Methods of Representation as Inferential devices

In this presentation, I will explain Stephen Toulmin's procedural theory of concepts and explanation (Toulmin 1953, 1972) in order to build on two overlooked ideas from his philosophy of science: *methods of representations* and *inferential techniques.* I will argue that developing these notions could be useful for shedding light on certain characteristics of scientific reasoning, namely: how scientific inference is related to representational structures, concepts and explanation within scientific practices.

Finally, I will argue that methods of representations are constitutive of scientific inference, and I will show how these notions could explain (among other things) the diversity of inferential practices in science.

The classical view of reasoning deems logic and probability the central engines of human reasoning, conceiving inference as an individual and propositional-based process (see Mercier & Sperber 2017). During the last decades, however, this view has been progressively abandoned by most cognitive scientists and (to a minor extent) by philosophers, mainly due to its unrealistic and highly idealized view of cognitive agents, and for completely ignoring the situated character of human reasoning and rationality (its historical, cultural, and social dimensions).

Different alternatives have come to replace this view. In general, following the tendency of developing theories capable of capturing this *situated* character of cognition and reasoning.

This tendency was echoed in philosophy of science, and has encouraged certain philosophers to propose more realistic and sophisticated accounts of scientific reasoning. Some well-known examples are Hacking's *styles of reasoning* (Hacking 2009); Nersessian work on model-based reasoning (Nersessian 2010); or Magnani's work on manipulative abduction (Magnani 2004).

However, before all these proposals, and within the framework of a systematic critique of classical logic as an adequate theory of reasoning and argumentation, Toulmin had already developed a *situated* view of scientific reasoning which is articulated around two main notions: *representational method* (MR) and *inferential* (or *inferring*) *techniques* (IT). The main point of this approach is that scientific reasoning cannot be fully explained by reducing it to a set of basic cognitive capacities working with an amodal type of input, and independently of any socio-cultural context. Instead, it must

be understood as a socially-embedded activity which requires the agent to master different methods of representing information that make possible specific forms of inferences.

In its broadest definition, MR are specific techniques and procedures that allow scientists to construct models of phenomena in specific ways. They are associated with basic explanatory schemes (or *ideals of natural order*) that respond to the theoretical background of scientific disciplines in specific periods of time. They are generative, since they establish the rules and the symbolic resources that will constitute particular models that allow scientists to represent, understand and think about phenomena. And they are not strictly linguistic-based but multi-modal: they can be constituted by the use of different symbolic notations, diagrams, images, or any combinations of those elements.

ITs come associated with MRs. They are procedures of reasoning that require the manipulation of the symbolic structures involved in the MR in question. For example, finding the length of a shadow in geometrical optics, implies the mastering of the diagrammatic techniques used to represent the phenomena as well as the relevant methods of calculations used in the MR. In general, scientist use techniques of representation and symbolic manipulation without which it would be impossible to arrive to certain conclusions.

One important consequence of Toulmin's ideas is that MR are constitutive of scientific inference and of conceptual development in science (this last point was explicitly developed by Toulmin himself). This is, that the content of many scientific concepts can only be grasped via the mastering of a particular MR and an IT, and that conceptual change, in many cases, is due to changes at the level of the MR in use within a scientific discipline.

For understanding this point it's necessary to explain Toulmin's *procedural* view of concept possession where concepts cannot be reduced neither to linguistic entities nor to abstract ideas, but instead, they gain content embedded in (cognitive) practices that involve the mastering of MR within certain symbolic environments. These practices are highly normative and public and, as a consequence, concepts are not constructed "in the head" of users after some kind of *cognitive grasping* of abstract ideas (as in Frege's view) but they are grasped when the user learns to correctly follow all the procedures involved in the MR in question. These procedures come associated with the ITs that

determine the concepts' inferential roles (this is: the set of inferences which the concept licenses, disallows, or participates in, within the framework of a specific conceptual network).

I will illustrate Toulmin's ideas by analyzing the development of the notion of instantaneous velocity during the passage from geometrical (Galilean) physics to analytical mechanics.

As Giusti (1994), Blay (1992) and Panza (2002) explain, until the development of analytical mechanics, the science of motion was mainly based on a geometrical method of representation which posed serious conceptual constraints to physicist, like the impossibility of reasoning with the notion of *continuity* and with a proper notion of *instantaneous velocity*.

Within the framework of geometrical physics (Galileo, Descartes, Newton) there was an operational – but non-explicit – notion of instantaneous velocity and we had to wait until the development of analytical mechanics in order to have an explicit one. This was possible thanks to Varignon's interpretation of Leibniz' infinitesimal calculus.

Varignon built on Leibniz' *differential* in order to define the velocity at instant *t* as valid for every infinitesimal interval of time *dt*. His argument is straight-forward, since t+dt ~ t, velocity doesn't vary and so v(t) ~ v(t+dt). This allowed Varignon to give an explicit (algebraic) definition of instantaneous velocity: $v = \frac{ds}{dt}$, $dv = \frac{d^2s}{dt}$ and $\gamma = \frac{dv}{dt}$ (accelerative force).

Varignon's interpretation of the concept of velocity at each instant that is valid for both rectilinear and curvilinear motion was only possible thanks to the new (representational) tools of infinitesimal calculus, which allowed physicists to overcome the conceptual limitations imposed by the old geometrical MR and to develop a new algebraic-based MR that was the foundation of a new mathematical physics: analytical mechanics.

I will argue that this case shows how the mathematical language used in physical theories (and more generally, the symbolic structure used in a MR) is not *conceptually neutral*, but quite the opposite, it is the condition of possibility of the very emergence of certain concepts and of their systematic use within a particular inferential technique.

Building on this example and in Toulmin's ideas I will propose to understand MR (and models) as *inferential devices*, this is, as symbolic-normative structures that, when

correctly manipulated, make possible the forms of inferences that will characterize scientific reasoning within a particular discipline.

Following this last point, I will argue that Toulmin procedural theory could work as the foundations for a model-based approach to reasoning, capable of shedding light on the diversity of inferential practices in science.

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