behaviours stem from internal, conscious deliberation, whereas in the other case these behaviours are partially determined by sub-conscious processes resulting from mental structures that partly internalize social structures. In the former case the individuals' irrational behaviours, from an economic point of view, are an anomalies against which the hard core has to be protected. This can be done by referring to constraints outside the field of economics. An attempt is made to eliminate the impact of these constraints by limiting the domain of validity of the model by means of ad hoc hypotheses. For example, we can consider that irrational behaviours have a biological determinant, and construct ad hoc hypotheses accordingly. In the latter case, by contrast, the problematic aspect is

[3] Further information on these approaches can be found for neo-classical economics in Guerrien 2004 and Allen 1986, and for historical institutionalist approach in Boyer 1990 and Jessop 1997

the observation of new behaviours and especially the mechanisms through which they result in the creation of new institutions. Here again, ad hoc hypotheses allow for the protection of the hard core. Note, however, that in each case the range of hypotheses to test and the scientific facts constructed are directly related to the characteristics of the hard core and that the same designation (e.g. 'institution') can therefore encompass very different scientific facts.

	Hard core (irrefutable hypotheses)	e.g. ad hoc hypotheses (such as behaviours)	e.g. fields of hypotheses to test on agriculture
Neo-classical economics	- Institutions are entities defined by their functional role; the market, in which prices are set, plays a key part in individuals' socialization. - Harmonious economic functioning can be obtained in a context of perfect competition. - Postulate of methodological individualism which maintains that agents' decisions, which are rational, result from internal deliberation. - Individuals have a rational behaviour. Actions are intentional and determined by conscious processes. They are the result of internal deliberation.	Irrational behaviours are explained by cultural, biological and other factors whose impact can be eliminated by reasoning in terms of 'all things being equal', based on an individual's behaviour that is representative for particular situations.	- Configuration of agricultura markets in a framework of perfect competition. - Models of allocation of resources at the agricultural household level.
Heterodox economics **Historical institutional ism**	- The process of accumulation is decisive in an overall economic dynamic. - It is not spontaneously balanced by the market and competitive dynamic, and has varying forms in space and time. - Institutions and structural forms are decisive for channelling this process through a set of collective and individual behaviours. *- Individuals' behaviours are partly determined by their integration in historically constructed institutions.* *Actions are determined by conscious AND unconscious processes.*	The emergence of new institutions is explained by the emergence of collective procedures during conflicts … which relate to sociology and to political science. They will be analysed ex-post.	**-** The roles of agriculture in the regulation of regimes of accumulation in different countries. - The evolution of institutional integration of different forms of agricultural activity.

Figure 1. From the discipline to research programmes

The possibility thus opened does not concern a trivial result. It is becoming possible to sketch the landscape of a discipline in a way that is accessible to those who are not directly integrated into it, and to the communities that keep each discipline alive. The history of scientific ideas is taught only in a limited number of courses. Even within a single discipline researchers usually have, outside their own field of investigation, limited knowledge of the heterogeneity of the approaches and of the precise consequences of the choices of hypotheses in research programmes concerning or belonging to other disciplines. Outside the scientific field, the differences between programmes are often analysed as subtleties that are too complex and difficult to grasp.

2.2. Integrating knowledge

** Contradictions between research hypotheses*

By making it possible, on common bases, to re-examine research programmes that are institutionally affiliated to different disciplines, it becomes easier to identify and to take into account possible contradictions which can stem from the will to combine conceptual architectures based on incompatible hypotheses. If we pursue our reasoning on the basis of the preceding example, we see the full advantage, for researchers who wish to articulate sociological and economic approaches to a common object (individuals' behaviour), of investigating the compatibility of the hypotheses of the hard cores of the theories to which they are attached. Figure 2 provides an example of this approach.

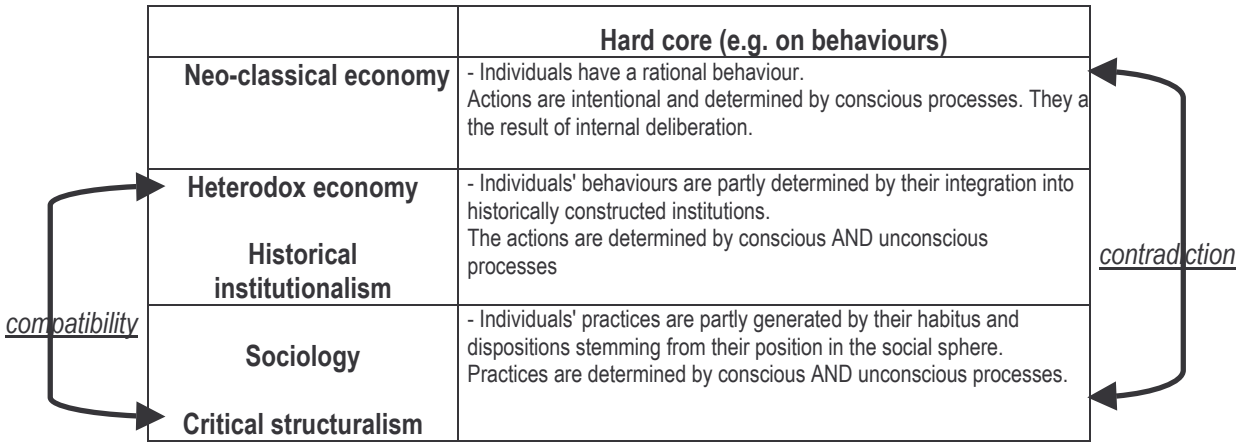

Figure 2. The question of conceptual compatibility

In the first approach, the forms of individuals' social integration can be neglected in order to apprehend their behaviour. By contrast, in the second and third approaches[4] individuals have to be characterized, at least partially, by the forms of their social integration which contribute towards guiding their behaviours. Consequently, it does not seem incoherent to try to connect the observation frameworks and results of the latter two research programmes. The articulation of an economics based on a postulate of methodological individualism, to a sociology of critical structuralism[5] seems, however, to be the source of many logical difficulties. These forms of complementarity or incompatibility can be analysed in this way between different disciplines.

Any research can be described by means of these elements, even if the scientists concerned have not explained it in these terms, and even if a large number of studies are undertaken without any formalization of this kind, of the theoretical structure on which the research practices are based. Moreover, it does not stand to reason that in all circumstances this formalization would be useful and more fruitful than the strategies of discovery which are implemented. The idea here is therefore not to use the notion proposed by Lakatos in a normative way, but only to point out that the concept of a 'research programme' can be used for description, to construct internal analyses of science in progress, and to make an overview of sources of available knowledge on a subject and the hypotheses on which they are based.

**** Unequal impact of questions set by the society on research programmes heuristic***

The advantage of the concept of a research programme is that it also allows for observation of the way in which approaches will be revised to ensure the programme's progress or, under 'external' constraints, to try to produce useful knowledge for answering a question raised by society. In the latter case, we observe that the hypotheses to test, derived from questions asked by society, will have heterogeneous statuses, depending on the research programme. For instance, to study the conservation of biodiversity in agricultural landscapes (figure 3), it is necessary to test hypotheses relative to interactions between ecological and social processes. But the importance of these hypotheses will differ as regards the advancement of the positive heuristics of the research programmes concerned. This is a key question for landscape ecology[6], but one that is entirely secondary for economics or even one that should momentarily be excluded to safeguard the heuristics of the programme.

[4] further information on this approach can be found in Bourdieu, Passeron 1989.

[5] further information on this approach can be found in Bourdieu, Passeron 1989.

[6] further information on this approach can be found in Burel, Baudry 1999

	Hard core *(irrefutable hypotheses)*	***Fields of hypotheses to test so that the original programme can progress***	***Hypothesis to test t answer a question raised from the outside***
Standard economics	- Institutions are entities defined by their functional role; the market has a key role in the socialization of individuals. - A harmonious economic functioning can be obtained in a context of perfect competition. - Postulate of methodological individualism: the decisions of agents, who are rational, are the result of internal deliberation.	- Configuration of agricultural markets in a context of perfect competition. - Models of resource allocation at the level of exploitation or of the farm household.	*Existence of causal relations between economic dynamics a agriculture and ecological processes.* ***Methodological consequences*** *Necessitates the spatialization of the collection and processing of data. Requires the territory in its continuity to be taken into account.*
Heterodox economics Historical institutionalism	- Processes of accumulation is decisive in the overall economic dynamic. - It is not spontaneously balanced by the market and competitive dynamics and has various forms in space and time. - Institutions and structural forms are decisive for channelling this process through a set of collective and individual behaviours.	- Roles of agriculture in the regulation of regimes of accumulation in different countries. - Evolution of institutional integration of different forms of agricultural activity.	
Landscape ecology	The analysis of ecological processes must: - explicitly take space into account; - recognize humans as an integral part of the ecological system; - recognize the spatial and temporal heterogeneity of the environments studied.	- Spatial and temporal dynamics of ecological processes in anthropized environments.	

Figure 3. The hypotheses to test have heterogeneous statuses, depending on whether they have been formulated by researchers or stem from a request by practitioners.

2.3. Assessing research results

We thus observe that by compelling certain programmes to reconsider sections of the reality that they eliminated in their processes of reduction, the collaboration between research programmes imposed by the necessity of practice can be a major source of anomalies in the established theories, but is also unequally disruptive for the programmes concerned.

3 Example 2: fundamental otherness of different types of scientific knowledge

3.1. Mapping science landscapes

We observe that not all research programmes produce statements with the same properties. Hacking (2001) highlighted the particular aptitude of the social sciences to produce knowledge of an interactive nature, and to produce classifications that induce a dynamic interaction with the classified individuals as soon as they are aware of that classification and their place in it. By contrast, the natural sciences primarily produce knowledge without any direct effect on the behaviour of the classified entities.

This question of the specificity of the social sciences stemming from the adjustment of human behaviours to the description of a situation is not new (e.g. Neurath, 1939). In a famous article on self-fulfilling prophecy, sociologist R. Merton (1949) considers behaviours which make a situation real because they are based on the belief that it is real. For instance, the customers of a bank cause its bankruptcy by withdrawing all their money because they believe that it is going bankrupt, when in fact it is financially healthy. In the examples chosen, the description of the initial situation is false and is based on rumour. But when it is known by the people concerned, the validated scientific knowledge can trigger adjustments in behaviours and thereby alter the characteristics of the observed situation.

These observations concern the human sciences above all, but there is no strict correspondence between types of knowledge and types of science. Genetics, for example, produces knowledge of an interactive kind when it causes individuals to be classified in terms of their risk of developing certain pathologies, and when at-risk subjects are informed of this classification. This can be a source of anxiety which aggravates the risk or, alternatively, may prompt the person concerned to adopt preventive measures that reduce the risk. Various disciplines can thus produce knowledge of an indifferent or interactive kind, even if one of these forms of knowledge may be dominant in a particular scientific field.

We might add, following G.Hottois (1996), that in addition to the symbolic interactions mentioned above, knowledge can also be a source of immaterial or material technical interactions when it leads to the creation of tools or the transformation of its material environment.

The production of knowledge of an interactive kind thus creates situations in which relations between scientific statements and prediction are totally different from those in which research produces knowledge of an indifferent kind. The consequences of these interactions reduce the predictive capacities of theories because even if at moment *t* a classification can make certain behaviours intelligible, at *t+1* the classified individuals who have taken this classification into account may change their behaviour in various ways. It is therefore possible to have statements or self-fulfilling theories, that is, theories which will be proved provided that they are considered to be true by the actors concerned, and those actors adjust their behaviours accordingly. We can show, for example, that a theory relative to certain economic fluctuations will be verified if each agent acts in the belief that the theory is true (Chiappori et Guesnerie, 1988). But a statement can also induce its own invalidation if the classification is associated with a strong probability of an event judged unfavourable, and the person classified has modified his or her behaviour to avoid that outcome. This makes it necessary to consider the principles of administration of evidence from a specific perspective, for the question of what is true and what can be proved becomes highly problematical in the case of knowledge of an interactive nature. It also makes it necessary to examine the place granted to the quality of predictions, if the results of a scientific approach are to be judged. This is a permanent source of heterogeneity of procedures for validating rational knowledge since, depending on the kind of knowledge produced, the validation of results demands the implementation of different procedures.

3.2. Integrating knowledge

A question arises when concrete research practices aim at integrating knowledge from sources: of what nature is the knowledge that will be produced when a model combines variables of different kinds?

The analysis of precise examples shows that when a model is mixed and combines variables of an indifferent kind (e.g. ecological classification of the richness of the flora in certain areas) and variables of an interactive kind (e.g. typology of farmers' practices), it will produce classifications whose properties are those of the classifications of an interactive kind. Hence, it is possible to produce typologies that combine these different sorts of variable, in order to link grazing practices to richness of flora. When they are known to the people implementing the practices concerned, such typologies can modify their future behaviour. Assuming that ecologists recognize and disseminate information claiming that a given grazing practice has a positive impact on the richness of the flora, this practice may then be adopted or rejected by farmers for various reasons: technical (a way of considering the quality of the grazing), symbolic (the farmer's personal interest in or rejection of certain arguments defending the environment), economic (anticipation or not of a possible remuneration linked to the maintenance of certain plant species), etc. All in all, the diffusion of this kind of typology has new effects on plant-related practices and dynamics which are not predictable within the limits of the initial model.

3.3. Assessing research results

This example shows that in certain circumstances of knowledge integration, knowledge will fall into an interactive kind thus has fewer predictive qualities. Predictivity implies, among other conditions, an adequate stabilization of the object under study so that the knowledge of a law characteristic of one of its states can inform on its future behaviour (Godard and Legay, 1992). But here, the classified individuals' knowledge of the highlighted regularity (on the interactions between practices and richness of flora) causes the destabilization of the object under study (dynamic of the richness of flora).

Thus, when they are engaged in pluridisciplinary models with the social sciences, researchers in the natural sciences can produce models whose predictive capacities are smaller than those usually required in their discipline. With a more complete approach to reality, the scientists concerned may be suspected of losing in scientificity from the strict point of view of the natural sciences where 'excellence' is often related to a certain predictive quality.

Conclusion

The two examples above show that it is possible to formalize shared principles of analysis which enable one both to take into account contradictions between research programmes and to construct a global vision of the regions of science. Such representations become indispensable for apprehending the internal difficulties encountered by scientists in rationally bridging the gaps between scientific communities and in specifying the conditions in which knowledge can effectively be incorporated in order to treat complex problems set by the society.

In a world in which the unity of science in progress were not problematical, the boundaries between scientific sub-communities would be easy to overcome. These sub-communities would not only share this ideal of rationality but would also aim to have compatible underlying hypotheses, and would have a common way of grading the procedures of revision of research programmes and of judging the results of investigations. But we are not in that world. From one research programme to the next, researchers' objectives differ. Moreover, the lack of knowledge about others' research programmes is growing. Interactions between sub-communities associated with competing research programmes, or programmes with very different research topics, are sometimes reduced to virtually nothing.

Yet, if as a last resort the validation of scientific statements is the outcome of critical intersubjectivity of a community (Fagot-Largeault 2002) that shares a demand for rationality, then the exercise of that critique is fundamental. Any renunciation of incursions into the knowledge of other communities, and any refusal of such incursions into that of one's own community, appear singularly threatening for the production of rational knowledge. This renunciation is not only the doing of researchers who refuse to look beyond the boundaries of their own research field; it can also take the form of a denial of the persistent heterogeneity of the conceptual bases of science in progress and, on the whole, this heterogeneity is seldom analysed. The three communities which, *a priori*, would have good reasons to feel concerned, avoid the problem. Scientists, who generally very legitimately reject theoretical eclecticism, focus on their own research programme since they have chosen the approach that seemed to them the best. Philosophers of science, who cannot in one movement embrace the growing complexity of the scientific scene, generally favour the dominant approaches in the social field of science, or confine themselves to *ex post* analyses, leaving it up to history to sort through rival paradigms. Research managers, harassed by this profusion and all the contradictions it entails, often prefer to assume that there are differences only in details, which can be ignored.

But, for a cross cutting critique to be possible, and for real progress to be made in the integration of scientific knowledge, it is necessary to build analytical frameworks that allow take into account that every research programme claims its own domain of demonstration and its own validation criteria. That is why it seems necessary, at a meta level, to construct analyses which on common bases explicate the hypotheses of heterogeneous research programmes, their criteria of scientificity, the part of arbitrary of each approach, and the limits of empirical validity of their results.

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