Informatics in the classification of sciences

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The question of the classification of sciences comes, in part, from the need to organize scientific institutions: schools, universities, laboratories, etc. For example, in the medieval schools, the teaching of sciences was organized according to Boethius' *quadrivium*: Arithmetic, Music, Geometry, and Astronomy. And, before its recent re-organization, the structure of the French *Centre National de la Recherche Scientifique* reproduced exactly Comte's classification : Mathematics (section 1), Physics (sections 2 to 10), Chemistry (sections 11 to 16), Astronomy (sections 17 to 19), Biology (sections 20 to 31), Social Sciences (sections 32 to 40), the only difference being the place of Astronomy.

But this question also comes from a more fundamental investigation on the nature of the sciences, on their similarities and differences. This is an original—because extensional—way of investigating the nature of science by investigating the nature of the sciences.

These institutional and epistemological reasons explain that this question reappears when a new science emerges: Social Physics in the time of Comte, Informatics today.

Objects and methods

Following a tradition that we can trace back at least to Kant, investigating the nature of a science consists in investing, on the one hand, the objects this science studies and, on the other, the method it uses to study them: the method to judge a

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proposition true in this particular science. This leads to view the classification of sciences as a two-dimensional array.

The first, ontological, dimension is concerned with the objects the sciences study. Here, the main distinction is between Mathematics, that studies abstract objects, also called objects of the *Logos*, or cognitive objects, and the Sciences of nature that study concrete objects, also called objects of the *Cosmos*, or objective objects. Equivalently, the truth can be qualified as *synthetic* in the Sciences of nature and as *analytic* in Mathematics, although this view of mathematical truth as analytic dates only from Frege's program and Hilbert's and Poincaré's modern view of axioms as implicit definitions of the mathematical objects. Before, the mathematical objects were viewed as ideal but real, the axioms were viewed as a description of this ideal reality, and the mathematical truth was viewed as synthetic. This transformation of the view on mathematical truth led to a transformation of the meaning of the words "analytic" and "synthetic", that gradually became synonymous to "necessary" and "contingent".

It is then possible to distinguish, within the concrete objects, the living ones, and within the living ones, the human ones, leading to the distinction between Physics—including Chemistry and Astronomy—, Biology, and Social Sciences, even if the specificity of the latter sometimes leads to put them in another category, and to distinguish, like Michel Serres, *les Sciences du collectif* from *les Sciences de l'objectif*. This progression from the general to the particular is the dominating principle in Comte's classification of the Sciences of nature. It also explains why Mathematics are before the Sciences of nature in Comte's classification, if we accept the idea that a proposition is necessary if it is true in all possible worlds and that nature is one among the many possible worlds.

The second, epistemological, dimension is concerned with the methods the sciences use to study these objects. Here again, the main distinction is between Mathematics, where judging a proposition true requires a proof and the Sciences of nature, where judging a proposition true requires either an observation or the construction of an hypothesis that is not in contradiction with the observations. For instance, we know that Jupiter has satellites because we have observed some, and we hold true that Mercury does not, because we have not observed any. In both cases, judging a proposition true requires an interaction with nature. Judgements in Mathematics can be qualified as *a priori*, and in the Sciences of nature as *a posteriori*.

We finally reach a relatively simple classification where the truth in Mathematics is analytic *a priori* and in the Sciences of nature synthetic *a posteriori*. The two other boxes of the array being almost empty. No truth seems to be analytic *a posteriori* and synthetic *a priori* truth is limited, after Frege, to one's own existence and a few similar propositions.

Where is Informatics in this classification?

The objects of Informatics

Let us first investigate the objects studied by Informatics. Informatics studies different kinds of objects: pieces of information, languages, machines, and algorithms. These four categories are very broad. For instance, the category of languages contains programming languages, but also query languages, specification languages, etc. The category of machines contains computers, but also robots, networks, etc.

It might be a specificity of Informatics that it cannot be defined as a science that studies only one kind of objects: Informatics is mutilated if it is reduced to the science of machines, to the science of algorithms, etc.

None of these four categories is new, but the novelty brought by Informatics is that these categories are then organized in a coherent science. Algorithms for instance have existed for more that four thousand years before Informatics, but the fact that they have designed algorithms is not sufficient to consider the scribes of Antiquity as informaticians. Informatics only begun in the middle of the 20th century when machines started to be used to execute algorithms, which led to create languages to express these algorithms and to represent the objects on which these algorithms operate in a way accessible to a machine, which led to information theory.

These four categories of objects do not play the same role in Informatics. Let us illustrate this with an example. A sorting algorithm is an algorithm that can be expressed in a programming language and executed on a machine to transform information. For instance it sorts the list `5,1,3` into the list `1,3,5`. All this endeavor of designing an algorithm, expressing it in a programming language, and building a machine to execute it aims at knowing that the result of sorting the list `5,1,3` is the list `1,3,5`. Thus, it seems that the ultimate goal of Informatics is to transform information and that algorithms, languages, and machines are elements of a method to reach this goal.

Here we can draw a parallel with Physics. The goal of Celestial mechanics is to make predictions about the position of stars, planets, and satellites, at a given moment. And momentum, force, energy, etc. are only elements of a method to reach this goal.

It could be objected that Informatics cares more about the complexity of various sorting algorithms, than about the result of sorting a specific list such as `5,1,3`. But, it could be objected, in a similar way, that Physics cares more about Newton's equations, than about the position of Jupiter next Monday. Nevertheless, the ultimate goal that defines Physics is to produce statements about nature, and not about differential equations. In the same way the ultimate goal that defines Informatics is to transform information and not to produce results about algorithms, languages, or machines.

This way, investigating the nature of the objects studied by Informatics is investigating the nature of information and not the nature of languages, machines, and algorithms. Information is an abstract object and the judgement that the result of sorting the list `5,1,3` is the list `1,3,5` is analytic.

Thus, from the point of view of the objects it studies, Informatics is analytic, like Mathematics.

The method of Informatics

It is possible to judge that the result of sorting the list `5,1,3` is the list `1,3,5` by a simple mental operation and such a judgement would be *a priori*. However mental computation is not a part of Informatics, because what defines Informatics is not just the application of an algorithm to information, but the use of a machine, that is a physical system, to do so. Judging that the result of sorting the list `5,1,3`, with a machine, is the list `1,3,5` does not require a mental operation, but an observation: the result of the computation is a state of a physical system, that needs to be observed. This link to nature is essential in Informatics: the possibility or not to perform some computation with a machine is determined by the laws of Physics: for instance, if the velocity of information were not bounded in nature, some functions, that cannot be computed with machines in our world, could then be computed.

The judgement that the result of sorting the list `5,1,3` with a machine is the list `1,3,5` is therefore *a posteriori*. From the methodological point of view, Informatics is therefore *a posteriori*, like the Sciences of nature.

Of course, it could be objected that if the judgement that the result of sorting the list `5,1,3` with a machine is the list `1,3,5` is *a posteriori*, other judgements, in Informatics, are *a priori*. For instance, the judgement that insertion sort is a quadratic algorithm is *a priori*. In the same way, in Physics, the judgement that the trajectories solutions of Newton's equation are conic sections is *a priori*.

But this does not make Physics *a priori*, because, as already said, the ultimate goal of Physics is not to produce statements about the solutions of differential equations, but about nature. In the same way, the existence of *a priori* judgements in Informatics does not make Informatics *a priori*, because the ultimate goal of Informatics is not to produce statements about the complexity of sorting algorithms, but to use physical systems, machines, to execute these algorithms.

Informatics

We thus reach the conclusion that Informatics is a science that is analytic, like Mathematics and *a posteriori*, like the Sciences of nature.

To the two traditional categories of analytic *a priori* and synthetic *a posteriori* sciences, we must then add a third one for analytic *a posteriori* sciences, category to which Informatics belongs.

The traditional classification of sciences and Informatics

Many universities have a department of Mathematics and Informatics, but, in the organization of the *Centre National de the Recherche Scientifique*, Informatics was a part of Physics as the 7th section, *Sciences et technologies de l'information (informatique, automatique, signal et communication)*, was between the section *Matière condensée : structures et proprietés électroniques* and the section *Micro et nano-technologies, électronique, photonique, électromagnetisme, énergie électrique*.

We have here two partial ways of looking at Informatics as an analytic science, like Mathematics, in the first case, and as an *a posteriori* science, like Physics, in the second. But both ways ignore the specificity of Informatics, that is to be both analytic and *a posteriori*, and therefore different both from Mathematics and from the Sciences of nature. These two ways of looking at Informatics mutilate it, to let it fit in a classification that precedes it.

Is Informatics the only analytic *a posteriori* science?

Before asking if Informatics is the only science in this category or if many sciences are analytic *a posteriori*, we can ask the same question for the two other categories. Mathematics seems to be the only analytic *a priori* science, while the synthetic *a posteriori* sciences are many: Physics, Biology, etc.

However, this difference is purely conventional. We could have separated Arithmetic and Geometry as two distinct sciences, like Boethius did, or merge all the Sciences of nature in a single one: Natural philosophy.

We can, in the same way, divide Informatics in various sub-domains, that study programming languages, networks, complexity, architecture, safety, security, etc. Considering these domains as different sciences or as branches of a single science is purely conventional.

Also, when an analog machine or even a wind tunnel is used to solve a differential equation, an analytic *a posteriori* truth is produced. Whether this is considered as a part of Informatics, or of another analytic *a posteriori* science is conventional.

Relativizing the distinction between *a priori* and *a posteriori*

Thus Informatics requires to extend the usual classifications of sciences to include analytic *a posteriori* sciences. But it also destabilizes the usual classifications of sciences in two other ways.

First, it leads to relativize the distinction between *a priori* and *a posteriori*. The externalization of thought and memory, that begun with writing and accelerated with Informatics, the utopia of transhumanism, and also the investigation and simulation of the neural mechanisms, the perception of oneself as another, and everything that leads us to think that we are not outside nature but part of it, leads to relativize the difference between *a priori* and *a posteriori* judgements.

For instance, we consider a judgement obtained with mental computation as *a priori* and a judgement of the truth of the same proposition obtained with a pocket calculator as *a posteriori*. But if we were able to graft an electronic circuit executing arithmetic operations to our brain, should we consider a judgement obtained with the help of this device as *a priori* or *a posteriori*?

Is this distinction between an *a priori* judgement obtained by a mental computation and an *a posteriori* judgement obtained with a pocket calculator due to the fact that our neurons are inside our skull, while the pocket calculator is outside? That they are made of carbon, oxygen, and hydrogen, and not of silicon? Or that to read the result of the computation we need to use our senses in one case but not in the other?

Thus, because it renews the methods to judge a proposition true, Informatics destabilizes the distinction between *a priori* and *a posteriori* judgements. Thinner distinctions need to be defined, that take into account the variety of tools allowing to establish the truth of a proposition: neurons, senses, measuring instruments, computing instruments, etc. insisting both on the failability of each of them and on their complementarity.

The role of technology in Informatics

Like the word "Chemistry" and unlike the word "Physics", the word "Informatics" denotes both a science and a technology, that is an activity whose goal is to establish the truth of some propositions, and an activity whose goal is to build objects: programs, machines, etc. with a purpose. This link between science and technology seems to be stronger in Informatics than in other areas. For instance, many questions in algorithmic originate from questions raised by the development of networks.

But, it is likely that science and technology have strong links in all areas and that our view that they do not, and that we can classify sciences without considering technologies as well, is an illusion. For instance in the 19th century, the title of Carnot's foundational work of thermodynamics was *Reflections on the Motive Power of Fire and on Machines Fitted to Develop that Power*. Thermodynamics was not, at that time, separated from the problem of the construction of steam engines. Thus Informatics reminds us the strength of this link between science and technology, that we might have forgotten, and raises the question whether we should classify sciences alone and or sciences and technologies together.

Thus, not only Informatics requires to extend the usual classifications of sciences to include analytic *a posteriori* sciences, but it also destabilizes the usual distinction between *a priori* and *a posteriori* sciences and the usual classifications of sciences, that attempt to classify sciences alone and not sciences and technologies together.