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EDITORIAL

Empirical Philosophy of Science

Where Philosophy of Science and Science Education Can Meet

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In a previous editorial, I argued about the importance of clarifying the meanings of concepts in science education. Scientific concepts have important representational and heuristic roles in the acquisition and justification of scientific knowledge because they both represent natural entities, properties, and processes and also make their investigation possible (Arabatzis, 2019). This is why the study of concepts has a central place in philosophy of science. However, there is an ongoing debate about how concepts should be studied, which reflects some of the most important issues in philosophy, such as the limits of empirical inquiry and the status of conceptual analysis. For many philosophers, conceptual analysis is a matter of a priori reflection only. For others, philosophy of science should be continuous with science (Margolis & Laurence, 2014).

Empirical philosophy of science looks into the actual conceptualizations and practices of scientists, both now and in the past, in contrast to a theoretical rational reconstruction of what scientists do or ought to do. This empirical approach comprises several different strategies such as the analysis of writings from history of science or of published articles in professional journals, as well as the application of methods from cognitive science in order to analyze the cognitive processes, conceptualizations, and practices of scientists. The research conducted so far has focused mostly on the cognitive processes of scientists or taken an anthropological/sociological perspective of scientific research (Osbeck & Nersessian, 2015). However, little attention has been given to the meanings that scientists attribute to concepts.

Philosophers of science can have several interests when analyzing scientific concepts, such as assessing concepts, improving or modifying concepts, understanding concepts, or describing how scientists think of particular concepts and why. However, to achieve this, it is not enough to look at a sample of historically important writings or textbooks, because the concepts found therein may differ substantially from those that scientists actually use. Rather, it is necessary to empirically examine how and why scientists themselves construe and use particular concepts. This can be achieved by conducting empirical research during which scientists define and apply concepts (Machery, 2016).

Karola Stotz and colleagues (2004), investigated whether scientists working in different fields defined the "gene" concept differently. Their initial assumption was that evolutionary biologists would conceptualize genes in terms of phenotypic effects, whereas molecular biologists would refer to features and processes at the molecular level. However, when

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evolutionary biologists were asked explicitly to choose among different conceptualizations of "gene," they preferred a molecular conceptualization over the phenotype-focused one. And yet, when the evolutionary biologists were asked to apply their conceptualizations in particular tasks, they showed a preference for phenotype-based conceptualizations. This difference in evolutionary biologists' explicit conceptualization and actual use of "gene" concepts shows that philosophical assumptions about the meanings of concepts may differ significantly from the meanings that scientists actually attribute to them.

The analysis of concepts by any single philosopher has limitations because it depends on his/her own linguistic competence and conceptual understanding, and cannot reveal the variation in the meanings attributed to a concept within or across different scientific communities due to different training, experiences, or research interests. Therefore, in order to study such differences, it is necessary to sample different groups of scientists and explore their thinking. But not all philosophers agree with this view. According to Ken Waters, an analysis of "gene" concept(s) should help clarify the explanatory power and limitations of explanations based on the "gene" concept, and account for the investigative utility and biases of the respective disciplines. To achieve these aims, it is necessary to conduct a diligent philosophical analysis rather than rely on poll-based studies. Even if it was shown that biology researchers do not actually use the "gene" concepts in ways that correspond to the philosophical analysis, this does not affect the validity and importance of the latter (Waters, 2004).

I would argue that both views have value, and that empirical research contextualized by philosophical analyses of concepts is what we need. This is what I call "empirical concept analysis," an analysis that focuses on the actual conceptualizations of scientists, and the related psychological processes of concept formation and change. This is a domain where philosophers of science and science educators can work together. On the one hand, philosophers of science are certainly experts when it comes to philosophical analyses, but not all of them are familiar with the psychology of learning. This is where science educators, especially philosophically minded ones, can enter the scene. Many science educators are very well familiar with research in conceptual development and conceptual understanding, and can thus conduct the research that would be necessary for empirical concept analysis. Cognitive scientists could be involved too, and a collaboration between them and philosophers would be ideal. But it seems to me that science educators can have a unique place as they usually are able to understand both the philosophical aspects and the psychology of learning.

Empirical concept analysis could thus become a domain where philosophy of science and science education meet.

Compliance with Ethical Standards

Conflict of Interest The author declares no conflict of interest.

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