EXPLAINING IN MULTIDISCIPLINARY AND INTERDISCIPLINARY SCIENTIFIC INQUIRY SOME PHILOSOPHICAL EXPLORATIONS

Richard David-Rus
Romanian Academy, Iasi Branch, e-mail: rusdavid@gmail.com

Abstract. *The subject of scientific explanation is one of the major topics in philosophy of science. The explanations that were primarily studied were from the mature disciplines of science esp. from physics and biology. The context of interdisciplinary and multidisciplinary research was usually ignored by philosophical reflections. The recent modelistic orientation in philosophy of science makes plausible such an approach on scientific inquiry. In the present paper I will first look at the ways the classical accounts on explanation can accommodate the explanations that draw on more disciplines. I will than argue for the modelistic view as a proper way to foster such an approach. A general schema of explanation through modeling will be also introduced and discussed in regard to the advantages it brings and some related issues.*

Keywords: *scientific explanation, model and modelistic view, model-based explanation.*

1. INTRODUCTION

The subject of scientific explanation in philosophy of science is one of the major topics that marked the debates of the discipline in the last half of century. It dominated the working agenda of the field and concentrated the efforts of the philosophers and logicians starting with the 'classical' period of neopositivism. The philosopher C.G. Hempel initiated and raised the subject at its prime status and its deductive-nomological model concentrated the debate for more than three decades[1]. The fourth decade was marked by major new approaches and fresh insights that diversified investigation and revealed important novel aspects. Nonetheless minimal agreement was not reached and the enthusiasm for the topic gradually faded. Towards the end of the last century the debate was marked by a sort of fatigue and lack of fresh insights.

In recent years the new tendencies in the philosophical research brought with it the possibility of reframing the topic. The search for a general account of explanation valid for all varieties of explanation ranging over different scientific fields was dropped. The investigation concentrates nowadays on particular forms of explanation in a more local setting taking into account aspects that were previously ignored such as the pragmatic ones.

The above mentioned philosophical literature focuses mainly on scientific explanations articulated within the boundaries of the disciplines. Scientific areas that involve the appeal to more than one discipline, either multidisciplinary or interdisciplinary studies, were ignored as possible subjects of philosophical inquiry. This reflects the legacy of the 'received view' in the agenda of the topic and discloses the limitations of the classical view. The recent developments and tendencies in philosophy of science, especially the one that emphasizes the importance of models in the economy of scientific knowledge, open the possibility to approach in a plausible way the question of how explanation practices take place in multidisciplinary scientific research.

2. THE CLASSICAL APPROACHES ON EXPLANATION

Hempel's [10] deductive-nomological (DN) account construes explanation as a deductive inference in which the phenomenon to be explained (the explanadum) takes the position of the conclusion. The premises (the explanans) contain two sets of statements: laws of nature and statements describing the conditions under which the explanandum occurs. So to explain why the bottle filled with water broke over night we invoke the law of physics that state the increase in volume of frozen water and the fact that over night the temperature dropped below the freezing point. This is a more mundane interpretation of an explanation but we can say, as Batterman [1] also noticed, that Hempel had in mind primarily the explanation given in physical sciences by solving initial value problems for ordinary differential equations. As for example when we want to predict and explain this way the position of the Earth at some future point we will need Kepler's equations and the positions at some specific moment. Extending this type of explanation to other areas of science proved in the end to be problematic.

Now for Hempel the laws he has in mind are the fundamental laws of nature as they appear in physics. More particular physical laws as Kepler's laws of celestian motion, or Galileo's laws of moving bodies at the Earth surface are to be explained in the same way by deriving them from the fundamental laws of Newtonian mechanics. This might pose a first problem for the DN-model in regard to multidisciplinary explanations. In such studies the laws that are referred must belong to one or another of the disciplines involved; they are laws specific for the disciplines involved. So for example the explanation of a social phenomenon by appeal to a physical law would not count according to the DN model as a genuine explanation. In fact this situation can be described better as a modeling situation which for Hempel refers to an exploratory aspect of scientific inquiry and not an explanatory one. Hempel addresses the issue of a possibility of explanation through modeling and his illustration draws on mathematical modeling in social science. He denies such a possibility claiming any attempt to be only a sort of heuristic attempt to extend the theory in the realm of new phenomena.

One could say that Hempel was on the right track when addressing the issue of explanation through models but the

[1] For a detailed historical review of the debate in its first decade one can use Salmon's book *Four decades of scientific explanation*. Salmon was an important participant in the debate with major contribution in the analysis of statistical explanation and causal explanation.

frame of the official conception, the neopositivistic one, prohibited him to pursue any further such an investigation.

I will further look to the other existing approaches in order to see how they might address the issue of multidisciplinary explanation.

The approach that conceived explanation as unification was proposed by M. Friedman [6] in a seminal paper in 1974. His account didn't got too far due to a logical flaw but the idea got propagated. Its best articulation at the time, is to be found in Kitcher's account [11]. Friedman's account took derivation of laws or lawlike generalizations as the paradigm of a scientific explanation. Explanation and also understanding[2] is given by unifying various disparate phenomena expressed through more particular laws under a general law. So for example we unify specific laws as Kepler's laws, Galileo's laws, Hook law and many other under the fundamental laws of Newtonian mechanics by deductive derivation.

Kitcher's account is more elaborated. He develops a special notion of argument pattern as sort of a more adaptable schema for an inferential judgment. Such a pattern is meant to capture also the specificity of the reasoning in particular scientific fields. An argument pattern is a triple that contains a schematic sentence, a set of filling instructions (with instructions for each term in the schematic sentence) and a classification which describes the inferential characteristics of the schema. An argument pattern becomes explanatory if it belongs to the set of argument patterns that best unifies the corpus of knowledge ("the explanatory store"). The determinant process for the establishing the explanatory virtues of patterns takes place as the macrolevel were the sets of patterns are compared weighted and selected.

For the purpose of our investigation it seems that nothing prohibits such patterns to be instantiated in multidisciplinary inquiry, which will mean that they are part of the explanatory corpus. But Kitcher's intention is to see these patterns at the core of the grand scientific theories. He illustrates his ideas by reference to Newtonian mechanics or the explanatory patterns of Darwinian evolutionary theory. We might think of pattern as involved in interdisciplinary research as partially transferred from other theories and showing variation in some of their components. The most obvious case would be the variation in filling instruction as we would apply a schematic sentence to another sort of phenomena than those initially intended. Nevertheless we cannot tell if this pattern will belong to the explanatory store. The criteria for such a decision are too global and involve comparison of entire corpuses of knowledge. They are too uninformative to be used for a more local inquiry into how explanatory claims are built.

What about the other major accounts on explanation? The causalist approach proved to be one of the most successful one. It is not only in the classical period through mainly Salmon's work [14]. Recently the causalist approaches found different articulations in more general accounts but also in specialized domain-specific accounts, the last ones by analyzing causal explanatory forms in particular areas of science. The basic intuition of the approach is that an explanation tracks the causes of an event or fact, identifies causal influence and exposes causal mechanisms. The next step undertaken in such account is to spell out what this causal relation involves. Hempel considered he accounted for this sort of explanation through his DN model, being also faithful to the neopositivistic attitude towards causality and demystifying it from any metaphysical interpretation. The later causalists nevertheless offered consistent explications of causality.

In what regards the multidisciplinary and interdisciplinary investigation, the causalist approach seems to have some clear advantages in comparison to other previously discussed approaches. Tracking causes is independent of the theoretical structure appealed. So one can read out here a neutrality towards the sort of theoretical setting: it can fall into the boundaries of one discipline or of more disciplines without any problem. In fact one can find some important work on explanation through causal mechanisms with reference to such interdisciplinary domains as biophysics or biochemistry. I will mention here only the extended studies of William Bechtel on complex systems found at the intersection between biology, physics and chemistry and neurology.

The major problem with the causalist approach is quite well-known. Not all explanations are causal. This limitation was acknowledged by the adherents of the causal approach. The major example that is invoked and draws the limits for this approach (as Salmon recognizes) is the case of explanation in quantum mechanics. For an multidisciplinary point of view it will be unreasonable to restrict scientific explanation only to causal types of explanation and exclude as pseudo-explanation any involvement of other disciplines.

A last type of approach that I'm going to address is the one that draws on pragmatics.[3] It found one of its boldest expression in van Fraassen's account on explanation [16]. Putting it roughly a scientific explanation is an answer to a why-question given by making use of scientific information. Inspired by the developments of the erotetic logic[4] he tries to formalize the why-questions in a similar way. Why-questions are problematic in comparison to the other wh-question that Belnap & Steele [2] analyze, due to their open structure. For van Fraassen why-questions are contrastive: we ask "why P_k rather than P_j ?" where these Ps are propositions. A why-question Q is represented by a triple of the form $< P_k, X, R>$, where X is the contrast class i.e. a set of propositions: $\{P_1, P_2, .., P_n\}$, P_k is one of these propositions (called the topic) and R the relevance relation. A direct answer might be formalized as "P_k in contrast to (the rest of) X because A"; so more precise "B is a direct answer to $Q = < P_k, X, R>$ if there is some proposition A such that A bears relation R to $<P_k, X>$ and B is the proposition which is true exactly if (P_k; and for all i other than k, not P_i; and A) is true".

2 Friedman argues for the fact that an approach on explanation should also give us insight into understanding.

3 Similar to linguistic studies in logic and philosophy of science the syntactic, semantic and pragmatic aspects are separated , the last one concerning the use of the constructs.

4 Belnap & Stele book *The logic of questions and answers* appeared at that time;

Letting apart the details of the account, the main emphasize falls on the relation of relevance R, which ultimately is determined contextually. Subsequently what might be taken as a satisfactory explanation is ultimately determined by contextual factors: such as the interest of the inquirer, the audience towards the explanation is directed etc. To see the main difference from a causal explanation I'll draw on a classical example from the literature. We can explain the length of a shadow casted by a flagpole by invoking the height of the flagpole and the laws of optics under both approaches; nevertheless only for the interrogative approach a derivation of the height of the flagpole from the length of the shadows will count as an explanation.

The interrogative approach is quite generous and can accommodate any sort of explanation. Its drawback seems to lie exactly in the fact that it is too generous – an almost "anything (that is an answer to a why-question) goes" sort of approach. That was what the critiques [12] pointed out from the beginnings; putting it a bit more precise the accusation goes to the fact that the relation of relevance remains unconstrained. The main point is indeed that there is a need for more than a totally open contextual determination. Nevertheless, taken the larger perspective of the debate on explanation van Fraassen's approach revealed the need to consider more seriously the contextual factors – a moral that was nowadays widely accepted.

An important consequence of the debate on explanation in its classical period is that a pluralistic view made its way as the most plausible one. Nowadays the existence of different irreducible explanatory formats is accepted by the philosophical community. Causal explanation is one of the most researched ones as it appears in various scientific areas. The investigation concentrates nowadays on particular forms of explanation as they are articulated in specific scientific domains.

There seems to be no problem with claiming the interrogative view on explanation as adequate to address the interdisciplinary explanation. The problem remains the same as identified by the general critique – the too unconstrained nature of the explanatory relevance relation. What we might need is some more consistent reference to scientific contexts and specific nature. I will further suggest a frame that can better harbor a philosophical inquiry into explanations in interdisciplinary settings.

3. TOWARDS A MODELISTIC VIEW

As we saw previously the philosophical accounts on explanation made reference to such scientific units as laws, theories or even larger types as field or entire corpuses of knowledge. Scientific models were neglected as potential bearers of explanations. This attitude can be attributed to the neopositivistic legacy and the fact that the topic of explanation was part of it. Interesting enough Hempel was the single major author that discussed the issue of explanation through scientific models; he rejected the possibility of any genuine explanation due the models limitations in range and purposes. Hempel, as one of the important figures of neopositivism, shared the "depreciative view" on models that the conception promoted (view that originates in P. Duhem's work [5]). According to this view models are only additional means that can be used for specific purposes in the production of scientific knowledge, usually for making more intelligible the abstract theoretical principles, but also for other purposes such as for example the search for new applications of a theory. Nevertheless they tell us little about the real structure of science. After we reach our goal they might be dropped; so they are dispensable means of little importance for scientific knowledge.

My suggestion, in the spirit of the recent modelistic orientation, points on the contrary to their importance in the scientific knowledge. In this sense, by taking seriously models as bearers of explanations we can better address and analyze the way explanations are build in multidisciplinary research. As I have argued in another place [4] taken into account the drawbacks of the classical approaches on explanation, a plausible direction of reframing it might be characterized as a local dynamic and non-theory driven sort of approach. Let me briefly clarify these characterizations. A local account is more sensitive to the contextual setting of the explanation in contrast to the global and generalizing modality of classical approaches. A dynamic view will take seriously the process of explanation rather than explanation as a final product of that process as it is conceived in the mentioned accounts. The non-theory driven sort of approach makes reference to the recent reactions against the sort of theory-dominated philosophical agenda as Cartwright called it, that characterized philosophy of science almost up to the end of the last century.

I have argued that such an approach could be developed in a modelistic frame - by investigating how the explanation builds up in the frame through modeling processes. There are some clear advantages that makes such a frame adequate for addressing explanation at a local level. Models are local units heavily influenced by the pragmatics of the investigation. They are constructs that represent specific aspects of reality or specific purposes. The scientists intentions play a major role in their building and functioning. The philosopher R. Giere [8] saw the relation between models and reality as a many-placed relationship and proposed the following definition for the model-based representation: "*S* uses *X* to represent *W* for purposes *P*."

The recent modelistic reorientation[5] in philosophy of science redefined also the working agenda that was previously marked by the theory-dominated sort of approach. By drawing on modeling practices in different scientific disciplines we can reset the general philosophical questions in more specific contexts. We make this way the philosophical investigation more relevant to scientific practice. In fact another recent trend stimulated and connected to the modelistic movement is the practice-oriented philosophy of science[6].

[5] The volume *Models as Mediators. Perspectives on Natural and Social Science* [13] edited by Morgan and Morrison gathers some important early works of this orientation.

[6] Developed around the Society of Philosophy of Science in Practice, it brings together philosophers that also have important contributions to the study of scientific modeling. A recent number from 2011 of the *European Journal of Philosophy of Science* gathers some of the works of this orientation.

Not least are the dynamical aspects of inquiry that a model oriented frame can accommodate. In comparison to other scientific units such as theories or laws, models could be much easier approached through a dynamic perspective involving their building, functioning or modification in the process of scientific inquiry. According to F. Weinert [17] models are ales constrained than theories and so it is easier to represent the alterations and modifications they are subjected to.[7] Besides we can much easirer draw on concrete examples from scientific practice in order to document these processes.

4. A GENERAL SCHEMA FOR MODEL-BASED EXPLANATION

I'll further present a general frame for approaching explanation through models proposed by Frigg and Hartmann (the LOOP account as they call it) [7]. The scheme is a sufficient general one but also enough articulated to provide a proper setting for an inquiry into explanation in multidisciplinary contexts.

The authors starting point are some scattered suggestions made by philosophers Hare and Cartwright. Hare [9] takes explanations to provide us pictures of the facts and these pictures are in fact presented through models. Cartwright [3] in her simulacrum account also states explicit that "to explain a phenomenon is to find a model that fits into the basic framework of the theory and that thus allows us to derive analogues for the messy and complicated phenomenological laws which are true of it." The LOOP account seeks to give a more detailed articulation of this idea by making explicit the dynamic in the model and between the model and the represented target system.

The explanandum is conceived to be a feature or propriety of the target system or an event or phenomenon within this system. They exclude other types of explanadum from their account. The explanans on the other side is the model itself. The problem is then: how does a model M explains an occurrence O exhibited by the target system T that is represented by M? Their account specifies four steps that make out the process of an explanation. The first two steps are called identification steps. In the first one we identify the occurrence in the target (OIT as they call it), i.e., the behavior of interest in the target system that has to be explained. Using their example, Boltzmann ideal gas model in which the gas is represented through an ensemble of a huge number of hard balls moving in a confined space under Newtonian classical laws, the OIT is the expansion of the gas in the entire volume of the container when a separating wall is removed. In the second identifying step, the occurrence in the model (OIM) is identified, i.e., the element in the model that corresponds to the occurrence in the target that we wish to explain. In our example it corresponds to the spreading of the balls in the entire volume.

[7] P. Duhem the French scientist and philosopher at the turn of the XXth century was warning against the dangers of these less rigourous constructs of science. His idea are at the origin of a depreciative view of models that got propagated by the neopositivists.

The next two steps are called the explanatory steps. In the first one, called explanation_1 we have to reproduce the OIM in the model, meaning that the OIM has to follow from the basic assumptions of the model. 'Follow' is not made more explicit in any way but is not reducible to deduction as in the DN model. In the mentioned example of the ideal gas one has to show that the approach to equilibrium follows from the assumptions about the balls (the fact that are hard, that they collide elastically, etc). The fourth and last step, called explanation_2, involves the translation of knowledge obtained in the model (and about the model) to the target system. In our example, we know that the balls bounce around such that they reach the equilibrium distribution (what Boltzmann proved) and that the balls are idealizations of a certain kind of the molecules. This way what holds true in the model approximately carries over to the real system.

Having laid out the above sketchy account before proceeding further I want to emphasize two important points. The first one is linked to the precaution the authors take regarding the issue of explanation and truth. I completely agree with their position that an explanation is an explanation due to its "inner constitution' and not for how good, bad or fruitful it is. The classical accounts were hinging on the truth requirement as a fundamental one. That anchored the explanation problem in a dense philosophical context and made it dependent on such philosophical topics as the subject of laws or of causality and the solution to such issues. The second point I want to make is that the LOOP schema is an empty, quite unsubstantiated schema that has to be filled out. The authors recognize this and see the needed content to be delivered by the different types of representations corresponding to different explanatory strategies. The LOOP schema makes sense only in reference to a specific scientific context, articulate in a particular modeling episode from a specific area of science.

***

For the remaining part I will briefly point to some advantages the LOOP schema offers for the inquiry into multidisciplinary explanations. I will also suggest some immediate issues that might rise and should be addressed in applying the schema.

The LOOP schema offers clear advantages over the older approaches. One of the major is the fact that it conceives explanations a process (not as a final product as in older accounts) that is embedded into the more general dynamic of the scientific inquiry. It makes this way possible to account for the production and modifications of scientific knowledge when engaging into scientific inquiry.

The schema offers the possibility to tackle the way different elements are integrated in the flow of the inquiry processes. This has direct relevance for the study of integration of different disciplinary contributions in case of interdisciplinary or multidisciplinary inquiries. Distinct methodologies or techniques specific to the engaged disciplines are integrated in the run of the LOOP cycles. The different conceptual frames belonging to different disciplines might interact and combine or be used subsequently during the explanatory process.

The schema allows also to draw and articulate some distinctions that we need to take into consideration. It allows this way to reveal and identify the division of labor and the different contributions of the involved disciplines. So, to point only to some first sight rough distinctions the schema can separate the fact that the explanation in the model (the E1 step) might belong (or characterize this way) to one of the disciplines. To take an example we can see such a derivation in the frame of a model specific to statistical physics which can be applied to the study of some social phenomena. The OIM is the occurrence that properly falls into the physics realm described by statistical physics. Meanwhile the corresponding OIT is the real feature of a social system that is targeted by the model. The derivation inside the model is an uninterpreted inferential move one that draws on techniques for the physical science. Nonetheless this is not a totally physics bounded affair since many assumptions made in the run of the derivation might quite well make use of information specific to the social phenomena modeled. The second explanatory step is the moment when we judge the result in the model transferring the knowledge to the targeted system. At this step we are involved in interpretation of the results obtained in the model and have to take into account the knowledge and constraints from the other discipline (in our example the particular social science that claims the system as its domain of expertise). Of course the above observations are only the general sketchy distinctions that could be drawn at a first sight. The application on a specific scientific episode would reveal the finer configuration and provide consistency to the analysis.

Another important distinction is the one that regards the understanding that builds by going through such an explanatory loop. The division of labor between E1 and E2 makes possible to distinguish between understanding developed in the model which might draw primarily on one discipline (the one on which the model relies more heavily) from understanding claimed for the target system, that draws on the other discipline. A further step of inquiry will look at the different moments, how they develop during the modeling process and how they might contribute to the overall final understanding that the researcher can gain. In the end we would like to gain some novel insight on the targeted system and make the conceptual resources of the model as much as possible relevant to the nature of the modeled system. Conceptual novelties and improvements coming from the modeling discipline could suggest a further level of extending the multidisciplinary inquiry suggesting the possibility of a further more complex level of modeling.

The above discussion sketched only some general lines on which we might follow and develop the further inquiry. In order to flesh out the schema and better articulated the questions and the sort of answers they generate we need to make reference to a particular scientific context, a concrete piece of scientific inquiry. Working into such a specific context we can identify and characterize the modality explanations and understanding articulates in particular areas of research but also how these characterizations might be transferred to other domains.

Not at least one last important thing to be emphasized. The LOOP schema allows a Bayesian reading of the knowledge dynamics but also of the explanatory claims. By running through the loop we gain new information and update this way the degree of belief in our findings. Regarding explanation, as the authors also suggested, we can attach them values between 0 and 1 and represent this way the degree of confidence in an particular explanation. We do not have to drop an explanation entirely if we are not totally confident about it and we cannot validate it beyond doubt. We might hold on and work with explanations though we have some doubts about them (which we may try to clarify by using it) and continue to expand this way our corpus of knowledge. This makes possible to adopt a failibilistic perspective over the production of scientific knowledge.

5. FINAL REMARKS

The recent modelistic reorientation in philosophy of science could be seen as sort of sub-paradigm change in the philosophical research. As its working agenda expands it unveils unexpected opportunities to rethink some older philosophical topics. Such is the well-honored explanation topic. The changes also brought with them the possibility to address issues that were ignored by classical approaches. Such is study of multidisciplinary and interdisciplinary research and the explanatory claims that could be made in such contexts. We are engaging here in new areas of philosophical research that open the possibility to gain fresh insights into the study of science. The most important thing of the recent tendencies is the fact that they promote in a more determined and efficient way the close contact of philosopher with the science practician.

6. ACKNOWLEDGEMENT

This paper was made within *The Knowledge Based Society Project supported by the Sectorial Operational Program Human Resources Development* (SOP HRD), Financed by the European Social Fund and by the Romanian Government under the contract POSDRU /89/1.5/S/56815.

7. REFERENCES

[1] Batterman, R. (2000), *A 'Modern' (Victorian) Attitude towards Scientific Understanding*, The Monist, vol. 83(2), pp. 228 – 257.

[2] Belnap, N.D. & Steele, T.B. (1976), *The Logic of Questions and Answers.* New Haven: Yale University.

[3] Cartwright, N. (1983), *How the Laws of Physics lie*. Oxford: Oxford University Press.

[4] David-Rus, R., (2011), *Explanation through Scientific Models: Reframing the Explanation Topic*, Logos & Episteme vol. II, (2), pp. 177-189.

[5] Duhem, P. (1954), *The Aim and Structure of Physical Theory*. Princeton: Princeton University.

[6] Friedman, M. (1974), *Explanation and Scientific Understanding.* Journal of Philosophy, vol 71, pp. 5-19.

[7] Frigg, R., Hartmann, St., (2005), *Models, Explanation and Understanding.* Draft of the presentation at the 2005 Conference on Philosophical Perspectives on Scientific Understanding, Vrije Universiteit Amsterdam.

[8] Giere, Ronald N. (2004), *How models are used to represent reality*. Philosophy of Science, vol. 71 (5), pp. 742-752

[9] Harre, R. (1983), *An Introduction to the Logic of the Sciences.* London: Macmillan.

[10] Hempel, C. G. (1965), *Aspects of Scientific Explanation and other Essays in the Philosophy of Science.* New York: Free Press.

[11] Kitcher, P. (1989), *Explanatory Unification and the Causal Structure of the World* in P. Kitcher and W. Salmon (Eds.), *Scientific Explanation*. *Minnesota Studies in the Philosophy of Science, volume 13* (pp. 410-505). Minneapolis: University of Minnesota Press.

[12] Kitcher, P. & Salmon, W. (1987), *van Fraassen on explanation*. Journal of Philosophy, *vol. 84,* pp. 315-330.

[13] Morgan, M. and Morrison, M. (Eds.) (1999), *Models as Mediators. Perspectives on Natural and Social Science*. Cambridge: Cambridge University Press.

[14] Salmon, W., (1998), *Causality and Explanation*, New York: Oxford University Press.

[15] Salmon, W. (2006), *Four decades of Scientific Explanation*, Pittsburgh: University of Pittsburgh Press.

[16] van Fraassen, B. (1980), *The Scientific Image.* New York: Oxford University Press.

[17] Weinert, F. (1999), *Theories, Models and Constraints.* Studies in History and Philosophy of Science, vol. 30(2), pp. 303-333.