Challenges and strategies to teach history and philosophy of science to graduate biologists

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Acknowledgements

I received no specific funding to write this manuscript.

Funding

I received no specific funding to write this manuscript.

Conflicts of interest/Competing interests

I have no conflict of interest to declare

Authors' contributions

DBP designed the research and wrote the manuscript.

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Abstract

Scientists have played an increasingly relevant role in our society. Biologists in special are being constantly required to provide advice to governments in subjects that go from how to deal with a pandemic to what are the consequences of deforestation. However, practicing science requires not only technical knowledge, but also understanding how scientific knowledge is produced, its limits, and consequences. In this piece, I briefly discuss the importance courses on History and Philosophy of Science (HPS) can play in biologist curriculum and dissect a syllabus I have been using to teach HPS to graduate biologists. The proposed course syllabus includes discussion on the scientific method, classic philosophers of science, causation, models, how scientific knowledge is acquired, criteria to delimit science from pseudoscience, and realism and anti-realism. Given that contemporary science is becoming complex, and increasingly harder to disentangle from our daily life, understanding the role scientist play in society is a necessary component of a doctoral student training.

Keywords: curriculum, philosophy of science for scientists, teaching methods, active learning.

Introduction

Scientists have played an increasingly conspicuous role in contemporary society, from advising governments during a pandemic to participating in striking discoveries that make the cover of popular magazines. This happens because science enjoys a reputation that citizens trust (Hendriks et al. 2016, Sharon and Baram-Tsabari 2020), given that it continues to provide solutions to human problems. At the same time, trust in science experiences its all-time low (McIntyre 2019; Oreskes 2019) and public funding has dropped in several developing countries (e.g., Andrade 2019, Escobar 2019, Tollefson 2019). This scenario requires that scientist be aware of the role science plays, its limitations, how scientific knowledge is produced, and how to distinguish science from pseudoscience. To cope with these challenges, training in history and philosophy of science is pivotal (Grüne-Yanoff 2014; Johansson 2016; Kampourakis and Uller 2020), since only by distancing from practicing science and looking at how philosophers have seen scientific practice in the past can help scientists to understand why they do what they do (Boniolo and Campaner 2019). The teaching of philosophy of science to non-philosophers has been often addressed in the literature, especially for medicine and nursery grad students (Boniolo and Campaner 2019). Conversely, the structure of courses on philosophy of science to biologists and ecologists has been less discussed (but see Kampourakis and Uller 2020), with less agreement on the content and teaching practices better suited for the training of this kind of professional.

Philosophy of science has been increasingly important to the training of biologists worldwide (e.g., Leite et al. 2010 for an example from Brazil). This is because as biology has been pushed to provide answers to pressing societal problems, such as global change and water shortage. Statistics has also been heavily used in many areas of biology, including alternative methods of inference, such as Bayesian and Maximum Likelihood. In order to fully understand statistical inference nowadays, it is key to comprehend the philosophical underpinnings of each method of inference (Mayo 1996), as well as how to make decisions in the presence of uncertainty (Brewer and Gross 2003). The practice of statistics also brings up other relevant epistemic aspects, such as causation and inductive reasoning (Bandyopadhyay and Forster 2011). As a consequence, it is impossible to use modern statistical tools without knowing their philosophical basis (Leite et al. 2010). Therefore, courses of History and Philosophy of Science has been taught more frequently to biology graduate students, since it can provide the proper scaffold that allows students to think critically about all these topics.

Until recently, professors struggled to find texts to use in class due to the paucity of the literature directed specially to scientists. This scenario has slowly changed and there are more books on HPS available that could be used in class. However, no single textbook covers all the topics of HPS that sufficiently addresses the needs of biologists (see Grüne-Yanoff 2014). The goal of this piece is to discuss the elaboration of a syllabus and teaching practices used in a course on HPS offered to graduate biologists without prior training in philosophy. I use a collection of texts drawn from not only books on philosophy of science, but also other companion subjects, such as books on scientific method, statistics, and scientific communication.

Motivation and local Context

The training of scientist often relies on learning to use a given methodology. The main reason to offer this course was that students who entered master's and PhD programs in our University lacked formal training in the History and Philosophy of Science (HPS). This gap in their curricula demonstrated to be a problem (see also Grüne-Yanoff 2014), because, despite having had courses on introductory statistics, experimental design, and scientific writing, students frequently were not able to relate those subjects and understand how they fit together (Laplane et al. 2019). A course on HPS could provide the very fabric that would make students understand how scientific knowledge is produced, how the scientific method works and how to work with theories. Also, one preoccupation was that we need to make students understand the implications of doing science in contemporary society (Valiela 2009), including the social and educational implications (Sharon and Baram-Tsabari 2020). Additionally, another goal of the course was to elicit a discussion on the values of science: is it always rational? Is it always unbiased? How scientific knowledge is validated? What role peer-review play? The course also included a discussion on how to apply the scientific method and use theory in a consistent manner to conduct their own research projects. As a last goal, because many of the PhD students were to become high school teachers and university professors, we wanted to educate students to distinguish science from pseudoscience in a post-truth world. Having a strong background in HPS can also help graduate students turned high school teachers to break the notion that scientific knowledge is definite and that most scientific field can "prove" something.

Proposal of a syllabus

The content of the syllabus, the reading assignments and sequence of classes can be seen in Table 1. Because students lacked previous contact with History and Philosophy of Science (HPS), we start that first class with a brief lecture that provides an overview on what philosophy is, the history of science, what is epistemology, how the discipline of Philosophy of Science was created and in which historical context.

After the lecture, we discuss two texts on why it is important for an aspiring scientist to study HPS (Table 1). This is the only class whose discussion is mediated by the professor. Usually, each class takes 3 hours. This class is key, because it sets the stage for the remaining of the course. The main message is that philosophy of science has its place in helping scientist think about the limits of science, to define new questions that could be addressed, and also questions that science will not be able to or does not want to answer (Rosenberg and McIntyre 2020). Then, the next class start by reading basic texts that try to give a definition of science (Table 1), mediated by a pair of students. Then, we go on by delving into the intricacies of the scientific method and a short history of empirism. The next classes are about how questions are made and how scientists try to answer them, we touch upon methods of inference, induction, deduction, and multiple hypothesis. We also cover content on how theories are created, how facts support them, what happens when a given theory is no longer able to explain a set of facts. We also have one class on models, how they are built and used in scientific practice. Then, we read the classic philosophers, such as Popper, Khun, and Lakatos. This is the time to discuss topics, such as theory ladenness of observation, Popper's demarcation principle, falsificacionism, and research programs. The last classes are about causation, scientific explanation, understanding, and realism vs anti-realism. Finally, in the last class we read three chapters of Sagan's *The demon-haunted world* on pseudoscience, its role and dangers in contemporary society.

I believe this syllabus fills the gap of confronting students with 1) historical development of science and how philosophy help us make sense of it; 2) how scientific theories are proposed, how scientist use them and how they are replaced over time by others; and 3) alternative views on scientific progress. The main learning objectives in each class is making students understand that science progress non-linearly and that the practice of science can be benefited by understanding its philosophical underpinnings. It also follows Kampourakisand Uller(2020) advice on not to present the history of philosophy of science in a chronological sequence, but in a more contextualized manner. My role as a mediator of the discussion is also to stimulate students to go beyond the text they have read, either by making questions that will be discussed afterwards or motive them to make connections between the theories and aspects discussion with their own research project. For example, how learning what

Lakatos called “research program” can help them organize the various theories involved in their own work?

Incorporating active learning practices to teach HPS in a post pandemic world

The teaching format of this course is entirely based on text discussion led by students. Classes take place twice a week, with an interval of two days between each class. In each class, pairs of students lead the discussion on the text assigned to that class (Table 1). The professor is responsible for only mediating the discussion, to avoid any detour from the defined goals. The interval between classes was designed to give each pair of students enough time to write a short essay about the set of texts assigned. We have been using the Wiki plug-in in Moodle to do that. This makes the effort more collaborative and allows other students to read the text in real time and eventually provide feedback. I believe this format that uses active teaching methods helps students to build two important skills: writing concise prose connecting the multiple texts and, at the same time, give their own opinion on the topic. This encourages students to take leadership roles during discussion (Freire 2000). Grading is based on the quality of both the Wiki text produced and the discussion led by students. One advantage of this format is that it could be easily adapted to online format, a benefit that is welcoming during a pandemic. Of course, for the course to work as proposed it is required that class size does not exceed 20 students.

Conclusion

Graduate biologist can have multiple benefits from having contact with a course on philosophy of science early in their training. However, including and choosing the right format for such a course can be challenging. By allowing students to take leading roles in class we can change the perspective in teaching-learning environments. The use of technology in a constructive way also brings additional help to cope with challenges of online teaching.

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Table 1. Proposed sequence of reading assignments for each of the 13 classes.

Class	Topic	Book/Paper	Chapter
Pre-class reading	Why Study HPS?	Rosenberg & McIntyre	1
		Leite et al. 2010	-
1	What is Science?	Okasha	1
		Chalmers	1
2	The development of the scientific method	Godfrey-Smith	2
		Losee	9
3	How to make good scientific question and why they are important for research	Ford	3
		Gonçalves-Souza et al. 2019	-
4	What is scientific evidence?	Valiela	1
		Chalmers	2, 3
5	The problem of induction, deduction and the hypothetico-deductive method	Godfrey-Smith	3
		Okasha	2
		Chalmers	4
6	The anatomy of a theory	Pickett et al.	4, 5
		Ford	5
7	Models in Natural Sciences	Levins (1966)	-
		Coelho et al. (2019)	-
8	Karl Popper and the demarcation problem	Godfrey-Smith	4
		Chalmers	6
9	Thomas Khun, normal science and scientific revolutions	Godfrey-Smith	5, 6
10	Lakatos and research programs	Godfrey-Smith	7
		Losee	14
11	Causality, explanation, and understanding	Godfrey-Smith	13
		Shipley	1
12	Scientific realism, anti-realism	Okasha	4
		Chalmers	15
13	Pseudoscience and its role in contemporary society	Sagan	12, 14, 17