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Understanding Futures of Science. Connecting Causal Layered Analysis and the Philosophy of Science

Abstract

In this paper, I analyze the similarities and connections between the philosophy of science and causal layered analysis. I point out that the philosophy of science can be understood as a kind of causal layered analysis of science. The philosophy of science has mythic/metaphoric, structural/worldview, and causal levels that make science understandable. Moreover, the philosophy of science has analytic tools that correspond to the items in the so-called poststructural toolbox. These similarities and connections mean that the insights in the philosophy of science can be used to investigate the important but neglected topic of possible futures of science. This makes it possible (i) to open up the present and past to create alternative futures of science, and (ii) to reveal deep worldview commitments behind surface phenomena in science-related discourses. Connecting the philosophy of science with causal layered analysis also provides fresh insight into the nature of each approach.

Keywords: Future of Science; Philosophy of Science; Causal Layered Analysis; History of Science

1. Introduction

In this paper, I analyze the connections and similarities between the philosophy of science and causal layered analysis (CLA). These similarities and connections indicate that the insights in the philosophy of science can be used to investigate the important but neglected topic of possible futures of science. The philosophy of science has improved our understanding of science, but this understanding has not been developed into future-oriented thinking. I argue that one way to remedy this shortcoming is to connect the philosophy of science and CLA. Understanding the connections and similarities between the philosophy of science and CLA enables us to conceive *the philosophy of science as a kind of CLA* that (i) has already provided insights on mythic/metaphoric, structural, and causal levels of science and our conceptions of science, and (ii) uses analytical tools that are similar to the poststructural toolbox. As we will see, explicating the relationship between CLA and the philosophy of science makes it possible to open "up the present and past to create alternative futures" and to reveal "deep worldview committments [sic] behind surface phenomena" (Inayatullah 1998, 815) with respect to the possible futures of science. To avoid confusions, I want to highlight that the aim of this paper is not to perform a CLA of the philosophy of science but to show how the philosophy of science has already provided insights that corresponds to those that CLA achieves. Given this tight connection, it follows that if CLA is a viable method to study the possible futures and our conceptions behind them, so is the philosophy of science.

Opening up the present and past of science to create alternative futures and revealing deep worldview commitments with respect to science and the future of science is important for three reasons.

First, science has changed considerably during its history. Not only have the contents, methods, goals, and assumptions changed but so have its technological, social, and cultural settings. Moreover, many, if not most, aspects of science are dependent on these settings. The technological, social, and cultural settings are in constant flux and it seems reasonable to conjecture that the rate of technological, social, and cultural change will increase in the 21st century. The conclusion, that (at least some aspects of) science will therefore also change in the future, follows immediately.

Surprisingly, very little has been said about the estimating of possible futures of science (or sciences, to be exact). Only fragmented lines of thoughts concerning the estimating of the future of science are present in the literature. While there are many reports (e.g. EU; NATO) that summarize possible future topics and methods in science, there has been little reflection on how the future of science can be estimated in a systematic way. As the philosophy of science has shown, science is opaque and difficult to understand. Given the opaqueness, the reports concerning the future of science appear hopelessly simplistic without reflection on the conceptions of science that they embrace. The problem is that the philosophy of science has not been much of a help here. Even though history and the philosophy of science have deepened our understanding of science, explicit conceptual tools to understand the estimating of possible futures of science are missing from its repertoire.

A similar blind spot with respect to the future of science can be found within futures research. No systematic account of the development of scientific practices from the past to the future exists. Scientific practices consist of an intertwined web of theories, models, concepts, ontological assumptions, values, methods, instruments, means of communication, and so on. The nature of the different items on the list varies between different periods and different scientific subfields. The complexity and heterogeneity that characterize science and its history are difficult to tame intellectually. Still, the idea of a “modern science” as some sort of a monolith dominates the futures research. For example, in their classical work, Funtowicz and Ravetz treat what they call "normal science" as a monolith that will be challenged by another understanding of what science, as a whole, is. This is called "post-normal science". The characterization has two problems that are common in the discussions about science. First, it assumes that a certain conception of science (in this case Kuhnian theory) captures the essence of science in the present and in the past and goes on to discuss an alternative future of science in terms of that single conception. Secondly, it simplifies the conception and leaves out important dimensions in order to provide a clear vision for the future. The first aspect of the characterization is problematic because the systematic estimating of the future requires that we reflect on our own conceptions about the subject matter and ask (i) where the conceptions stem from, and (ii) how justified the conceptions are. The second aspect is problematic because it makes the vision of the future easily misleading. For example, the characterization of Kuhn's notion of normal science by Funtowicz and Ravetz appears misleading because scientific revolutions are not mere conceptual revolutions (as claimed in Funtowicz and Ravetz 1993, 704) but, according to Kuhn, the whole disciplinary matrix, including standards and metaphysical assumptions, undergoes revision. Moreover, different paradigms differ in what is taken as a relevant problem to be solved (Kuhn 1970, 148). Finally, there is individual variability in the application of values even when the values are shared, especially in high-risk contexts. "The points at which values must be applied are invariably also those at which risks must be taken" (Kuhn 1970, 186). Thus, it is not the case that normal science "is unexciting, indeed anti-intellectual" or that in the "'normal' state of science, uncertainties are managed automatically [and] values are unspoken (Funtowicz and Ravetz 1993, 704). It is difficult to understand what kind of alternative future the concept of post-normal science constructs when its basic conception of actual science is so simplified and unchallenged by alternative conceptions. It is quite likely that the whole enormous discourse about post-normal science is built upon challenging science that never existed and modifying a conception that was never held.

Another example of such monolithic reading of science is found from Inayatullah who writes, in connection to CLA, about “alternative sciences” and argues that “Part of futures studies, then, is dramatically rethinking our categories, including the category of the empirical. Instead of one science, an interpretive perspective allows for a world of many sciences, of many ways of knowing the real. Each culture can have its own science, its own view of the real.” (2004, 65). Now, assume that the category of science is transcultural and transhistorical (which is debatable, see Daston 2009; Dear 2012; Cunningham 1988). Even then the question about alternative sciences is not limited to intercultural comparisons. There are many important questions concerning the nature, history, and future of the complex phenomena we are accustomed to calling “science” and which has been the main subject of study in the philosophy and history of science and science studies. In terms of CLA itself, the existence of some monolith science is a myth that is often repeated and that hinders us from understanding science-related issues in the futures research. In order to remedy this dominance of the myth, we need to systematically study the nature and development of science from a future-oriented perspective.

Secondly, the future of science is too important a topic to be left without attention. Not only funding decisions and science policy depend on (more or less implicit) estimates of how science can develop but also – and more importantly – our ability to understand the future of society in general. There are countless ways in which the future of science and the future of conceptions of science affect society: What technologies we have (e.g., EU; NATO), who we consider as epistemic authorities (e.g. Mede & Schäfer 2020), how we perceive the human-nature relations (e.g. Allen 2018), how to generate novel innovations (e.g. Kuhlman & Rip 2018), and so on. Our ability to anticipate and prepare for changes in many areas of life depends on our ability to estimate the future of science. Simplistic pictures of science do not enable us to achieve this goal any more than simplistic pictures about other areas of life. We need deep understanding about the nature and development of science and we have to critically analyze our conceptions of science.

Thirdly, systematic inquiry into the nature and development of science and into our conceptions of science is necessary in order to develop sound self-understanding about the nature of the futures research as a field of research. It is rather difficult to locate the futures research among different sciences if we do calmly analyze the nature and development of those sciences and the conceptions that guide our judgements about scientificity. It is too compelling to stick with simplistic conceptions of science. Even though it is not my main task to analyze the nature of futures research but the estimating of the future of science, I hope the paper will make obvious how complex and multilayered task it is to locate different branches of the futures research among other fields of research and improves the self-understanding of the field by doing so. Ironically, the futures research has revealed how complex a task it is to locate human activities into temporal cultural and social systems, but this understanding has not been widely reflected back on the debates about the nature of the field itself and the associated conceptions of science. Connecting the philosophy of science and CLA provides analytical tools to critically reflect on the conceptions of science that futures research uses in its self-understanding.

In what follows, I will first analyze how different philosophical analyses and debates are connected to different levels in CLA from myth to litany and point towards the interplay between these different levels. I then proceed to argue how the “poststructural toolbox” (consisting of deconstruction, genealogy, distance, alternative pasts and futures, and reordering knowledge, see Inayatullah 1998; 2004) already has a counterpart in the analytical tools of the philosophy of science. The discussion shows how philosophical analysis of science can be used to open up the present and past to create alternative futures and to reveal deep worldview commitments with respect to the possible futures of science. As I proceed, I show how the successful connecting of the philosophy of science and CLA requires that each adopts elements and insights from the other. In this way, we can find new perspectives on both the philosophy of science and CLA by studying the possible futures of science.

2. The Levels of CLA

The method of causal layered analysis (CLA) "is concerned less with predicting a particular future and more with opening up the present and past to create alternative futures" (Inayatullah 1998, 815). It is a "method that reveals deep worldview committments behind surface phenomena" (ibid.). CLA consist of analysis in/of four levels:

"The first level is the 'litany'—quantitative trends, problems, often exaggerated, often used for political purposes. [--]

The second level is concerned with social causes, including economic, cultural, political and historical factors. [--]

The third deeper level is concerned with structure and the discourse/worldview that supports and legitimates it. [–] The task is to find deeper social, linguistic, cultural structures that are actor-invariant (not dependent on who are the actors). [--] Discerning deeper assumptions behind the issue is crucial here as are efforts to revision the problem. [--]

The fourth layer of analysis is at the level of metaphor or myth. These are the deep stories, the collective archetypes, the unconscious dimensions of the problem or the paradox. [--] This level provides a gut/emotional level experience to the worldview under inquiry. The language used is less specific, more concerned with evoking visual images, with touching the heart instead of reading the head." (Inayatullah, 1998 pp. 820).

In what follows, I show how the philosophy of science has already provided insights on these different levels with respect to science and our conceptions of science. Philosophical research has mapped (i) myths, metaphors, anecdotes, and slogans, (ii) possible structures that guide scientific development, and (iii) causal factors that shape science. Moreover, while the philosophy of science is not directly producing litany, I point out that there are interesting discrepancies between science-related litanies and the philosophy of science. As I proceed, I indicate how the items (i)-(iii) are connected to each other in the philosophy of science and how this enables us to move between the different levels as required by CLA.

2.1 Myths and Metaphors in the Philosophy of Science

In order to understand the mythic and metaphoric level in the philosophy of science, let us consider three famous philosophical theories about the core methodology, goals, and possibilities of science: falsificationism, Kuhnian revolutions, and scientific realism.

Popper's falsificationism (1963) is based on the idea that science does not attempt to verify theories but falsify them. A good theory has rich empirical contents that makes it possible to make risky predictions which might be false. If a prediction of the theory is false, the theory is falsified; if the prediction is correct, the theory is corroborated.

In Kuhn's theory, there are (mainly) two kinds of periods in the development of science: *normal science* and *revolutionary science*. A normal science period is a one in which a paradigm defines the research in a scientific field. A paradigm is a "universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners" (Kuhn 1970, viii). A paradigm, then, is the condition under which science can develop in a steady fashion. Revolutionary science, on the other hand, is a period in which the existing paradigm is challenged due to its inability to solve important problems and a new paradigm is established. Different paradigms are mutually *incommensurable,* as there are no shared standards that enable scientists to choose between competing paradigms in the period of revolutionary science.

According to scientific realism, science has been able to produce approximately true theories of a mind-independent world. Our successful and mature theories are approximately true descriptions of both observable and unobservable world. It would be a miracle if the theories were successful without being approximately true. (E.g., Psillos, 1999.)

Popper's falsificationism and Kuhnian theory of revolutions both have an explicit anecdotal base that is appealing. There is a famous story of how Popper became dissatisfied with psychoanalysis because all human behavior could be interpreted in accordance with its theories and how, at the same period, Popper heard about Einstein's theory and Eddington's observation of the gravitational deflection which put Einstein's theory under a severe test. (See Hacohen 2000, 93-96). Kuhn, on the other hand, has told a story of how he wondered how absurd Aristotle's physics was until he understood Aristotle's system of science as a whole and in terms different from the modern science (Kuhn 1977, xi-xii). We can understand the theories of Popper and Kuhn by understanding these stories that belong to the fourth level of CLA. The stories make understandable the gut feelings that the theories of Popper and Kuhn attempted to explicate: That knowledge is improved by taking intellectual risks and by abandoning one's views (Popper) or that the development of science introduces fundamental changes in our understanding of the world and that "the proponents of competing paradigms practice their trades in different worlds" (Kuhn 1970, 150). Realism, on the other hand, has been (somewhat critically) summarized in a metaphor of desk-thumping, foot-stamping shout: "What then of the realist, what does he add to his core acceptance of the results of science as really true? [...] what the realist adds on is a desk-thumping, foot-stamping shout of "Really!"". (Fine 1984, 97). Even though originally used in a critical tone, this metaphor can be interpreted as revealing the basic conviction that science is about the world we live in, never mind the philosophical quibbling about the nature of truth and reality. Another famous slogan for realism that explicates the gut feeling is “if you can spray them, then they are real” (Hacking 1983, 23). The existence of mythic and metaphoric stories and slogans means that the philosophy of science is already in the business of revealing and expressing “deep stories” that shape our understanding.

It is remarkable that there are many severe criticisms for all the theories above. It is extremely difficult to formulate and justify the theories even if the gut feeling behind them is strong. For example, we know that, contra Popper, all observational tests of a theory require background assumptions and simple falsification is not possible. In the case of Eddington, for example, Einstein’s theory was corroborated only because Eddington interpreted the data against his knowledge about the instruments (Kennefick 2019). On the other hand, there have been, contra Kuhn, unexpected discoveries with wide-reaching consequences that did not lead to a scientific revolution, such as the discovery of the structure of DNA (Bird 2018, 6.1.). Finally, it seems that there have been, contra realism, successful theories that were not approximately (Laudan 1981, known as the pessimistic meta-induction). The basic worldview commitments at the fourth level face problems when developed into explicit and rationally assessed theories. This indicates that their origin is independent of the explicit reasoning that attempts to justify them.

Interestingly, all the positions can be found in many science-related debates. For example, there is a debate on whether to build and what to expect from the Future Circular Collider (FCC). Sabine Hossenfelder (2020) has argued that the cost of the FCC is too great given the chances of possible discoveries. Michela Massimi (2020) has argued that the FCC can be defended once we understand scientific progress not in terms of “great” discoveries but in terms of excluding possibilities. The baseline of the debate concerning FFC is colored by scientific realism. “With the new machine, particle physicists want to measure its [Higgs boson] properties, and the properties of some previously discovered particles, in more detail” (Hossenfelder 2020).

However, the Popperian and Kuhnian pictures are in the mix: For example, Massimi (2020) explicitly argues that “particle physics community has long stopped (if ever did) following any Popperian method of hypotheses-testable predictions-falsification” and the possible future of the FCC should not be understood in those terms. Massimi also makes an important note on the scientific revolutions: The direction of a revolution is not arbitrary. Rather, a revolution can only change a field whose foundations have been examined by a long tradition of detailed research. We cannot expect a revolution in the foundations of the Standard Model without “the ongoing, unfailing, and indefatigable efforts of experimentalists at places like Cern”.

Recognizing different myths and metaphors that lurk behind our conceptions of science is an essential step in revealing deep commitments in those conceptions. However, it is important to notice that the mythic or metaphoric core or origin of a conception does not mean that it is incorrect or benign. We need to cherish the core and, at the same time, distance ourselves from it. The cherishing means that we attempt to stay faithful to the core and understand what it might capture about science and its possible futures. Intellectual courage? Fundamental changes in the scientific worldview? Epistemic optimism? The distancing means, in this context, that we come to understand different mythic and metaphoric cores that might dominate the visions of the future of science. Moreover, recognizing the mythic and metaphoric core enables us to understand where our preferences for certain types of future comes from. Why do we want impressive experiments? Why do we want to measure the properties of particles? Finally, cherishing the mythic and metaphoric core is essential when an explicit theory of the structure of the development of science, belonging to the third level of CLA, is constructed. We need to ask what insight the theory, despite all the inevitable problems it will face, attempts to capture. Distancing is necessary, at the third level, in order to understand that a gut feeling might be wrong after all and that the theories that attempt to capture the feeling are dead ends (as falsificationism probably is, see Hansson 2006; Lakatos 1978).

The discussion about the mythic and metaphoric level of philosophy of science underlines two methodological insights. First, the fourth level of CLA can begin from *conscious* stories, anecdotes, slogans etc. about the basic insight that some view on the subject matter attempts to capture. There can be an explicit connection between what is conceived in the mythic or metaphoric level and the theories that attempt to capture that something in explicit language. Still, the fourth level is not redundant because it provides the basic anchor through which we can understand the basic motivation and convictions of the explicit theories. Secondly, the philosophy of science can benefit from admitting its mythic and metaphoric base in that the mythic or metaphoric base reveals and makes understandable the basic motivation and convictions behind different views. All philosophical views face difficulties but we defend and improve only some of them. We can make these methodological choices more understandable if we make explicit what it is that we find appealing about a particular philosophical theory in mythic or metaphoric level.

2.2 The Structures of Science

With respect to the third level of CLA, the philosophy of science can be seen as an analysis of the structures that shape different aspects of science. For example, theories of explanation are not theories about any particular explanation or explanatory practice but the nature of explanation in general. A theory of explanation attempts to answer questions like the following (Woodward 2003; Virmajoki 2020): What it is that makes something an explanation? Why explanations are important and how this is reflected in how explanations are build and formulated? What makes a deep explanation? Answering these questions reveals implicit assumptions and motivations behind scientific practices that guide the actions of individuals and are therefore actor-invariant. These questions are important when we estimate the futures of science. For example, we might wonder to what extent sophisticated machine learning practices might provide explanations. Will they become uninterpretable black boxes, or can they help us in our explanatory tasks? In order to answer, we need to define the threshold of explanatoriness and find ways to evaluate the depth of an explanation, i.e. we need theories of explanation. Moreover, philosophical accounts of explanation are often normative in the sense that they recognize "that causal and explanatory claims sometimes are confused, unclear, and ambiguous and suggests how these limitations might be addressed" (Woodward 2003, 7). This kind of normativity is important because (a) it enables us to clarify implicit tensions in our views that might obscure our views of the possible futures, and (b) it enables us to clarify what kind of futures are desirable in that the limitations (confusion, unclarity, and ambiguousness) are addressed within those futures.

Going back to our earlier examples, at the third level of CLA there are theories about the development of science, such as falsificationism, Kuhnian, and realism. As already noted, such theories are often involved, in some form or another, in discussions about the possible futures of science such as the one about the Future Circular Collider. The theories describe deeper social, epistemic, linguistic, and cultural structures that are actor-invariant which constitutes the third level of CLA. This is most obvious in the case of Kuhn. His famous book was even named "The *Structure* of Scientific Revolutions". *Paradigm* is a canonical example of an actor-invariant framework. A paradigm is a "universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners" (Kuhn 1970, viii). "Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, i.e., for the genesis and continuation of a particular research tradition." (Kuhn 1970, 11.) As we already noted above, according to Kuhn, a paradigm-driven period of normal science is followed by revolutionary science when the existing paradigm is challenged due to its inability to solve important problems and a new paradigm is established. Kuhn postulates a clear cyclic structure for scientific development: The formulation of a paradigm creates a normal-science tradition. The tradition will face anomalies (i.e., important and unsolved problems) which will generate a crisis and a phase of revolutionary science. The revolution will produce a new paradigm, and the cycle is completed. Kuhn's theory explicates the structure of scientific development and "deeper social, linguistic, and cultural processes that are actor–invariant" (Inayatullah 2004, 12) and provides insights at the third level of CLA.

Scientific realists, on the other hand, tend to interpret the history of science in less dramatic terms. In response to the observation that there appear to have been successful but untrue theories in history (which undermines the realists' supposed link between success and truth), realists argue that the successful theories had parts that have survived through theory-change and are true in the light of to our current theories. This is known as the *divide et impera* strategy of realism (Psillos 1999, ch. 5). A similar suggestion is made by structural realists who argue that the mathematical or structural contents of successful scientific theories are preserved through theory-change (Worrall 1989). Scientific realism seems to commit to a worldview that carries over into the visions of possible futures: Despite the theory-changes in science, successful theories form a historical series where the crucial elements are preserved through theory-change. Some contents of our current theories will also carry over into the future. There has not been radical incommensurability between successful theories (like Kuhn thinks) and this trend will continue in the future.

The third level of CLA is fruitful with respect to the future of science because it enables us to steer clear on the tensions in our visions of the future of science. We understand that science might change in the future. Otherwise, there would be no point in investing in things like the FCC. However, it is unclear how much science will change and what to expect from the change. Usually, we expect new discoveries and improved models, and "the nightmare scenario would be a project [--] that would only reveal what some theorists call "the desert," a barren region otherwise devoid of new discoveries. (O'Callaghan 2019; see also Hossenfelder 2020). The evaluation of the possible discoveries is made in the light of current theories and is best understood in a realist's tone: We have approximately true theories the crucial parts of which are preserved in the future; what we want is a more detailed picture. However, the desert might also be framed in other terms in order "to revision the problem" (see the third level of CLA): "[The] wonderful successful singular prediction of Einstein's theory was preceded by century-long vain attempts at building mechanical models of the ether. Some of the best scientists of the time (including Maxwell and Hertz) engaged with the then open problems of electromagnetic theory by devising more and more ether models and experiments designed to detect the ether drag. [--] Maybe the solution to some of the open problems within the Standard Model requires a revolution similar to the one behind relativity theory in rethinking the theoretical foundations for a new physics." (Massimi 2020.) It might, of course, be a bit awkward for the scientific community to frame the future of science in terms of the expectation that the current models will be abandoned after vain attempts to perfect them but considering this (historically based) possibility is necessary in order to understand what types of future changes we might be committed to when advancing new scientific projects. Different theories about the development of science enable us to challenge and revision any particular expectation and demand we have towards the future of science.

Finally, it is necessary to loosen up the philosophy of science and tighten up CLA in order to connect them in a natural way. On the one hand, the philosophy of science does not have to choose one theory as the correct description of science when sketching the possible futures of science. Even if it is rational to rank theories according to their relative merits theoretical and empirical merits, it necessary to keep the less plausible theories in sight in order to be aware of what seems like unlikely futures. For example, even if scientific realism were a better theory than the Kuhnian one, keeping the Kuhnian theory in sight makes it possible to sketch the possibly disruptive dynamics of the future of science. On the other hand, the theories in the philosophy of science have been rigorously analyzed and tested against the history of science (e.g., Donovan et al. 1988; Bolinska and Martin 2020; JPH). Even if we cannot reach an agreement about the best theory, the relative merits of the theories can be compared. When we are doing CLA, we do not need to stay at the level of recognizing and acknowledging different worldviews. We can also analyze the relative merits and plausibility of those worldviews. I come back to this issue in Section 3.4.

2.3 Causes in Scientific Development

Factors that are relevant in the development of science and explain it causally have been discussed to a great extent. These causal explanations are often related to the structural or mythic/metaphoric level of analysis. For example, Kuhn writes "How, then, are scientists brought to make this transposition [between paradigms]? Part of the answer is that they are very often not." (1970, 150.) Kuhn continues by citing Max Planck: "a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it" (ibid. 151). This is known as the "Planck's Principle". Interestingly, it has been tested recently (Azoulay et al. 2019). The finding was that "publications and grants by scientists that never collaborated with the star [eminent scientist] surge within the subfield, absent the star. Interestingly, this surge is not driven by a reshuffling of leadership within the field, but rather by new entrants that are drawn from outside of it". It appears plausible that Planck Principle provides a sound causal explanation of scientific change in many cases, at least in life sciences. While such dynamics are difficult to interpret with respect to their future consequences, it is clear that the dynamics are far from transparent and do not correspond to the mythic story about radically open-minded science.

Scientific realism, on the other hand, is committed to explaining important scientific changes in terms of theoretical and empirical insights achieved in science. For example, Psillos describes how the theoretical and experimental breakthroughs by Einstein and Perrin settled the reality of atoms in the early 20th century (2011, 340.) The explanation underlines the straightforward relevance of theoretical and experimental work in science that does not involve social maneuvering.

Finally, there are interesting (future-relevant) issues in science that do not stem in any obvious way from the mythic/metaphoric or structural levels of analysis. Still, studying these issues can have implications on the level of worldviews and especially on the level of myths. For example, Bedessem and Ruphy explicate "three epistemological conditions that influence the occurrence of the unexpected in the course of a scientific inquiry" (2019, 1). The study enhances understanding and especially challenges conventional thinking according to which "a research whose agenda is set according to external considerations is less hospitable to the full flourishing of the unexpected than a research whose agenda is freely set internally by scientists" (ibid.) Bedessem and Ruphy argue "that the importation of exogenous problems may actually favor the occurrence of the unexpected, by diversifying the objects under study and the local models and experimental protocols used (our second criteria), by leading to intervene in poorly known and controlled objects and causal mechanism (our first criteria) and by limiting the tendency to integrate a surprising result within an existing, dominant epistemic framework" (2019, 5).

While the study of causal mechanisms in the production of the occurrence of the unexpected does not speak for any general theory of science, it does speak against the myth (and litany, see below) that only autonomous science, free of all external influences, is able to produce groundbreaking insights. The study also enables us to reconsider structural issues related to scientific development as an interplay between theories and empirical findings. For example, it challenges the idea that science is mainly involved in theory-testing and points toward problem-solving motivations of science (see discussion in Laudan 1977).

2.4 Litany

The litany level does not have similar connections to the philosophy of science as the other three levels, since the philosophy of science does not produce litany in the same sense as it produces causal analysis, structural analysis, and metaphoric insights (as discussed above). However, we have already seen that there exists a rich level of litany with respect to possible futures of science that correspond to the first level of CLA where: “Events, issues, and trends are not connected and appear discontinuous. The result is often either a feeling of helplessness (what can I do?), or apathy (nothing can be done!), or projected action (why don’t they do something about it?). This is the conventional level of most futures research that can readily create a politics of fear.” (Inayatullah 2004, 11-12.) Quite often, the discussions about the future of science are not rigorously analyzed in the light of our best understanding of science (i.e., events, issues, and trends are not connected; assumptions are rarely questioned), as Massimi (2020) strongly emphasizes: “It is a good rule of thumb that one should not take physics lesson from a philosopher, or, equally, lessons of philosophy of science from a physicist. In either case, the risk is that the discussion is not going to be well informed.“ Moreover, the litany often produces “politics of fear”. The framing of the future of physics as a mere “desert” (see above) is one example. Another example is the constant fear that external influences will ruin scientific progress, something that is discussed by Bedessem and Ruphy (2019; see above) and already by

Merton who wrote, on the basis of historical studies "it may then be said that necessity is the (foster) mother of invention and the grandparent of scientific advance" (1968, 664).

3. Poststructural Toolbox

In this section, I will point towards interesting connections between the "poststructural toolbox" and philosophical analysis of science. The poststructural toolbox consists of deconstruction, genealogy, distance, alternative pasts and futures, reordering knowledge. Next, I show how each element can be found from the philosophy of science and how the insights in the field enable us to shed new light on the poststructural toolbox.

3.1 Deconstruction

Inayatullah (2004, 8) characterizes deconstruction as follows: "The first concept is deconstruction. In this we take a text (here meaning anything that can be critiqued [--]) and break apart its components, asking what is visible and what is invisible? Research questions that emerge from this perspective include:

Who is privileged at the level of knowledge? Who gains at economic, social and other levels? Who is silenced? What is the politics of truth? In terms of futures studies, we ask: *Which future is privileged? Which assumptions of the future are made preferable?"*

The philosophy of science is essentially based on the analysis of (i.e., "breaking apart") scientific concepts, notions, and practices. The philosophy of science attempts to define, explicate, and characterize concepts, notions, and practices and make visible the implivit conceptions, assumptions, and tension in our thinking. A canonical example of such a tradition of analysis concerns the concept of causality in science. An important component of such analysis is "to make distinctions among different sorts of causal and explanatory claims, distinctions that are often overlooked by those who make such claims" and to recognize "that causal and explanatory claims sometimes are confused, unclear, and ambiguous" (Woodward 2003, 7). Also the theories of scientific development that we used as examples earlier serve this purpose. For example, Popper recognized that we have overlooked how easy it is to confirm a theory if it lacks real empirical content. Kuhn recognized that there are scientific changes that are not accounted for by theories of linear accumulation of scientific knowledge. He also recognized that scientific development requires an interplay between various elements, ranging from values to ontology to observations, and cannot be reduced to straightforward theory-observation dynamics. Finally, scientific realism argues, in its *divide et impera* strategy, that despite the apparent radical changes in the history of science, there has been theoretical continuity in the history of science that can be made visible through analysis of past theories (Psillos 1999).

All the theories highlight certain aspects of science and de-emphasize others. They provide insights on what is and what should be privileged, silenced, and how the notion of truth functions in science. For example, the Kuhnian theory suggests that social aspects and cohesion of science are silenced in traditional accounts and that the notion of truth is irrelevant to understanding scientific development (1970, 170–171; 206).

Finally, we have already seen, in Section 2.2, that the different philosophical theories privilege different futures and prefer different assumptions about the possible futures of science. For example, scientific realism privileges futures where our current understanding is improved in a piecemeal manner and assumes that there probably will be continuity from the present to the future science. The Kuhnian theory privileges futures with radical disruptions and assumes that current scientific paradigms might come to an end. The privileging and preferring are based on the prior analysis of the dynamics of scientific development that each theory is based on. Given how science is analyzed (or “broken apart”/”deconstructed”), different visions for the future arise. Philosophical analysis and the estimating of the future of science are linked together.

3.2 Genealogy

Inayatullah (2004, 8) characterizes genealogy as follows: “The second concept is genealogy. This is not a continuous history of events and trends, but more a history of paradigms, if you will, of discerning which discourses have been hegemonic and how the term under study has travelled through these various discourses. [--]

Which discourses have been victorious *in constituting the present? How have they travelled through history? What have been* the points *in which the issue has become important or contentious? What might be* the genealogies of the future?”

The idea that the historical trajectory of science has shaped its nature is widely recognized in the history and philosophy of science. For example, Schickore argues that “[--] a history of the present should remain part and parcel of our present efforts to understand the sciences. Fully to understand the concepts, practices, and methodological and epistemological goals and commitments of present science, we need to trace how they have come into being”. (2011, 477.) Moreover, Psillos concludes that “[--] what science tells us about the world, as well as the reasons to take what it tells us seriously, are issues that are determined historically, by looking at the patterns of convergence in the scientific image of the world”. (2012, 101). A historian of science, Daston, has suggested that “[the historians of science] must explain how [the distinctive] character [of science] crystallized out of practices, both intellectual and manual, designed for other purposes”. (Daston 2009, 807).

A canonical work in the spirit of genealogy is *Leviathan and the Air-Pump* by Shapin and Schaffer where they ask "*Why* does one do experiments in order to arrive at scientific truth?"

(1985, 3). They continue: “We want our answers to be historical in character. To that end, we will deal with the historical circumstances in which experiment as a systematic means of generating natural knowledge arose, in which experimental practices became institutionalized, and in which experimentally produced matters of fact were made into the foundations of what counted as proper scientific knowledge.” (ibid.) The authors study how one discourse became victorious in constituting the present by looking at a historical point in which experimentation became important and contentious. “Yet we want to show that there was nothing self-evident or inevitable about the series of historical judgments in that context which yielded a natural philosophical consensus in favour of the experimental programme. Given other circumstances bearing upon that philosophical community, Hobbes's [anti-experimental] views might well have found a different reception.” (Ibid. 13.)

The study of important junctures in the history of science that could have led elsewhere is important with respect to the issue of inevitability vs. contingency of science. The I-C issue concerns the possibility of an alternative science. If science is inevitable, there could not be a fundamentally different science (at least not as successful science as the actual one). If science is contingent, there could be a fundamentally different science (see Soler et al. 2015; Kinzel 2015). This issue is important with respect to the future of science because possible answers to it enable us to map the amount of possible change in the future of science. One strategy to answer the question of contingency is to seek points in history such that: had that point been different, the present would be different. If such points are plausible, then science could have been different. (Virmajoki 2018.) There have been studies that conduct exactly this kind of counterfactual analysis (e.g. Bowler 2013; Pickering 1984; Cushing 1994). The counterfactual approach makes it also possible to write genealogies of the future. If we know how the present could have been different, we are in a good position to tell how we could achieve a certain future: we can reflect on the future in the same terms as we reflect on counterfactual alternatives to the present. There is no fundamental difference between the two.

3.3 Distance

Distance is characterized as follows (Inayatullah 2004, 8-9): "The third crucial term is distance. [--] Scenarios become not forecasts but images of the possible that critique the present, that make it remarkable, thus allowing other futures to emerge. [--]

Which scenarios make the present remarkable*? Make it* unfamiliar*?* Strange*?* Denaturalise *it? Are these scenarios in* historical *space (the futures that could have been) or in* present *or* future *space?*"

The major philosophical theories of science have the tendency to distance ourselves from the current science. For example, the Kuhnian theory forces us to take seriously scenarios where there are radical changes in science, not only on the level of theories, models, and concepts, but also on the level of methodology, ontology, and values, as all these are ingredients in a paradigm that might be replaced. Even realism does not assume that there is a straightforward development from the present science to the future science. First, it is not committed to the approximate truth of theories whose success is unclear. Secondly, even the most successful theories might be replaced with theories that preserve only certain parts of the current theories and rethink other components. That the philosophy of science distances us from the current science is a rather automatic consequence from the fact that the field does not take for granted received views of science but attempts to analyze science in its complexity.

The historical analyses of science that were discussed in the previous section also distance us from the present science. For example, Shapin and Schaffer distance us from the experimental tradition by denaturalizing its origins, as we saw. Another example is Bowler's *Darwin Deleted* where he analyses “What would a world without Darwin look like?” (2013, 8). Bowler explains: “My interest in exploring what happens in a world without Darwin is driven by the hope of using history to undermine the claim that the theory of natural selection inspired the various forms of social Darwinism. The world in which Darwin did not write the Origin of Species would have experienced more or less all of our history’s social and cultural developments.” (ibid., 10.). The work does not describe a world where the catastrophic history of racism and ideologies of struggle did not exist (ibid., 10-11) but it nevertheless challenges an explanation of that history thus distancing us from how the history appears to us. “We need to think harder about the wider tensions in our culture responsible for the ideologies that came to have the inoffensive Darwin as their figurehead.” (Ibid., 11.)

Finally, there is exists metalevel discussions in the philosophy of science about the limits of our ability to distance ourselves from the present science.

First, in the inevitability vs. contingency issue, it has been suggested that, in order to really know whether there could be successful alternative science, one should build one. This is known as the “put up or shut up” argument (see Soler 2015). The obvious problem with this argument is that establishing a scientific tradition requires enormous resources. The lack of alternative science might not tell us anything about the plausibility of the alternatives but only about the allocation of resources.

Secondly, there is a strong argument, known as “the problem of unconceived alternatives”, by Stanford, that we simply are not able to conceive alternative theories to those we have at any given point of time. (2006, 19.)

Thirdly, Tambolo (2020) has pointed out that even counterfactual histories may not be able to distance us from the present science. Tambolo argues that “In the case of general history, it is often possible to imagine a consequent dramatically different from actual history, and yet plausible; in the case of history of science, imagining outcomes far removed from the results of actual science seems more complicated" (2020, 2012). The problem is that, in order to construct a counterfactual narrative, we need knowledge of how the world works. Given that the actual science provides this knowledge, the present science leaks into the counterfactual narratives thus shaping their direction towards the present state of science.

It follows that, while the philosophy of science can distance us from the current science, there might be general limitations to the ability to make the present remarkable. However, we should not be demoralized by this. Rather, the arguments should be seen as a crucial methodological insight: Even if we cannot (in some cases) distance ourselves from the present world, it does not follow that the present world is inevitable and the only possibility. Rather, the present world might look inevitable only because we do not have the tools to think it away.

3.4 Alternative pasts and futures

Alternative pasts and futures are characterized as follows (Inayatullah 2004, 9): "Futures studies has focused only on alternative futures, but within the poststructural critical framework, just as the future is problematic, so is the past. The past we see as truth is in fact the particular writing of history, often by the victors. The questions that flow from this perspective are: Which interpretation of past is *valorised*? What histories make the present *problematic*? Which vision of the future is used to *maintain* the present? Which *undo the unity* of the present?"

In the philosophy of science, there has been a long debate about testing the philosophical theories against the history of science. This debate has shown that it is extremely difficult to choose one theory over another by confronting them with historical evidence. The many problems are summarized recently by Bolinska and Martin (2020). One straightforward problem is that philosophers of science can choose historical cases that support their theory. It is possible to highlight certain episodes in the history of science that make the theory look appealing. Deeper problems arise when we analyze how historical episodes are interpreted. Lakatos (1971) famously suggested that we should rationally reconstruct the history of science. We need to explain as much of the history of science as we can in terms of a philosophical account. The more of the history of science an account deems rational, the better the account is. The obvious worry with this theory-driven account is that it seems to lead inevitably to a distortion of the past. Why should historical reality conform to our philosophical theories? It has been pointed out that this worry is rather naïve. A philosopher of historiography Kuukkanen has argued that "All history writing includes a theoretical basis of some kind and is indeed normative, implying selectivity and emphases on what is important and explanatory in history. [–]. [Lakatos unlike others] explicitly accepted that the same historiographical data can be brought into several alternative accounts, and he formulated some viable options using schemes and 'philosophies of science' of his time." (2017, 91.)

If we wish to know which philosophical theory we should accept as the correct one, the considerations above create a problem because there is no neutral arbiter against which we could compare the theories. However, the absence of neutral arbiter does not mean that every interpretation is equally good. As Bolinska and Martin point out "[h]istory, philosophy, and indeed most academic disciplines rely on careful, critical analysis to answer difficult questions, even if a firm answer is not immediately forthcoming" and that "whatever stand we take, we should admit its fallibility" (2020, 40). Moreover, if we conceive the philosophical theories as worldviews and descriptions of the possible structures (the third level of CLA), the problems associated with historical thinking turn out to be strong methodological tools. First, when we have scenarios of the future of science that are based on a particular worldview, we can critically engage the historical interpretations that justify the worldview. We can ask what cases are chosen and what interpretations are influenced by that worldview and find out which cases it ignores and what alternative interpretations are possible. Secondly, we notice that all scenarios of the future of science are shaped by theoretical interpretations. Even if a scenario appears natural, we have to explicate its theoretical underpinnings and ask how alternative theoretical frameworks would construct alternative scenarios. Awareness of the interpretive frameworks makes it possible to move between alternative histories and alternative futures. There is a shared epistemic ground between different presentations of the past and different presentations of the future.

3.5 Reordering Knowledge

Reordering of knowledge is characterized as follows (Inayatullah 2004, 9): "Reordering knowledge is similar to deconstruction and genealogy in that it undoes particular categories; however, it focuses particularly on how certain categories such as 'civilization' or 'stages in history' order knowledge.

How does the ordering of knowledge differ *across civilization, gender and episteme? What or Who is* othered*? How does it denaturalise current orderings, making them* peculiar *instead of* universal*?*"

The philosophy and history of science are especially well equipped to perform such analysis. For example, the core idea in the Kuhnian theory is that different stages in history, paradigms, differ radically in their assumptions about "the right" methodology, values, and ontology. Moreover, we have already seen how *genealogy* and *distance* in the philosophy of science involve analysis of historical origins and contingencies in the development of the present science. As we saw, these analyses denaturalize current orderings and make them peculiar.

There has also been a shift from the history of science to the history of knowledge, a shift that acknowledges the historical contingency and peculiarity of science. History of knowledge does not focus only on academic setting but also on production of knowledge in settings that are far removed from them (Renn 2015)

Moreover, the history of knowledge is not merely interested in how knowledge has been produced and understood in different social and historical context, but it also analyses the processes that shaped how different forms of knowledge were classified and valued and how hierarchies of forms of knowledge were established (e.g., Mulsow 2018, 180). In this way, the philosophy and history of science and knowledge enable us to understand how knowledge has been ordered in the past and how the current ordering is not a self-evident part of the future of science.

4. Conclusion

In this paper, I have argued that the future of science requires systematic attention. We have a deceptive conviction that we understand what science is, but a closer look reveals a plurality in our myths, metaphors, worldviews, and causal understanding about the workings of science. In order to understand and challenge visions and scenarios about the future of science, we have to critically reflect on our conceptions of science.

I have suggested that we can conduct causal layered analyses of science on the basis of the long and diverse tradition in the philosophy of science. I pointed out the similarities and connections between CLA and the philosophy of science and argued that the philosophy of science can be understood as a kind of CLA: The philosophy of science has mythic/metaphoric, worldview/structural, and causal levels and it critically engages in the analysis and assessment of the items at each level. In this way, the philosophy of science can reveal deep worldview commitments behind surface phenomena. The philosophy of science is a viable tool to critically evaluate the conceptions of science that ground our visions and scenarios for the future of science.

I have pointed out how the methods in the poststructural toolbox have their counterparts in the philosophical and historical literature on science and how the philosophical insights enable us to answer the central questions of the poststructural toolbox. The philosophy of science, with historical orientation, makes it possible to "open up the present and past to create alternative futures" in the same way as CLA and the associated toolbox.

The conclusion is that one way – certainly not the only way – to study the neglected topic of possible futures of science is to perform CLA by using insights from the philosophy and history of science and science studies in general. The similarities and connections between the philosophy of science and CLA guarantee that if CLA is a viable method to study the possible futures and our conceptions behind them, so is the philosophy of science. We need to futurize the philosophy of science and philosophize CLA in order to understand the crucial topic of the future of science.

We also need further exploratory research on whether other disciplines could be conceived as already containing the elements of CLA and thus understood as a kind of CLA. The connections between a discipline and CLA might not be obvious but, once explicated, the connections could provide energy-efficient way to approach the future of the subject matter of the discipline. We would not need to start CLA of the subject matter from scratch. Rather, we could use resources that are already available.

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