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► **To cite this version:**

Lucie Fabry. A dialogical philosophy. Philosophical Inquiries, 2021, 9 (1), pp.211-230.  
10.4454/philing.v9i1.362 . halshs-03156041

**HAL Id: halshs-03156041**

**<https://shs.hal.science/halshs-03156041v1>**

Submitted on 2 Mar 2021

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## **A dialogical philosophy: Bachelard's Introduction to "Le Rationalisme appliqué"**

***Philosophical Inquiries*, vol. 9, n° 1, 25 février 2021, p. 211-230.**

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In 1940, Gaston Bachelard became a Professor in Philosophy of Science at the Sorbonne and Director of the Institute of History of Science and Technology on the *rue du Four* in Paris. He published *La Philosophie du non* at the Presses Universitaires de France (Bachelard, 1940; Eng. tr. 1968a), which was his 13<sup>th</sup> book. To that date, his books had focused mostly on the history of physics and chemistry, even though Bachelard's interests extended far beyond these disciplines and included notably psychoanalysis (Bachelard 1938a; Eng. tr. 2002a; 1938b; Eng. tr. 1968b) and literary criticism (Bachelard 1932; Eng. tr. 2013; 1939; Eng. tr. 1986). Between 1940 and 1949, however, Bachelard did not publish any epistemological book. This nearly 10-year gap in Bachelard's prolific epistemological production is explained by the Second World War, a period during which he continued to write intensively but focusing on the powers of imagination (Bachelard, 1942; Eng. tr. 1983; 1943; Eng. tr. 1988; 1948a; Eng. tr. 2002b; 1948b; Eng. tr. 2011). As a counterpart to his works on the psychology of the scientific mind, he thus dedicated himself to the psychology of aesthetic emotions, inquiring how poetical images reverberate in us. The publication of *Le Rationalisme appliqué* in 1949 marked Bachelard's return to epistemological concerns.

The following text, available for the first time in an English translation by Gennaro Andrea Lauro, is a preliminary version of what would become the introduction to *Le Rationalisme appliqué* (Bachelard, 1949). Bachelard published that text separately in February 1947 in the first issue of the international journal *Dialectica* (Bachelard, 1947). The version of 1947 and that of 1949 are almost identical, except for minor revisions. We can, therefore, regard its translation as a first step towards making *Le Rationalisme appliqué* accessible to the English readers, hoping that it may lead to a translation of the entire work. It is nonetheless interesting to wonder why Bachelard chose to publish that introduction separately in

Lucie Fabry, "Past/Present": Bachelard, Gaston, "La Philosophie dialoguée", *Philosophical Inquiries*, Special Issue on Ian Hacking, ed. by Marica Setaro & Matteo Vagelli.

*Dialectica*, and I will start by questioning the meaning and function this text had in the context of its first publication.

***Dialectica: International review of philosophy of knowledge***

Bachelard was one of the founding members of *Dialectica: International review of philosophy of knowledge*, along with Paul Bernays, a Swiss mathematician close to David Hilbert, and Ferdinand Gonseth, a Swiss mathematician and philosopher with whom Bachelard had strong intellectual affinities. The three authors opened the first issue of their journal with an Editorial published in English, French and German, which stated how strongly the Second World War had shaken the faith in the value of scientific knowledge: "Some people say: we refuse to accept this century in which we live; we refuse its knowledge and its inventions; we refuse to accept this civilization for which we feel ourselves less and less conjointly responsible, its technical ideals, its false values." (Bachelard *et al.*, 1947: 1). Despite their understanding of what motivates such rejection of the "scientific era", the authors refused that search for a way out and instead claimed that "the remedy against the dangers of knowledge is better knowledge" (1). They presented their international journal as part of "a sustained philosophical effort" which was required in order to keep science "on the horizons of human values" (1). An indication that *Dialectica's* reflections on science had a civilizational scope is also found in the text that concludes the first issue: the French translation of a speech by Pope Pius XII to the members of the International Congress of Philosophy held in Rome in November 1946 (Pius XII 1947). In this speech, the Pope affirmed that both (Catholic) religion and philosophy stood against "a certain pessimistic irrationalism" (Pius XII 1947, 110; Eng. tr. is our own) and wanted to lead the new generation towards the "sublimation of human tendencies in favor of superior ideals" (109), in spite of "the extreme atrocities that this youth has had to endure in recent years" (109). It would be excessive to claim that the choice to publish that allocution implied that the funders of the review subscribed entirely to the Pope's view—the journal also had the ambition to keep track of the activities that took place in and around these international congresses. This choice of publication may, however, indicate that the authors aspired to a broad syncretism around the belief that a better understanding of scientific thought could help us achieve a better humanity.

Bachelard's article was published in the pages which directly followed the Editorial: in that sense, it completed the journal's Manifesto and specified what conception of science was able to support these humanistic values. In Bachelard's article, however, the question of the dangers of technology and

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the quest for the norms and values of scientific civilization is almost entirely set aside to focus on a more traditional epistemological question: what is science, and how can it achieve true knowledge of reality? *Dialectica* as a whole did give precedence to the analysis of scientific activity over the consideration of broad humanistic issues. The Journal would soon welcome publications from the most prominent scientists of that time, with a special issue in November 1948 on the notion of complementarity in atomic physics edited by Wolfgang Pauli (1948) including articles from Niels Bohr (1948), Albert Einstein (1948), Louis de Broglie (1948), Werner Heisenberg (1948) or Hans Reichenbach (1948); in December 1958, a remarkable double issue on mathematics and formal systems included, among others, texts from Rudolf Carnap (1958), Kurt Gödel (1958), Reuben Goodstein (1958) and Thoralf Skolem (1958). The founders of the journal refused, however, to separate these works on science from a broader philosophical framework, as indicate the very name *Dialectica* and the fact that the first issue was dedicated to that notion of dialectics, which was deliberately chosen as a broad and traditional philosophical concept. Even though this journal constitutes in its current form the official organ of the European Society for Analytic Philosophy, it is interesting to keep in mind that its original editorial line knew no divide between continental and analytic philosophy: these articles from Hans Reichenbach, Rudolf Carnap, Karl Popper (1978) or Alfred J. Ayer (1958) were peacefully cohabiting with texts from Jean Piaget (1950, 1954, 1959), Carl Gustav Jung (1951), Eugène Dupréel (1957) or Raymond Ruyer (1959).

### **A philosophical dialogue between theoreticians and experimenters**

Let us now consider Bachelard's text a little more closely. At its core stands the diagram on page 235, of which Bachelard may have been the only one to believe that it is so clear that "it is barely necessary to comment on it" (234). This diagram displays philosophical tendencies: at the center stands a duo, "applied rationalism and technical materialism". Other trends stand on a ladder that goes up and down that center: Formalism and Conventionalism aligned with the ascent that leads to Idealism; Positivism and Empiricism aligned with the descent that leads to Realism. The aim of the remaining parts of this presentation will be, simply and solely, to understand what Bachelard meant when he drew that diagram. I will start by focusing on the center, "applied rationalism and technical materialism", which designate, as a couple, Bachelard's own position. I will then specify the role Bachelard gave to the other philosophical tendencies as he displayed them around that center.

One can be surprised by the fact that Bachelard did not give one name, but two complementary ones to his philosophy of science: "applied rationalism and technical materialism". He also designated it earlier in the text as "an *applied rationalism* and an *instructed materialism*" (234). Not only did he use a combination of two expressions, but each of these expressions has itself a dualistic character: the name of a philosophical current is always associated with an adjective that specifies it. Jean-Claude Pariente (2015, 251; Eng. tr. is our own) remarked that "these expressions are always syntactically dualist and semantically auto-correcting. These expressions are composed of a noun and an adjective. The function of the adjective is to straighten, fix the effect of the noun and warn against its heaviness. They must always be taken with an implicit 'but' in it." The combination of two of such expressions looks like a series of checks and balances: Bachelard's philosophy is rationalism *but* it is applied *but it is also* materialism, *but* it is technical and instructed.

That way of naming his philosophy reflects Bachelard's commitment to a "dialogical philosophy" (*philosophie dialoguée*), that is, a philosophy that stems from a dialogue and is constituted by it. That notion can be regarded as a Socratic legacy, and so does Bachelard's use of the notion of dialectics in a sense that is close to its Greek etymology, referring to a dialogue. Less traditional, however, are the protagonists of that dialogue, and what they are talking about. The philosophical dialogue Bachelard referred to at the beginning of "La Philosophie dialoguée" was not, he insisted, a dialogue between philosophers, but a dialogue between scientists. Bachelard claimed that philosophers do not know how to have a fruitful philosophical dialogue, only scientists do. By that, he did not mean that scientists should practice philosophy on their spare time, and would then become, thanks to their scientific knowledge, the best philosophers. Even though he claimed that a precise knowledge of science was required to do good philosophy, he also deplored that scientists, once they start philosophizing, often become philosophers like any others, prompt to commit the same mistakes (see for instance Bachelard, 1953: 19–20). Bachelard did not claim that scientists should turn to philosophy, but rather that scientific discussions *as such* constitute the best philosophical debates one can hope for. The dialogue he presented occurs, more specifically, between a specialist of theoretical physics and a specialist of experimental physics. Their conversations constitute the concrete and daily relationship between theory and experience, which, according to Bachelard, is the place to look to seriously address the question of the relationship between mind and reality. However, why should we consider their discussions as a philosophical dialogue, considering that they are not talking about philosophy but rather

exchanging precise theoretical or experimental information? According to Bachelard, the theoretician and the experimenter adopt, by virtue of their professional specializations and without necessarily being aware of it, two different philosophies: rationalism and empiricism. Rationalism, as Bachelard understands it here, gives primacy to theory: it is above all concerned with the search for theoretical coherence, completion and rigor. It defines, from that perspective, the role of experiment, claiming that theoretical hypotheses should lead experimental programs and that experimental knowledge has little value without its theoretical interpretation. Empiricism, on the other hand, gives the primacy to experimentation: it is mostly concerned by experimental precision and claims that we should consider the facts even when they do not match our theories, arguing that facts can suggest new theories, lead to a modification of admitted theories or even to their rejection. In philosophy, according to Bachelard, these attitudes towards theory and experimentation have crystallized in two antithetic views on knowledge and science. Therefore, when a debate occurs between rationalists and empiricists, there is little hope that it will lead to a reduction of their antagonism. In the daily practice of physics, however, rationalism and empiricism exist as two professional attitudes: theoreticians are professional rationalists, experimentators professional empiricists. However, these attitudes are shared between people that know they have to work together. Despite the growing division of labor and specialization which allowed that theoretical and experimental physics are practiced by different persons with different trainings and professional habits, it is nonetheless clear, according to Bachelard, that physics as a discipline lies at their intersection: "If one of the two terms is missing, we can still do experiments and we can still do mathematics, but we cannot participate in the scientific activity of contemporary physical science." (234). This solidarity between theoretical and experimental physics takes very concrete forms: for instance, "no physicist would spend 'his credit' to build an instrument with no theoretical destination" (233).

Bachelard's ambition as a philosopher was to draw lessons from the fact that rationalism and empiricism are actually combined in scientific activities, as two complementary professional attitudes. This is what prevented him from adopting what he calls "monodromic philosophies", "*philosophies monodromes*" (Bachelard, 1949: 159): pure rationalism or empiricism, and led him to look for a way to combine them. Dualist expressions such as *applied rationalism* designate that philosophical combination. The expression *applied rationalism* was built in analogy with the distinction between *pure* and *applied mathematics*. However, this analogy may be misleading if one considers that pure mathematics does exist as an

autonomous scientific field: even if the possibility of finding long-term applications is one of the reasons why this field receives funding, it is a fact that not all mathematics is applied mathematics. Following that analogy, one could assume that pure and applied rationalism could coexist, equal in value, investigating different aspects of rationality. However, Bachelard focused on physics, where mathematics must, by definition, be applied to the knowledge of physical reality. He precisely intended to elucidate the conditions under which mathematics can be made to serve such purpose and stated that they take the form of an endless dialogue between theory and experiment. From that perspective, pure mathematics can be nothing but flawed physical theories, that is, theories that tend to withdraw from experimental control or are unable to suggest new experiments. By analogy, Bachelard argued that pure rationalism misunderstood the way the mind constitutes knowledge because it underestimated the way our reasoning is shaped by experience. He addressed a symmetrical accusation to empiricism or materialism—it seems that Bachelard regarded these terms as synonymous in that text, even though a later text, *Le Matérialisme rationnel* (Bachelard, 1953), gave another, more specific sense to the notion of materialism. As a result, were Bachelard to make his own the notion of materialism, it would only be with the qualification that materialism is technical or instructed, which are two manners of underlining the way experience is shaped by theory.

That ambition to apprehend the solidarity between theory and experiment led Bachelard to be conceptually innovative. Besides the expressions of *applied rationalism* and *instructed materialism*, he elaborated the notion of *phenomenotechnique*, which can be regarded as one of Bachelard’s most significant contribution to the philosophy of science (Bontems, 2010; Castelão-Lawless, 1995; Chimisso, 2008; Donatiello *et al.*, 2018; Fabry, 2019; Granger, 1987; Gaukroger, 1976; Rheinberger, 2005). When he elaborated it in the early 1930s, and as he used it ever since, that notion is inseparable from another neologism, *noumenology* (Lamy, 2005). Noumenology is the name Bachelard gave to theoretical activities *considered in their relation to experiment*; phenomenotechnique is the name he gave to experimental activities *considered in their relation to theory*. The notion of phenomenotechnique insists on the technological character of a scientific experiment: it is not the mere observation of a fact but the production of a phenomenon. Even though they serve different ends—when industry and science are not actually combined—a laboratory and a factory are analogous, according to Bachelard, in the sense that both create artefacts that meet specific ends and comply to specific constraints. However, Bachelard insisted on the technological character of a scientific experiment only since it was indicative

of its dependence towards theory. Indeed, he retained from Pierre Duhem (2006; Eng. tr. 1991) that “instruments are theories materialized”, in the sense that the conception and use of scientific instruments rely on a set of theoretical assumptions. Hence, artificially produced phenomena “bear the stamp of theory throughout” (Bachelard, 2020; Eng. tr. 1984: 13). On the side of theory, Bachelard’s concept of noumenology acknowledged that mathematical theories possess their own dynamic and may legitimately explore paths that do not seem to have any empirical correlate. However, the notion of noumenology nonetheless insisted on the fact that such mathematical excursions would only be valued, in physics, according to their capacity to lead the successful production of phenomena that conform to its expectations. Even though the experiment relies on theoretical assumptions, as the notion of phenomenotechnique indicates it, the experiment may nonetheless address objections to these theoretical premises by departing from what was expected. Bachelard’s dialectics between theory and experiment, or, more precisely, between noumenology and phenomenotechnique, thus designates the dialogue through which theory and experiment conjointly evolve and shape each other, as theoretical suggestions meet experimental objections, or unexpected experimental results look for their theoretical interpretation.

### **Dialectics, doublets and idoneism**

In “La philosophie dialoguée”, Bachelard assimilated his own concept of dialectics with two other conceptual innovations: Léon Brunschvicg’s *doublets*, and Ferdinand Gonseth’s *idoneism*. In an earlier text (Bachelard 1945), Bachelard had presented Léon Brunschvicg as his philosophical Master and claimed that *L’Expérience humaine et la causalité physique* (Brunschvicg, 1922) offered an eminent analysis of the way theory relates to the experiment. He noticed Brunschvicg frequent use of distinctions such as *numbering number* and *numbered number*, *spacializing space* and *spacialized spaced*, and called such expressions “Brunschvicgian doublets”, claiming they were built in reference to Spinoza’s distinction between *natura naturans* (naturing nature) and *natura naturata* (natured nature) (239). Even though the actual intent of Spinoza (2020) when he borrowed this distinction to Scholasticism is subject to much discussion (Ramond, 2011), it seems that Bachelard regarded it as a way of distinguishing God from its creation whilst claiming that they constitute the same thing, considered from two different perspectives. Similarly, Brunschvicg’s doublets would distinguish two complementary ways of conceiving scientific objects whilst claiming that they cannot, in fact, be dissociated. The solidarity between theory and experiment implies, according to Bachelard’s reading of



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Brunschvicg, that the same facts can be translated in “two languages”: “the translation of scientific experiment and the translation of rational coherence” (Bachelard, 1945: 81; Eng. tr. is our own). If one looks back to Brunschvicg’s work, however, it appears that Bachelard’s reading minimized some aspects that made this work closer to pure rationalism, in the sense stated above, than applied rationalism. When Brunschvicg introduced the distinction between *numbering numbers* and *numbered numbers*, in the sense of a distinction between the activity of counting and the things counted, he insisted on the fact that the understanding of the prevalence of numbering numbers was a necessary condition for the emergence of mathematics and the further development of human knowledge (Brunschvicg, 1922: 473–477). He significantly did not refer to Spinoza but to Malebranche (see for instance Robinet, 1961 for an analysis of Malebranche’s use of the notion of numbering number). The main thesis of his “philosophy of judgment” (Brunschvicg, 1922: 474) was that science progresses as the mind gets more aware of its constitutive activity, instead of conceiving the world as a pre-existing given. One can, therefore, argue that even though Bachelard was deeply influenced by Brunschvicg’s rationalism (Vinti, 1997), he nonetheless departed from it progressively by giving a more important role to scientific experiment (Dagognet, 1965).

The second author with whom Bachelard claimed to have affinities, Ferdinand Gonseth, seems to stand closer to his applied rationalism. Gonseth’s notion of *idoneism* may be regarded as an attempt to express the way in which knowledge and its objects conjointly evolve in an open process of mutual adjustments (Bertholet, 1968; Bontems, 2013, 2018). Gonseth wanted to substitute this neologism—built from the French adjective *idoine* (which could be translated as adequate, appropriate to something)—to the traditional notions of *correspondence* or *adequacy* between knowledge and reality, because he considered that these notions conveyed the idea that knowledge and thought may exist as separate, static entities (Gonseth, 1936; 1939). Instead, *idoneism* designates an adequation which is always in the making and perpetually transforms the entities that aspire to be adequate to one another. Interestingly, whereas Bachelard’s main reference when he theorized his *applied rationalism* was mathematical physics, Gonseth elaborated his notion of *idoneism* by reflecting mainly on mathematics (Gonseth, 1936). The philosophical problem of the relation between knowledge and reality could be addressed, Gonseth claimed, within the field of mathematics itself, when one considers, for instance, the axiomatization of mathematics. The process through which an axiomatic theory is built does imply, according to Gonseth, an evolving relationship between an abstract, theoretical object and a mathematical object which

can be regarded as concrete and intuitive, even though it is not a physical entity. Since *The New Scientific Spirit*, Bachelard had similarly claimed that the dialectics between theory and experiment could, paradoxically, already be found in pure mathematics: “this need of application is felt just as strongly in pure mathematics, though there it is more hidden. It introduces an element of metaphysical duality into the mathematical sciences, which appear to be purely homogeneous . . . every pure idea is accompanied by an imagined application, an example that does duty for reality . . . In a reasonably clear-cut manner, mathematical realism (in its various functional roles) sooner or later operates to *give body* to pure thought” (Bachelard, 2020: 28; Eng. tr.: 4–5).

It is remarkable that both Bachelard and Gonthier, having a specific discipline dominantly in mind, intended to elaborate concepts that would apply to knowledge in general, or, at least, scientific knowledge. Bachelard claimed that his concepts, built in a reflection that focused mainly on physics, could also apply to pure mathematics. In contrast, Gonthier claimed that his idoneistic analysis of mathematics could also apply to the knowledge of the physical world. The strong similarities noticed between Bachelard and Gonthier theses seem, indeed, to indicate that such an extension of their concepts out of their initial field is possible. However, the philosopher and physicist Jean-Marc Lévy-Leblond (2017) has argued that Bachelard's dialectics between noumenology and phenomenotechnique may well be an accurate description of physics, but can hardly be applied to other scientific practices. In “La Philosophie dialoguée”, Bachelard himself suggested that an analysis of “other sciences, such as mathematics, biology, sociology and psychology” (237) could lead to other kinds of philosophies. Throughout his epistemological work, the history of physics constituted Bachelard's favorite philosophical playground, even though he also offered in-depth analyses in on the history of mathematics (Alunni, 2015) and chemistry (Bensaude-Vincent, 2005, 2012). He regarded these sciences as different regions of knowledge, who have their own history and dynamics, and do not build a unified system (Bachelard, 1949: 149 sq.). When questioning the history of these disciplines, he used the same set of epistemological concepts, wondering what forms of rationalism are applied in mathematics or chemistry. Concerning biology, sociology and psychology as sciences, Bachelard said very little. Does this indicate that these disciplines would have required a completely different epistemology? Since the 1960s, one of the leading questions among the historians and philosophers, who acknowledged some kind of Bachelardian legacy, has been the whether and how Bachelard's concepts could be useful to the study of biology or human and social sciences (Althusser, 1965; Eng. tr. 2010; Bourdieu *et al.*, 1972; Eng. tr. 1991; Canguilhem,

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1965; Eng. tr. 2008; Granger, 1967; Eng. tr. 1983; Rheinberger, 2010).

### **Two perspectives of weakened thoughts**

Let us go back to Bachelard's diagram on p. 235. The center, "applied rationalism and technical materialism", designates what he regarded as the legitimate way of conceiving the relation between theory and experiment, giving them an equal epistemological weight and stressing their deep solidarity. The other philosophies are ordered in what Bachelard called "two perspectives of *weakened* thoughts which, on one hand, lead from rationalism to naive idealism and, on the other hand, from the technical materialism to naive realism." (235). These "*weakened* thoughts" are characterized by the fact that they have lost the balance between theory and experiment: once you start overestimating the importance of theory and considering it aside from experiment, you are on the path to idealism; if, on the contrary, you overestimate the importance of experiment alone, and consider it aside from theory, you are on the path to realism. To put it boldly, Bachelard's diagram classes the philosophical positions of his predecessors and contemporaries by indicating how they failed to be Bachelardian. It must be noticed, however, that his intent is not purely critical: he claimed that he would "mutilate philosophy of science" if he did not take into account that, aside from applied materialism and technical materialism, other philosophical attitudes are part of "the psychology of the scientific mind" (238). He agreed, at least for those philosophies that are not too far from the centre of his diagram, that they also play an active and positive role in scientific thought: that these are not philosophers' ratiocinations that have lost track of what science is, but philosophical attitudes of scientists, in a sense that I mentioned earlier. He also felt that the philosophies that are at the same rank in the centre of his diagram could somehow dialogue with each other. That is to say that formalism and positivism as professional ways of conceiving theory and experiment, respectively, could somehow be combined. Their combination would constitute a way of articulating theory and experiment that would be looser than the one that characterizes noumenology and phenomenotechnique, but that would nonetheless be quite satisfying.

What may make it difficult to understand Bachelard's diagram is that he had his own definitions of such notions as positivism, formalism, idealism or realism, definitions which he never plainly formulated but can be inferred from his use of these terms. All these *-isms* function like ideal types: it is less important for Bachelard to target specific philosophers than to identify broad philosophical attitudes. *Formalism* could be defined by the assumption that scientific theories are

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autonomous deductive systems, which stems from their own postulates and can be considered independently from the experiment, from the perspective of their logical consistency alone, even though conclusions can be drawn from these systems that we can submit to experimental control. *Positivism*, as Bachelard used that term, would stand for the assumption that scientific theories sum up our knowledge of facts and registers regularities in observable phenomena, but do not pretend to reflect, accurately, what reality is. Formalism and Positivism are not incompatible: Bachelard did claim that a dialogue could be set between them. If we assume that a theory is a deductive system, which is built up independently of experience, we may well admit that different theories could be applicable to the same set of facts, as they do not claim to reflect their inherent nature, but to provide an accurate representation of our data. We could look for philosophers who stood for such of a combination of formalism and positivism, perhaps among the tenants of logical empiricism. It is, however, more interesting to note the role that Bachelard gave to this philosophical position: he felt that such an alliance of positivism and formalism was unsatisfactory as a discourse on science in general but could nevertheless provide an accurate description of certain aspects of scientific practice. He was dissatisfied by formalism and positivism since they both state too loose a connection between theory and facts, in comparison to his concepts of noumenology and phenomenotechnique: formalism grants too much autonomy to mathematical reasoning by considering that the contact with experience is only terminal, instead of considering that it actually permeates conceptual activity throughout; positivism granted too much autonomy to experience by claiming that the role of a theory merely consists in summing up the facts, while Bachelard held that it actively produces them through phenomenotechnique. However, while positivism and formalism were deemed unfit for a depiction of these parts of contemporary physics which had reached the level of phenomenotechnique, Bachelard admitted that there were other parts of scientific activity where the connection between theory and experiment *actually was* looser. While asserting that his concepts of phenomenotechnique and noumenology provided a good understanding of the most advanced practices in contemporary physics and chemistry, he also acknowledged that these concepts made very specific demands on theory and experimentation. The belief that these demands were always met would lead to an idealized view of scientific practices: we should rather explore the diversity of theoretical and experimental practices that can be found in the past and present of these disciplines. Positivism could therefore describe correctly the status of emerging theories: in a subsequent work, Bachelard (1953) studied the history of chemistry and argued that this

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discipline was once positivist. Looking at chemistry in Kekulé’s time, it could very well be said, for example, that the geometric representation of the four valencies of carbon was a theoretical synthesis of experimental knowledge that did not claim to represent what carbon really looked like at the microscopic level. However, the status of this representation evolved as the phenomenotechnique of mass spectrometry, as well as the theories of microphysics, developed and gave it a higher objective value: any positivist account of contemporary representations of carbon would therefore be condemned as reductive. Bachelard did not only claim that the intensity of the solidarity between theory and experiment varied historically, but he also considered that it could vary synchronically, from one field of chemistry to another: “Chemistry, epistemologically speaking, did not reach the same point of realistic maturation in each of its parts. One must, therefore, constantly take stock in order to determine how deep the different symbols and schemata are embedded in reality” (Bachelard, 1953: 122–123; Eng. tr. is ours). This is why Bachelard claimed that the study of chemistry required a *polyphilosophism* (236-237): a variety of philosophical positions which reflected the plurality of relations between theory and experiment.

However, Bachelard became more sharply critical as he commented on the philosophies that stand as the two extremes of his diagram: idealism and realism. In that text, *idealism* stood for the belief that the laws of the world follow the laws of the mind: the knowledge that the spirit elaborates independently from any relation to experience is by itself knowledge of reality. *Realism* stood for the belief that the mind cannot fully understand reality, that reality irremediably exceeds our cognitive capacities. This definition explains why Bachelard often associated realism with irrationalism, i.e. the depreciation of the powers of reasoning. One reaches these philosophical positions, according to Bachelard, when one completely loses track of either experiment (idealism) or theory (realism); the articulation between these philosophies would consist in an oscillation between two incompatible views, as one shifts from one extreme to another. Bachelard associated such combination of realism and idealism with one philosopher: Émile Meyerson, who can be regarded as Bachelard’s designated enemy (Fruteau de Laclos, 2015).

Bachelard referred more specifically to *Identity and Reality* (Meyerson, 1912; Eng. tr. 2007), where Meyerson claimed that the human mind has one fundamental need: the search for identity, that is, the will to find something which remains permanent through changes. He presented such identification as the most fundamental form of intelligibility and intended to prove that it stood behind most of our intellectual

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operations such as the structuration of perception and the search for causes of phenomena. Meyerson, however, noted that there is another factor at play in the constitution of knowledge objecting to our quest for an identity: the willingness to report in detail the reality in its changing diversity. Bachelard sure gave a caricatural view of Meyerson’s work, as he stated that it pictured a static opposition between the mind, defined by its search for what is identical, and reality, defined by the resistance it opposes to that operation. *Identity and Reality* instead showed how the will to combine these two requirements gave its dynamics to the process of knowledge: the search for identity and what we call reality take different forms, according to Meyerson, which evolve conjointly as new experiments challenge our first attempts to find an identity—which is, one may argue, closer to a Bachelardian dialectics than Bachelard himself would have admitted it.

While Bachelard's reading of Meyerson may be unfair, I propose looking at the extremities of his 1947 diagram from another angle: I will regard the critic of Meyerson as an indirect form of self-criticism, revealing of Bachelard’s own philosophical evolutions. Jean-Claude Pariente (2015) indeed stated that such hesitation between idealism and realism characterized Bachelard’s 1927 two doctoral theses (*Thèses de doctorat d’État*), the *Essai sur la connaissance approchée* (“Essay on approximate knowledge”) and the *Étude sur l’évolution d’un problème de physique, la propagation thermique dans les solides* (“Study on the evolution of a physics problem: thermic propagation in solids”). Even though these two works were written at the same period, there are deep tensions between them, which is probably linked to the fact that they belong to two different genres: the first one belonging to the traditional philosophy of knowledge; the second being a study of the history of physics. In his philosophical *Essay*, Bachelard was deeply influenced by Bergsonism and by Émile Meyerson himself, which can be regarded as part of Bergsonism in a wide sense (Fruteau de Laclos, 2009). He made a positive reference to the work of Meyerson and stood much closer to what he later came to designate pejoratively as “naïve realism”: “Mr. Meyerson has proved that science commonly postulates a reality. In our point of view, this reality presents, in its inexhaustible unknown, a character which is eminently favorable to the development of an endless research. All its being lays in its resistance to knowledge. We will thus take as the postulate of epistemology the fundamental incompleteness of knowledge.” (Bachelard, 1928: 13; Eng. tr. is ours). The philosophical essay thus stresses the limitations of scientific knowledge. It regarded mathematical physics as an example of the mind’s activity of tracking (*repérage*), which artificially structures reality by neglecting some of its aspects and claimed that it should

ultimately give way to a more direct apprehension of reality. The study of the history of mathematical physics, however, has given more power to mathematics: while Bachelard was studying the process that led to the formulation of the Fourier differential equations on heat propagation, he realised that mathematics does not simplify reality, but rather complicates our thinking and is the key to achieving objective knowledge. The first chapters of his study insisted on the fact that the common knowledge of heat was superficial and did not open any path for further progress; only the mathematical search for the equation of propagation would ultimately allow us to understand what heat is and how it works. Bachelard's conclusion was tempted by the adoption of a certain form of idealism—as we found in the introduction to *Le Rationalisme appliqué*, i.e. the assertion that reality follows the rules of the spirit. He insisted on the “prophetic sense of mathematical physics” (Bachelard, 1973: 168; Eng. tr. is ours), and claimed that such predictive power was all the more surprising that, according to him, these mathematical relations follow properly mathematical rules that “are at no time inspired by the relations of reality” (169). He considered that such power of mathematical reasoning could not be accounted for by assuming that mathematical theories merely sum up our empirical knowledge: “We can thus understand to a certain extent that mathematics offers an appropriate language in order to handle general elements that the scientific analysis of phenomena has set apart. However, our astonishment entirely subsists when we see mathematical physics, which Cauchy calls *sublime physics*, get ahead of observation and predict laws which refine and extend experimental laws.” (Bachelard, 1973: 168; Eng. tr. is ours). The study of the history of mathematical physics, therefore, led Bachelard to insist on what Eugene Wigner (1990) would later call “the unreasonable effectiveness of mathematics in the natural sciences”.

Bachelard's philosophical evolutions in the early 1930s can be considered as a way to solve the tensions that existed between his two doctoral dissertations. Since *The New Scientific Spirit* (Bachelard, 2020; Eng. tr. 1984), his presentation of a dialectics between theory and experiment can, indeed, be regarded as a way of combining two requirements which seemed incompatible. Bachelard granted that mathematical reasoning does have the power to “get ahead of observation and predict laws which refine and extend experimental laws” (Bachelard, 1973: 168), but he denied that it could do so independently from a perpetual dialogue with experiment. On the other hand, he granted that reality could exceed our rational constructions, but denied that this should be regarded as a fundamental limitation of scientific knowledge and rather claimed that this limit manifests itself in the form of concrete technical difficulties or experimental objections, which can only lead to a refinement of

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our theoretical knowledge. In his 1947 diagram, Bachelard presented realism and idealism as two extreme poles that can be reached when one loses the balance between theory and experiment. It seems that such a presentation inversed the real biographical order, the evolution through which Bachelard could finally overcome his hesitation between idealism and realism and combine them in the form of an applied rationalism and technical materialism.

The introduction to *Le Rationalisme appliqué* can be regarded as one of the most canonical expositions of Bachelard's philosophy of science. It echoes the introductions and conclusions of each of his epistemological works since *The New Scientific Spirit*, in a series of small philosophical treatises which offer a remarkable continuity. The central chapters of his epistemological works put these philosophical conceptions into play, offering an analysis of the latest scientific developments of his time. Bachelard's passionate readings of scientific publications enabled him to investigate the concrete and specific forms of this dialectics between theory and experiment. His legacy can be found in further attempts to investigate the solidarity between theory and experiment, as illustrated, for instance, the new trend of historical epistemology which developed at the Max Planck Institute for History of Science. Hans-Jörg Rheinberger (2005) praised how the notion of phenomenotechnique "conceptualizes the relation between scientific thinking and technology in modern science" (313), revealing that each scientific object "derives its existence from a circuit that is at the same time material and discursive" (316); he tried to investigate other kinds of material and discursive circuits in his personal work (Rheinberger, 1997, 2010). We could also say, using the concepts developed by (Daston, 2000), that the noumenon and the techno-phenomenon are the two sides of a scientific object: its theoretical and experimental mode of existence. We can finally question how these authors relate to Bachelard's work by wondering where they would stand in Bachelard's philosophical diagram: take, for instance, the social constructivism of (Latour and Woolgar, 1986) or the entity realism of (Hacking, 1983). Would they stand at the center of Bachelard's diagram, as a new form of his applied rationalism and technical materialism, or should we consider that they bend towards idealism and realism respectively (Vagelli, 2018)? Wondering what legitimate grounds for historians and philosophers could be to acknowledge a preference for one of the sides of Bachelard's diagram seems like the most efficient way to challenge his applied rationalism.



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