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THE CENTRALITY OF DISCOVERY IN SCIENTIFIC THEORIZING

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ABSTRACT

Scientific frame of mind consists in a certain mode of thinking and type of response to certain problems. In order to develop these qualities and attitudes one has to imbibe and internalize the dynamics of the method of science. But the vital question is, what is that pattern of thought, if at all it exists, that lies behind the discoveries of science? The answer to this question has something substantial to contribute to our knowledge of scientific method and therefore, to science training and to the philosophy of science education. The recognition of the centrality of discovery in scientific theorizing will enable us to realize what mode of thinking we must inculcate in the minds of science students and also how to enable them to see the relation between science and other domains of human creative endeavor such as art. An attempt is made in this paper to develop the philosophical position of Gary Gutting and Richard Burian on scientific discovery against the backdrop of Thomas Nickles ideas of problems and constrints. These two philosophers of science have succeeded in brining to fore the idea of problems and constraints as the pivotal concepts in characterizing scientific thinking. It is true that Karl Popper was the first philosopher to emphasize the role of problems in scientific thinking. However, he stopped at it without laying bare the texture of the scientific problematic, a task which is very ably performed by Gutting and Richard Burian who have been taken the problem of discovery as the central methodological issue. Most importantly their position on scientific discovery fundamentally distinguishes itself from the conservative views in terms of categorial reorientation, which replaces the old categories by the new ones through which the essential nature of science is described and explained. As will be elaborated in the following discussion, these changes have fundamentally altered the discourse about discovery in ways that can be of momentous significance to science education, formal or otherwise.

Keywords: *scientific discovery; scientific invention; background knowledge; problems and constraints;*

INTRODUCTION

In October 1978 hardcore physicists,cognitive psychologists,historians of science and philosophers of science across the globe assembled at the University of Nevada, Reno to review and discuss various philosophical issues of scientific discovery.In this historical conference, “the simplistic dichotomy between discovery and justification was rejected, and it was acknowledged that discovery can either refer narrowly to original generation or broadly to the process which starts with generation (or even before) and ends up with final acceptance" (Sintonen and Kiikeri 2004). The serious deliberations in the conference enabled them to recognize the need and importance of multidisciplinary investigations and the epistemological and philosophical significance of scientific discovery. This intellectual congregate highlighted the idea of *problems* and *constraints* laying stress upon perpetual and radical change in science and also by bring to light the *background knowledge* that is overlooked by the conventional understanding of science.

DISCUSSION

Popper was the first person to recognise the seminal importance of problems in the structure of scientific thought. However, Popper failed to fully work out the rich texture of the scientific problematic. This is in of the fact that he rightly recognises science as essentially a problem-solving activity and man as problem-solving animal. This is because for Popper the recognition of the centrality of the problem was important only to the extent that such a recognition replaces 'data' as the beginning of scientific thinking - an idea that was central to inductivism. In other words, undoubtedly in Popper's scheme the problem stands in the beginning but it only any epistemological dynamics. (Sudhakar 1993).

Nickles goes a long way in doing justice to the ideas of problems and science as a problem-solving activity by laying bare the rich texture of the scientific problematic. Central to Nickles' idea of problems is his notion of "constraints" as constitutive of problems. According to him, Problem = constraints + demand. The solution lies in the direction pointed to by the constraints. The direction may be sometimes straightforward when the constraints imply logically or deductively a solution or may be sometimes round about. Note that it needs reasoning to go from constraints to solution. Also the perception of a problem involves the grasping of the constraints and understanding the demand made under those constraints - a perfectly rational process. It may also be noted that the constraints may not be given at one go. The progressive formulation of constraints is the progressive articulation of a problem which is how a problem grows. The perception of a problem, the developing of a problem and arriving at a permissible solution are all fully rational exercises that precede the stage of the so-called rational evaluation of .solution. That is to say, generation involves percep-tion of a problem and some kind of selection for preliminary evaluation and therefore the terms of its articulation are to a great extent normative. It is because of this normativity that problems and constraints constitute two faces of the same kind such that the distinction between them is possible only in the abstract and not in the actual scien-. tific practice. The inseparability of problems from constraints makes the structure of a problem rich and complex lending it *"crucial importance to the methodology of discovery"*(Nickles 1980) . The idea that discovery is illegitimate as a philosophical topic is the result of the neglect of "problem" as a methodological category. The result of this neglect, Nickles believes, *"is a theory-oriented bias in philosophy of science, but one which can be corrected by a more problem-oriented approach"*(Nickles 1980).

Gary Gutting and Richard Burian provide a somewhat more elaborate and focussed presentation of the concept of constraint which also figures at the core of Nickles' analysis. In doing so, Gutting and Burian invoke the concept of background which denotes what lies behind the foreground constituted by the theoretical structure. Their idea of background is an extended version of Nickles' notion of constraints in the sense that background works as a constraint for the foreground constituted by theories.

In his article 'The Logic of Invention' (1980) Gary Gutting attempts to uncover the fundamental reason due to which Hanson's abductive analysis of discovery remained unfruitful. In this connection he says that Hanson, by focussing exclusively on the logical form of abductive inference, ignores Peirce's own emphasis on another feature of abduction viz., its dependence on a set of principles regulating the choice of the explanatory hypothesis . The inseparable association of abductive reasoning with the regulative principles accounts for the fact that in abductive reasoning the hypothesis occurs as a key premise in deriving a result that meet the condition set down by the relevant regulative principles such that it is the latter which constitutes the conclusion of an abductive reasoning and not the hypothesis and therefore the charge against abductive reasoning that it places the very hypothesis whose plausibility has to be established in the place of the key premise, is absolutely misplaced. Secondly, the role of regulative principles in abduction explains why abduction typically fails to lead to a full-fledged scientific hypothesis but at best only to a plausible idea. The explanation is that regulative principles are *"general constraints that will usually under determine the choice of an answer to a scientific question"* (Gutting 1980) , such that *"There will almost always be a significant range of possible hypotheses meeting all of those constraints"(*Gutting 1980). Two things are to be noted in what Gutting says. Firstly, even though he talks of regulative principles in the context of abductive reasoning presented by Peirce and Hanson as a logic of discovery, the point holds in all cases of reasoning involved in the process of discovery, abductive or non-abductive. That is to say, though the idea of regulative principles is contextualized by Gutting to abductive reasoning, they are present, according to Gutting, in the case of any type of scientific reasoning in the development of a scientific idea. Secondly, it may also be noted that Gutting's talk of regulative principles as constraints can be treated as an extention of or an enrichment of Nickles' notion of constraints (Sudhakar 1993).

However, let us look at Gutting's elaboration of his central idea of regulative principles. The regulative principles which govern the invention of any scientific hypothesis or idea are of three types, namely,

1. heuristic principles,
2. scientific intentions and
3. cosmological principles.

Heuristic principles facilitate the process of developing scientific ideas and are therefore concerned with a hypothesis' efficiency as a means to the ultimate goal of finding an acceptable theory. Gutting considers simplicity and analogy as two such principles. Many times in science simpler hypothesis and hypothesis which are analogous to familiar ones are taken up and even accepted provisionally even if their being true is not known for the simple reason that they might help us later to go in the correct direction even if they were false. Of course it is true that simplicity is an extremely complex notion. There are many types of simplicity like pragmatic, syntactical, semantic, etc., and there are no objective criteria to decide the relative merits of these different types of simplicity (Bunge 1961) . Secondly, the decision concerning what is simple is more often subjective; what appeared to the followers of Copernicus as a cumbersome process of artificial patching appeared to the followers of Ptolemy as the natural extension of their theory (Kuhn 1957). Further, *'analogical reasoning is more often fallacious than not'*, as the saying goes. However, Gutting recognises that the notions of simplicity and analogy are problematic and accepts that appeals to simplicity and analogy are best construed as having just the minimal heuristic sense.

The next type of regulative principles is constituted by what Gutting calls *'scientific intensions'*, that is to say, the goals and purposes that direct scientific activity. Scientific intensions can be of two types, namely, basic intensions and subsidiary intensions. The former define what Habermas calls "Cognitive interests" of science and can be variously construed as truth, explanation, prediction, control, problem-solving, etc. The latter concern the demands for, for example, mathemetization or particular type of mathematization, for evolutionary or mechanic-models, etc. Thus these principles are related to the various ideals of science that scientists with different persuasions hope the theories they develop will he able to realise. The idea of scientific intentions functioning as regulative principles, obviously is in line with the post-Positivist view of science as primarily a human activity rather than an abstract system of propositions. It also accounts for certain historical facts that point to the role of methodological commitments in the shaping of the actual scientific practice. Moreover, recognition of the role of scientific intentions critically affects our received view of scientific rationality and to a great extent promotes a more adequate alternative.

The third type of regulative principles which are called cosmological principles concern substantive views about the nature of the world or more particularly, of that aspect of the world that a particular science is purported to study, as for example, Matter in the case of Physics, Life in the case of Biology, Society in the case of Social Sciences. Needless to say, such views are far removed from the empirical data of day-to-day science. But this does not minimise the integral role of those philosophical world-views in science in general and fundamental (theoretical) science in particular. The role of such views is a necessary feature of science, since scientific activity consists in the construction of a scientific world-view with a starting point *"that is developed and tested to obtain a picture of nature that meets certain scientific standards of conceptual precision and empirical adequacy. By definition, such a starting point must be a non-scientific conceptual framework"(Gutting,1980).* The fertility of a cosmological principle depends upon the possibility of its success in generating acceptable hypotheses. The recognition of the cosmological principles as regulative adversely affects the thesis of the autonomy of science that is so central to the positivist philosophy. Such a recognition will go a long way in placing science within the broader intellectual mosaic of a milieu.

The crucial methodological role of cosmological principles so spiritedly enunciated by Gutting is more convincingly brought by Rom Harre (1964), who draws our attention to the fact that it is what he calls general conceptual systems peculiar to a historical epoch that determines our conceptions of reality which in their turn determine the character of our explanations. A general conceptual system of a given epoch consists of basic assumptions about what types of processes and structures underlie the world. That is to say, it consists of the answers to the fundamental questions concerning the nature of the stuff the world is made of. The methods of investigation considered to be proper and the kinds of explanation deemed to be appropriate in any given epoch depend, Harre points out, *"in part, on the particular specification of general concept of matter popular in that epoch"* (Harre 1964). It is this fact which accounts for the qualitative difference between the type of explanations characteristic of Aristotelian science which is by and large teleological and those of Galllian science which is by and large mechanistic. Galilian science heralded the abolition of the world as a finite closed system with a structure that is determined by a heirarchy of values - the world of Aristotle. It replaced it with the conception of an infinite universe held together only by a set of non-hierarchical components and mechanical laws. Unless this fundamental difference between these modes of scientific theorizing is appreciated one fails to grasp the significance of the intellectual spectrum whose initial point is the Copernican revolution and the end point is the corpuscular theory. Further it must be noted that in science we do not go on explaining *ad infinitum* but stop at a point and say "no more explanation is needed". As Harre says, *"at any given epoch there is an end to explanation and this end is reached when the entities and processes of an explanatory mechanism are those which form part of the denotation of ... the general conceptual system of an epoch"* (Harre 1964). In other words, reaching the rock-bottom of all explanation, however provisionally, is an essential feature of science as an explanatory endeavour and the rock-bottom is specified in terms of what is constituted to be the ultimate constituents of that domain of reality into which a particular science inquires and in particular the conception of matter. Since the general conceptual system is historically specific, the recognition of role of general conceptual systems as regulative principles brings to the surface the essential historicity of scientific activity and scientific rationality.

A similar emphasis on the historicity of science can be found in the treatment of discovery given by Richard M. Burian (1980) who provides a further development of the idea of constraints. An adequate philosophical understanding of scientific discovery, according to Burian, must seek *"to establish a cognitively useful classification of conceptual innovations or of methodological guidelines for achieving such innovations"* (Burian 1980). And that "this classification should play a significant part in cognitive *evaluation* of conceptual innovations or of programmes or methodologies aimed at achieving conceptual innovations" (Burian 1980). In doing so, such a philosophical understanding of discovery should not take recourse to context-free rules by means of which to rank the plausibility of alternative hypothesis. Burian (1980) says, *"It is primarily in the light of substantive knowledge of the structure and interactions of the objects, events, or processes under investigation that we can evaluate our ways of trying to learn more about those objects, events or processes".* In other words, according to Burian, the constraints governing plausibility, adequacy and rationality in the context of discovery vary with scientific contexts and purposes. Therefore, an adequate philosophical account of discovery must exhibit the role of contextual factors by which Burian means, among other things what Nickles has called 'Constraints' on adequate solutions" (Burian 1980).

The contextuality of scientific theorizing via the contextuality of the constraints, Burian seeks to bring out by focussing on what he calls the background to and preparation for discovery. According to him, a synoptic account of discovery is contingent upon coming up with adequate classifications of the kinds of backbround to and preparation for discovery, of the patterns of inference employed in hypothesis generation, of cognitive and non-cognitive factors affecting the content of discovery and of factors bearing on plausibility and trustworthiness of a hypothesis. In this connection Burian notes three features that chacracterize the background and pave way for discovery. The first concerns isolation of a domain of phenomena concerning which there is a body of moderately exact and reliable results. Such an isolation involves more than collection of data.

Burian draws our attention to the distinction between the factual knowledge of electricity possessed by Greeks and that possessed by scientists at the time of Frankline. The latter was definitely more systematic in the sense that a coherent body of facts was delineated in terms of certain principles through which the facts were refined and unified. As Burian points out, *"To be acceptable, the resultant discovery is often constrained to account for the* *apparent unity of the relevant domain of phenomena either' by offering, in prospect, a unified account of the entire domain or by providing the principles by means of which to reallocate some phenomena to other domains"* (Burian 1980). Such a systemati-zation and unification, apart from providing the constraints on acceptable hypothesis, points to the direction in which the search for an adequate hypothesis must proceed. As Burian aptly points out, *"as we learn more about the princples on which our information regarding the phenomena of a given domain can be unified, we learn more about how to learn about the phenomena of even distantly related domains"* (Burian 1980).

The second feature pertains to the structure of the background knowledge. It may be recapitulated that the first feature concerns the refinement and unification of a subset of background knowledge into a domain for which a hypothesis is proposed. The second feature concerns the change that might occur in the other domains and its impact upon the discovery. Of course, the degree of the impact that might decisively shift the constraints on the domain depends upon the degree of connection expected between the "neighbouring" domains, the character and relative success of the theories deployed in those domains, etc. In this connection Burian gives the example of the wave theory of heat. It may be noted that this theory replaced in 1830's the caloric theory of heat. The reasons for this change were neither the results of the theories of Davy and Rumford nor Joule's experimental determination of mechanical equivalent of heat. The most decisive reason was the success of the wave theory of light over its competitors. Thanks to the work of Fresnel's in 1820's and the analogy between heat and light, not established by any unifying theory but pursuasively brought about by experiments of W:Herschel and and M. Melloni on radiant heat. This example very clearly brings out how the background knowledge constituting. a nighbouring domain can. (through an analogy with a neighbouring theory) decisively affect the constraints on discovery in a particular domain.

The third feature concerns the relation between problem and background knowledge. In this context it is apt to recall Popper who rightly recognizes the importance of problem as the initial point of scientific theorizing and fails to work out in detail the rich texture of scientific problematic. Scientific reasoning undoubtedly is characterized by the presence of constraints but there are a great many ways, not easily noticeable, of violating these constraints, without inviting the charge of irrationality. There are built-in mechanisms to escape from such a charge. These built-in mechanisms basically consist in ensuring some possibility of a prospective success.

In other words, a forward looking orientation works as a guarantor of rationality. Nickles brings out successfully in this way the complex-texture of scientific reasoning in and through the concepts of problem and constraint. Nickles(1980) goes a long way in doing so by pointing out the inseparability of a problem from constraints on its solution. This point is reinforced by Burian who relates constraints and therefore, the problem, to the background knowledge. This means that the structure of a problem undergoes a transformation if a change is brought in the background knowledge. In this context Burian (1980). says, *"it is the definiteness of problem structure and of the shifts in that structilre when the background knowledge changes which account for many of the notorious cases of simultaneous discovery".*

CONCLUSION

The above discussion brings to surface the precise ways by which Nickles, Gutting and Burian have enriched the concept of discovery by invoking the concepts of problem, constraints, regulative principles and background knowledge. By this they greatly effected a categorial re-orientation to the discourse about discovery by means of categorial innovation best expressed in highlighting the concepts of problem and constraint as the foci of methodological interest. Hence scientific discovery will have some bearing on an adequate construal of not only science education in the formal sense of the term but also in the informal sense i.e., in the task of making science part of our public ethos, in shaping the role of science in increasing the mental horizons of the layman who stands outside the pale of formal science education.

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