The Discussion between Heisenberg and Dirac Regarding the Nature and Meaning of Scientific Knowledge

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Abstract

In this paper we aim to put under discussion two issues. The first refers to the way in which physicists’ ideas on the nature and meaning of scientific knowledge may add up to a philosophical discourse. The second issue we argue about refers to the face-to-face discussion between two renowned physicists, Dirac and Heisenberg, in the attempt to highlight the benefits of direct dialogue as opposed to an academic correspondence carried out in writing though the medium of books, articles or letters. For each of these separate issues we come to analyze, we used two relatively recent articles signed by Alisa Bokulich.

1. Introduction

In the history of thinking, especially the recent one, we find more forms of getting, presenting and debating ideas or theories about phenomena or subjects considered legitimate and useful for a better understanding of problems under debate. Within the more restrained space of the philosophy of science and scientific knowledge, there is a great variety in the ways ideas and theories are presented and discussed about. Therefore, scientifically inclined authors, but especially authors shaped by philosophical tradition, express their ideas about what they consider relevant subjects through articles or even books.
Expressing a point of view in the classical manner, although necessary, is not sufficient for a veritable dialogue in a certain field. This explains why, usually, the authors and their views were conveyed in dialogue, or conversation, by other authors, deemed secondary in importance, which undertake work as historians or sociologists of the philosophy of science. They play the role of the editor who gathers between the same covers exemplary or relevant contributions of some authors in the field. In the 20th century such volumes were edited over many years and across many editions especially because they bring together articles which have become true landmarks for those concerned with an introduction in the respective fields.

There is yet another way of presenting and debating ideas, and that is the direct dialogue between authors. This dialogue can be written, between authors who are separated in time and space, or it can be a face-to-face dialogue, in which the exchange of ideas is made lively and directly. In the first category, letters exchanged by representative authors like Einstein, Bohr, Heisenberg, Schrödinger, Dirac and others are famous in the field of philosophy of science, and in the second category, we can mention the dialogue between Heisenberg and Dirac, or the dialogue between Heisenberg and Kuhn.

In all these forms of public manifestation of ideas it can be argued whether, for each category at a time, the minimal conditions of dialogue had been met, so that we can say authors really related to one another and a genuine dialogue occurred. The reader, or the one passionate about the common issues of these authors is many times under the circumstance of becoming aware that, though authors communicate through books, articles, letters, interviews or discussions, oftentimes they do not speak about the same things. Consequently, the minimal conditions for these contributions to be considered dialogues are not rigorously and genuinely met. This shortcoming can be found in branded authors of 20th century physics but also in renowned authors of philosophy. If this be the case, it is no wonder we discover each author was speaking about different things and misunderstandings between them came not from opposing views on the same subject but from the fact they spoke about different subjects altogether; hence, eventually, misunderstandings were only apparent, even when authors contradicted one another in precise matters. To this we add the temptation of the general public to have access to discussions or disputes between authors considered exemplary due to this type of more or less personal conflicts. Similarly, for didactic reasons, these ways of receiving philosophical traditions by contrast, opposition or philosophic argumentation - like punctual criticism (reproaches) - were always preferred.

2. The benefits of direct dialogue in the philosophy of science

In this article we analyse a talk between Heisenberg and Dirac regarding a number of subjects in the philosophy of science and knowledge; we consider this talk relevant because it clarifies the positions of the two in relation to their own philosophical ideas and constructs. The usefulness of following the direct discussions between authors stems from the fact that it enables us to witness the way in which these authors use their opinions and theories beyond the manner in which they expose the same ideas into books and articles. In other words, there is a difference between how these authors present their ideas to the public and how they use them for themselves.

The talent and skills of authors in this respect are oftentimes not identical. Thus, there are authors that prefer a succinct, synthetic style, like Heisenberg, whereas others prefer more argumentative methods, based on clarifications and detailing. Works of the first will be less numerous and will often need specifications whereas works of the latter are extensive, being more suitable to comparisons and analyses. These styles can be found both in the works of consecrated authors and in the works of the founding scholars of quantum mechanics. From a meta-philosophical point of view, these preferences of expression contribute to the crystallization of styles, traditions or even trends in philosophy and their analysis in time can lead to a collection of such styles.

According to Heisenberg and Dirac, their discussion took place in 1929, during a rather long voyage by sea between San Francisco and Yokohama; its central topic was the way in which various theories of physics create or not a process of continuous knowledge of reality. Of course, this discussion on the nature and meaning of scientific knowledge touches some specific topics, such as: the methodology of science, change in science, the relationships between theories and the scientific progress.

The dialogue between Heisenberg and Dirac is not carried on specific themes in quantum mechanics - a subject under debate at the time and to which both have contributed heavily - but it is a talk in the area of philosophy of
science and knowledge. In this area, both philosophers have significant and differing contributions although they are considered “colleagues” of the Copenhagen school of thinking. References to this talk are to be found in the book Physics and Beyond: Encounters and Conversations, 1971, but also in references Heisenberg makes on other occasions, for example the three day talk in February 1963 that Heisenberg had with Thomas Kuhn, and which belongs to the Harvard University archives¹.

Heisenberg’s outlook on the topics listed above rely on his idea of closed theory; from this point of view he claims that the entire knowledge about physical reality is based on four closed theories and the last of these closed theories is quantum mechanics. According to the criteria of closed theories, these theories are correct at all times; therefore, by merely formulating the idea of closed theory, as an epistemological instrument of describing world’s reality, in agreement with the “four stroke” evolution of knowledge, Heisenberg’s vision is a holism: within any closed theory, each concept or particular theory contributes to the whole and any modification affects the whole. Thus, change in science can occur gradually and it rather takes place as a break.

In essence, Dirac’s point of view may be conveyed as such: at any moment, no matter how well a theory is confirmed, it can be subject to future revisions. Revisions may be made through extension, modifications or even amends and, in the long term, nothing can be held as immune to revisions.

Regarding change in science, Dirac’s position is progressive and gradualist. A new theory represents a better, more encompassing reformulation of old theories and eventually of the entire former knowledge. Significant in this respect is the way in which Dirac understands the relation between classical and quantum mechanics. For the historical relation between the two types of mechanics, he uses the term of analogy by which he claims that, in agreement with his gradualist view, the new mechanics represents an extension of the old mechanics and perhaps, to the limit, we may in the future even talk about a reduction of the classical mechanics to the quantum mechanics. In a famous article, Dirac says:

*There are two forms in which quantum mechanics may be expressed based on Heisenberg’s matrices and Schrödinger’s wave functions respectively. The second of these is not connected very directly with classical mechanics. The first is in close analogy with classical mechanics, as it may be obtained from classical mechanics simply by making the variables of classical mechanics into non-commuting quantities satisfying the correct commutation relations.*²

From the point of view of scientific methodology, or of describing the context of scientific discoveries, Dirac, as opposed to Heisenberg, adopts a conservative position, considering that the new theories must be developed in agreement with the old ones by extensions or analogies, and that success is always measured by the degree in which a new field of facts or theories may be integrated in the larger context from which it was extracted, or in the tradition which it may be ascribed to. It is clear that, for Dirac, relationships between the theories considered adequate in relation with a field of facts are closely related between them, forming a network of inter-theoretic connections. Within this network there are no radical breaks but, at most, more or less close connections between general theories of reality.

We notice that this vision may serve as an argument in favour of a strong realism that claims the entire process of knowledge across history is an increasingly accurate description, and we hold the truth about world. On this idea of unity of knowledge we can also advance in Heisenberg’s terms: we can obtain an image of reality not based on a single unifying theory, identical to the entire history of knowledge, but similar to a categorial grid as in ancient ontology, i.e. by relating to the four closed theories. Thus, with Heisenberg, we do not face the arguments against realism but, at the same time, we do not lose the ideal of the unity of knowledge either. For Dirac, the road to knowledge is continuous, whereas for Heisenberg it is discontinuous, but both the road and the destination are the same.

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¹ The merit of bringing these media resources to public attention belongs to Mrs. A. Bokulich.
² P. A. M. Dirac, *On the Analogy between Classical an Quantum Mechanics*, p. 195.
3. Recent contributions

In a relatively recent article, this discussion between Heisenberg and Dirac is considered useful for understanding the way quantum mechanics relates to classic mechanics. The structure of the argument in this article presents opposing points of view of Heisenberg and Dirac on three specific topics: methodology of science, change of theories in science and inter-theoretical relations. The way in which Mrs. Bokulich uses this discussion has both advantages and disadvantages. The most important positive aspect is that, in what concerns Heisenberg, his entire conception about the nature, form and evolution of knowledge relies on the idea of closed theory. Although this intuition is correct, at the level of a rigorous interpretation Heisenberg’s work poses a difficult problem; according to the German scholar’s thinking, the idea of closed theory represents the foundation of his entire philosophy. A shortcoming of the way in which Mrs. Bokulich poses the question in this article is that it creates the impression Dirac is mirroring the closed theory in a sort of open theory.

We believe comparing the idea of closed theory with a vision on the nature of knowledge and the evolution of physics has to be done cautiously, because the idea of closed theory is a meta-theoretic construct, an epistemological instrument stemming from the complementary way of considering our relation to the world; the only acceptable comparison, in agreement with the author’s intention, that the idea of closed theory admits, is that of Kuhn’s paradigm. The comparison between the idea of closed theory, which is well articulated, and Dirac’s opinions on the structure of knowledge is however a little bit forced. The objection is principled and can be overthrown if the investigation is historical and comparative, with the role to offer a better understanding of the authors’ conceptions of knowledge. On the other hand, as the title of the article implies, Dirac does not speak of an open theory concept.

Mrs. Bokulich underlines unequivocally the holistic character of closed theories:

*The holistic and interconnected nature of a closed theory means, for Heisenberg, that the solution to a scientific problem can never be achieved by modifying just one element of the theory.*

From this holism A. Bokulich shows that a gradualist model of evolution of knowledge based on the change in scientific theory is unacceptable in that it treats the problem of the unity of physics like a problem of exact science. It is precisely the concept of closed theory that allows us to legitimately approach a model in which the laws of physics form a consistent system of descriptions of nature. There are also some unfortunate expressions of Heisenberg’s holism:

*In other words, new phenomena require the formation of a new closed theory.*

Holism and disunity of knowledge do not mean that there is a need to create a new closed theory each time a new phenomenon is registered, but only when a significantly large number of facts and phenomena can no longer be explained by reference to the theoretical framework unanimously accepted before, and the attempt to integrate these phenomena in the theories confirmed until then has failed. It is only then we can speak about a new closed theory.

To Dirac, the evolution of science or the progress in physics is similar to progress in technology, precisely engineering, which explains his gradualist vision regarding the evolution of science.

As a prolific participant to the fundaments of mathematics, Dirac supports the idea that quantum mechanics is an open theory, i.e. still under debate, and the way in which he understands this development will set him apart from both Bohr and Heisenberg within the Copenhagen school of thinking. At the same time, Dirac shall put considerable effort into showing the continuity between classic mechanics and quantum mechanics.

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3 A. Bokulich, Open or Closed?, Dirac, Heisenberg and the Relation between Classical and Quantum Mechanics.
4 Bokulich herself mentions that the name of open theory does not belong to Dirac and that it has illustrative purposes, to enable comparison. Under this aspect comparison is easy to make.
5 Bokulich, Open or Closed?, Dirac, Heisenberg and the Relation between Classical and Quantum Mechanics, p. 8.
6 Ibidem, p. 9.
7 Ibidem, p. 14.
4. Conclusions

Although Heisenberg’s visions and Dirac’s are different and at times even opposing, what reunites them is the outstanding interest in researching the way in which the two types of mechanics influence the way of understanding and describing physical reality. Frequently the relation between classic mechanics and quantum mechanics varies from the radical position that claims quantum mechanics has replaced classic mechanics to the more moderate position – also called reductionist – claiming that quantum mechanics may be integrated, through limit procedures, into classic mechanics. Conversely, if for Heisenberg, classic mechanics is a closed theory always valid within the limits of its language and area of reality, to Dirac classic mechanics continues to occupy, at least until the 50’s, a dominant role in the accurate description of physical reality; the future can only bring modifications in the form and not the substance of quantum mechanics.

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