



The Hows and whys of philosophy of science teaching: a comparative analysis

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Abstract

What makes teaching philosophy of science to non-philosophy students different from teaching it to philosophy students, and how should lecturers in philosophy adapt to an audience of practitioners of a field of study that they are reflecting on? In this paper we address this question by analyzing the differences between these student groups, and based on this analysis we make suggestions as to how philosophy of science can be taught to non-philosophy students in an effective and attractive way. Starting-point is the observation that not only the background knowledge and interests of these students but also the aims of the respective courses will differ. We present a comparative analysis of the demands and conditions for teaching philosophy of science to the different types of students, focusing on learning objectives and didactic approaches. Next, we apply our analysis to a concrete example, the role of values in science, and discuss how this may be taught to either philosophy students or non-philosophy students. Finally, we discuss an alternative format for teaching philosophy to non-philosophy students.

Keywords Teaching philosophy of science · Dilemma-Oriented Learning Model · Philosophy of science in practice · Science and values

1 Introduction

Richard Feynman supposedly said that philosophy of science is as useful to scientists as ornithology is to birds. We assume that readers of this topical issue disagree, and so do we. Fortunately, in the universities where we teach every undergraduate

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student has to take a compulsory course in philosophy of science (and other relevant philosophical topics, such as ethics), typically in their second year. In these courses students learn to reflect critically upon the nature and status of their own discipline. A key learning objective is “to develop a nuanced and well-argued view on the value of scientific knowledge, on the status of science in our society, and on your future responsibilities in professional practice”.¹ As philosophers with a background in science, we teach such courses to students in various undergraduate science programs, and we strongly believe that they are crucial for helping students to develop into reflective and responsible scientists and citizens. However, we also know from our own experience how difficult it can be to make such courses a success. Various factors play a role here. To begin with, these students have not chosen to study philosophy, and for many of them philosophy seems – at first sight – far removed from what they are really interested in. Moreover, it does not suffice to simply copy a philosophy of science course intended for undergraduate philosophy students, or a ‘light’ version of it, to achieve the learning objectives. Non-philosophy students need something different.

For example, Thomas Kuhn regularly features in introductory courses in philosophy of science, and rightly so: his concepts of ‘paradigm’ and ‘scientific revolutions’ have had a strong impact on our thinking about science, both in philosophy and beyond. So Kuhn’s ideas should be taught both to philosophy students and to non-philosophy students. But the how and why differs. Philosophy students encounter Kuhn after they have studied the advent of philosophy of science as a sub-discipline within philosophy, with logical positivism and Popper’s criticism of it. Kuhn enters the scene as the scholar who radically transformed the field with a historical turn. The famous first sentence of *The Structure of Scientific Revolutions* says it all: “History, if viewed as a repository for more than anecdote and chronology, could produce a decisive transformation in the image of science by which we are now possessed.” (Kuhn 1970, p. 1). For philosophy students, the associated meta-methodological questions will be relevant. Also, they will be interested in Kuhn’s position in the realism debate, and in how it relates to the philosophies of Kant and Wittgenstein. The notorious Chapter 10 (‘Revolutions as changes of worldview’) will be a highlight for them, while it is probably better to ignore this chapter in a course for non-philosophy students.

For non-philosophy students Kuhn’s work is also highly relevant, but in a different way. In our course for students in the biomedical sciences, for instance, one theme concerns the role of evidence in medical treatment and research. Naturally, evidence-based medicine (EBM) will be discussed, in particular the strengths of EBM, but also the objections to this way of conducting research (Timmermans & Berg 2003). It turns out that a lot of knowledge in medicine – for example, with regard to genetics and infectious disease outbreaks – is not obtained through EBM, but through observational research such as cohort studies. Of course, medical evidence also plays a role in this type of research. Thus, students learn that the search for evidence and the confirmation and falsification of medical hypotheses depends on what kinds of evidence and what types of research are appropriate for a particular

¹ From the learning objectives of our philosophy of science course for BSc students in geosciences.

medical topic. To explain that researchers in medicine deal with evidence in specific ways and from the perspective of a particular research tradition, the concept of ‘paradigm’ is helpful. Sometimes this concept is actually part of the vocabulary of a particular academic discipline. In the movement sciences, for example, the terms ‘motor paradigm’ and ‘action paradigm’ were introduced in the 1980s, to represent two radically different theoretical perspectives on human movement, which include specific images of the body. According to the motor paradigm movement is analyzed in terms of mechanisms inside the body and explained in relation to causes and effects of bodily movements. The body is seen as a closed unit isolated from its environment. In case of the action paradigm movement is considered as functional behavior and understood as an action in a meaningful context. According to this approach the human body is intrinsically related to the world in which it exists. (Meijer and Roth 1988; Tamboer 1988). The differences between the motor paradigm and the action paradigm can be explained listing and comparing the elements of Kuhn’s ‘disciplinary matrix’.

Another topic that may be part of an introductory course in philosophy of science is Robert Merton’s ‘ethos of science’, as described in his classic 1942 paper ‘The normative structure of science’. Philosophy students will be interested in the question of whether Merton’s analysis entails a particular philosophical conception of science. Moreover, they will want to discuss the status of Merton’s CUDOS norms: are these regulative ideals or accurate descriptions of how science actually functions? Criticism of Merton’s work by later sociologists of science will appeal to them because this concerns its empirical adequacy as a theory of science. For non-philosophy students the practical applications of Merton’s ethos of science will be relevant. An example is the issue of ‘sloppy science’, a recent topic of debate in the social sciences. Sloppy science can be related to phenomena such as verification bias, missing replications, incomplete or incorrect information about research procedures, statistical flaws, and in general to the failure of scientific criticism (Levelt et al. 2012). A discussion of these problems might start by analyzing how Merton’s norms can help to prevent instances of sloppy science in the student’s own field of study. A further question to be raised is whether Merton’s ethos can still be helpful today, almost eighty years after it was introduced, as science is now practiced in a quite different context, featuring a growing influence of economic and political values. Accordingly, students should also discuss contemporary codes of conduct to prevent sloppy science (cf. Radder 2010).

These examples support the idea – which is the starting-point for the present topical collection – that non-philosophy students and philosophy students need different (introductory) courses in philosophy of science. Surely there will also be substantial overlap, but essential differences remain. This is plausibly related to the differing background knowledge and interests of the students, but also to the differing aims (learning objectives) of the courses. In the present paper, we will explore and analyze these differences, on the basis of which we make suggestions for effective teaching of philosophy of science to non-philosophy students. The outline of the paper is as follows. In Section 2 we present a comparative analysis of the demands and conditions for teaching philosophy of science to the different types of students, focusing on learning objectives and didactic approaches. Section 3 contains a detailed case

study of the way in which a specific topic (namely, the role of values in science) may be taught to, on the one hand, an audience of philosophy students, and on the other hand, an audience of non-philosophy students. In Section 4 we discuss an alternative teaching format that can make philosophy courses for non-philosophy students more effective. Section 5 concludes.

2 Aims and approaches in teaching philosophy of science

What are the relevant differences between non-philosophy students and philosophy students when it comes to teaching philosophy of science? As noted already, their background knowledge will differ (unless the course is offered at the very start of the first year, which is not recommendable for non-philosophy students nor for philosophy students). Moreover, they have different interests, and accordingly their attitude towards the courses will differ (assuming that the courses are compulsory for both types of students). These differences have implications for both the content and the teaching format of the respective courses. In order to develop suitable courses for these different audiences, one should first determine learning objectives of the courses, which may be derived from the final qualifications of the respective educational programs. While this is often considered to be a formal exercise, it should be taken seriously, especially when developing philosophy courses for non-philosophy students. The reason is that the aims of such courses (and accordingly the learning objectives) differ fundamentally from the aims of a philosophy of science course for philosophy students.

Final qualifications of an educational program in one of the non-philosophical academic disciplines characteristically contain specific, ‘philosophical’, learning objectives such as, in the case of the life sciences: “students have acquired knowledge of and insight into social and ethical aspects of life science research aimed at human health and disease”. In contrast to such objectives, final qualifications of a program in philosophy may read as follows: “students have acquired (i) knowledge of and insight into the history of philosophy, theoretical and practical philosophy; (ii) philosophical skills so that they are able to analyze philosophical texts and articulate philosophical thoughts and insights orally and in writing”. Thus, for non-philosophy students, knowledge of and insight in the history of and contemporary debates in philosophy of science is not an *aim in itself* but a *tool for reflection* upon their own discipline and (future) professional practice. For philosophy students, by contrast, it is an aim in itself, as they are trained as academics who may become researchers in this subfield of philosophy. This translates into differing learning objectives regarding particular courses²:

For philosophy students:

1. Knowledge of and insight into the most important problems and debates in contemporary philosophy of science.

² The following examples of learning objectives are taken from courses taught in our universities.

2. Applying this knowledge and insight to timely issues with respect to the nature of science and its role in present-day society.
3. Developing a well-argued view with respect to philosophical questions regarding science.

For non-philosophy students:

1. Knowledge of and insight into the most important problems and debates in contemporary philosophy of science and the way these problems relate to your own discipline.
2. Applying this knowledge and insight in order to obtain a broader and more profound perspective on your own discipline.
3. Developing a well-argued view with respect to the value of the scientific knowledge offered in your studies, on the status of science in our society, and on your future responsibility as a citizen and academic professional

The most important difference in learning objectives appears to be that philosophy courses for non-philosophy students aim at improving skills to critically reflect upon their own discipline and their future responsibility as scientists and professionals. Philosophy students will of course also develop reflective skills, but these are of a more general kind and not directly focused on a particular discipline or subject area.

As a more general and substantive goal of courses in philosophy for non-philosophy students, one could state that these courses strive for an in-depth understanding of *the underlying framework* of a particular discipline on the basis of examples from actual (scientific) practice (Aalberts et al. 2012). Understanding this framework leads to deeper insight into one's own discipline. An underlying framework is a collection of assumptions, expectations, values and beliefs, methods, skills, disciplinary views and other orienting tendencies, that partly determines the way in which reality is observed and expressed in theoretical terms (Koster and Boschhuizen 2018, pp. 29–30). Motor and action paradigms in the movement sciences, for example, are based on two totally different underlying frameworks. Because of the emphasis on an in-depth understanding of one's own discipline by way of disclosing underlying frameworks, courses for non-philosophy students have a particular focus. Rather than acquiring abstract knowledge of, for instance, the theoretical distinction between realism and instrumentalism, the focus is on the implications of this distinction for disciplinary research. Students gain insight into questions such as: Which assumptions and interests guide scientific research in general and in, for instance, biology, educational studies, computer science, or English literature, in particular? Does conducting science have certain ethical consequences, and what is the social effect of the application of scientific knowledge? This type of education leaves room for some theoretical discussion, but philosophy of science courses for non-philosophy students will typically and mainly be based on contemporary, concrete, and applied examples.

This difference in learning objectives and general aims entails that philosophy of science should not be taught in the same ways to non-philosophy students and to philosophy students. As regards the content of the course, we submit that (at least) the following three distinctions should be taken into account:

1. Historical – Contemporary
2. Abstract – Concrete
3. Theoretical – Applied

First, in general the history of philosophy of science is relevant for non-philosophy students only insofar as it allows them to better understand current concepts and theories of science. Surely, it may be useful to teach ideas about scientific method by first introducing logical positivist ideas about verification and confirmation, and subsequently discuss Popper's criticism and principle of falsifiability. But learning about this historical development is not an aim in itself. Second, it is advisable to make abstract philosophical ideas concrete by relating them to the students' own discipline. Most non-philosophy students will not be interested in the problem of induction or in paradoxes of confirmation if it is not clear what the implications for real science are. Accordingly, making these issues concrete by using swans or ravens may be helpful for explanatory purposes, but the next step should be to connect them with cases from scientific practice (cf. Green et al. 2021). This immediately leads to the third distinction: for many non-philosophy students theoretical philosophy in itself is uninteresting and irrelevant. They will only appreciate the value of philosophy if it can be applied to concrete scientific examples. To be sure, this does not hold for all non-philosophy students: some of them will have or develop an interest in philosophy, and they may be guided towards philosophy electives, minors, or master's programs. Moreover, there will be variation across the various groups of non-philosophy students (for example, social science students might be more historically interested than physics students). However, since the function of a philosophy course within a non-philosophy curriculum is to improve students' skills to reflect on their discipline, emphasis on contemporary and applied philosophy, using concrete examples, appears more effective.

The above-mentioned differences concern the *content* of the course, but they also have implications for *teaching methods and teaching formats*. In philosophy of science courses for non-philosophy students the student's learning process should be attuned to a progression from pre-reflective, via quasi-reflective, to fully reflective thinking (King and Kitchener 1994, 2004). These concepts indicate an increasing understanding of the role of underlying frameworks. In *pre-reflective thinking*, scientific knowledge is regarded as certain: science provides correct answers to all questions. The certainty is obtained by relying on textbooks, lecture notes, the authority of the lecturer and, sometimes, student's own observations. Students are unaware of underlying frameworks. In *quasi-reflective thinking*, knowledge claims may be questioned. Evidence is understood as a core aspect of the process of gaining knowledge. There is room for different

perspectives on evidence and different underlying frameworks, although in quasi-reflective thinking students are not yet able to fully grasp the implications of this multiplicity. In *reflective thinking*, uncertainty about knowledge is accepted. It is recognized that contextual values, assumptions, and practices are important in the formation of knowledge. Students are aware that what counts as evidence depends on underlying frameworks on which experts may reasonably disagree. Therefore, the willingness to rethink conclusions and knowledge claims is growing. Empirical research by King and Kitchener (2002, pp. 44–49; 2004, p. 15) shows that students gradually attain a higher level of reflection during their studies, but that the established growth in many students is limited and that students rarely achieve the level of reflective thinking. Courses in philosophy can contribute to realizing these goals, as we will show in Section 4.

To be successful, this type of education needs to be dialogical, functional, exciting and challenging, and structured, as earlier empirical studies in educational science and neuropsychology have shown (see Aalberts et al. 2012, pp. 439–442; Koster et al. 2011, pp. 261–266). First, to achieve the goal of reflective thinking, *dialogue* is central (Mezirow 1997, 10). Students are encouraged to reflect on relevant issues together with their peers and teachers. This dialogue teaches them to take their own assumptions, beliefs and values seriously, and to raise them for discussion. Secondly, this type of education must be *functional*. Learning to critically reflect on underlying frameworks aims at gaining deeper insight into one's own field of science. By taking distance and thus detaching themselves, students may discover assumptions, presuppositions and hidden values of particular pieces of disciplinary knowledge. This enables them to critically discuss underlying frameworks, and to develop alternative and more promising frameworks if needed. Thirdly, philosophy of science teaching to non-philosophy students should be a thought-provoking process: lectures, assignments and discussions need to be *challenging and exciting*. Science students, for instance, are not necessarily interested in philosophy. For these students a compulsory course in philosophy of science may be hard to digest, unless the lecturer is able to construct a highly relevant and interesting course. This may be done by starting from problems, related to their own field of study, about which reasonable people may reasonably disagree (King and Kitchener 2004). Ideally, these problems are related to societal and/or personal issues, and cause feelings of discomfort because they are in conflict with common sense and introduce the possibility of alternative views and perspectives (Dewey 1933). Such problems stimulate students to critically discuss received views, to construct arguments, and to clarify underlying values and assumptions. Finally, this type of education must be *structured*. Students are neither acquainted with philosophical questions, nor used to reflect upon underlying frameworks. Because they are not familiar with these types of questions and because they often experience philosophy as highly abstract – or, in their own perception, as strange and vague – philosophical education for non-philosophy students should be structured along clear lines and students should be guided in their reasoning processes and argumentation.

3 An example: Teaching on science and values

We will now illustrate the general considerations in the previous section with a concrete example: introducing the philosophical debate about science and values to students in different programs. The role of values in science is currently a hot topic in philosophy of science and deserves a place in any introductory course in philosophy of science. For non-philosophy students it is highly relevant: whether they will become practicing scientists or will be concerned with science in some other professional context, the relation between science and values will directly affect their activities – it is therefore important that they develop a nuanced and well-argued view about it. Most students (as well as many scientists and laypeople) still adhere, consciously or unconsciously, to the thesis that science is – or should be – a value-free enterprise, believing this to be an obvious and unproblematic ideal (Corrigan, Dillon and Gunstone 2007; Fisher and Moody 2002; King and Kitchener 2004). This position has ample consequences for scientific research and science policy: it implies that science can and should be autonomous, neutral, independent, and does not have normative implications. However, the thesis of the value-freedom of science is contested by many philosophers of science (see Elliott 2017, which is an introductory text that is highly suitable for teaching the topic to non-philosophy students). If they are right and science cannot be value free, this has to be taught to non-philosophy students as well. In any case, they should be aware of the problems with the value-free ideal and develop their own view on the issue. In the present section we will discuss how the debate on science and values can be taught to non-philosophy students. But first we will explain how it may be taught in a philosophy of science course for philosophy students, thereby introducing the main elements of the debate.

Placing the debate in a historical context, a natural starting-point is Max Weber's defense of the value-freedom of (social) science in his famous 1917 lecture *Wissenschaft als Beruf* (Weber 1946). In philosophy of science the value-free ideal remained largely unchallenged until Thomas Kuhn allowed for a role for values in his postscript to *The Structure of Scientific Revolutions* (1970) and in his seminal paper 'Objectivity, value judgment and theory choice' (1977). Kuhn argued that values such as accuracy, consistency, scope, simplicity and fruitfulness play a role in scientists' decisions regarding theory choice. He claimed that although scientists may differ in their prioritization and application of these values, together they form a "shared basis for theory choice" (1977, p. 357), and thereby guarantee the objectivity of science. Kuhn's 1977 paper started a long-standing debate about the status and function of these values, which Ernan McMullin (1983, p. 18) dubbed 'epistemic values' because "they are presumed to promote the truth-like character of science, [...] the most secure knowledge available to us". Helen Longino (1990, p. 77), another influential author in the debate, introduced the notion of constitutive value, which is related to but not completely identical with epistemic value. Longino contrasts constitutive with so-called contextual values, which may vary with the socio-cultural context in which scientists practice their trade. The subtle differences between Longino's

and McMullin's distinctions, and the very possibility of sharply drawing such distinctions, are – although important – relatively theoretical in nature. They will be food for debate among philosophy students, but will distract non-philosophy students from the main issue: Can the value-free ideal be maintained by allowing for epistemic (or constitutive) values, but excluding non-epistemic (or contextual) values from scientific practice?

Longino's answer is negative: she argues that contextual values will often – if not always – play a role in scientific practice. However, this does not necessarily threaten the objectivity of science, because any biases that come with the influence of contextual values may be filtered out in the social process of knowledge production in a scientific community. This requires that the community respects four criteria: recognized avenues for criticism, shared standards (the constitutive values), community response, and equality of intellectual authority (Longino 1990, pp. 76–81). Longino's analysis has given rise to further debates about the notion of objectivity, and its role in science. From a philosophical perspective objectivity is a notoriously abstract and ambiguous concept, and philosophy students will revel in discussing its intricacies and relations to fundamental issues in epistemology and metaphysics. Recently, Heather Douglas (2004) has analyzed objectivity as a heterogeneous concept, distinguishing between eight different senses of objectivity. Douglas has also contributed to the science and values debate by reviving the problem of inductive risk, showing that this implies that (non-epistemic, contextual) values unavoidably play a role in all scientific research that involves statistical hypothesis testing.

Teaching the topic of science and values by presenting it in such a theoretical and relatively abstract way, with a focus on conceptual issues and the historical development of the debate, will suit philosophy students well, but is clearly not the way in which non-philosophy students should be introduced to the issue. We will now outline how it may be presented to them, such that they acquire basic knowledge and insight about the philosophical debate and will be able to apply this in their own field, reflect on it, and develop a well-argued view on the issue, which will be useful in their future career as a scientist or academic professional.

As mentioned above, many non-philosophy students subscribe to the view that science should be value free. Most, if not all, of them will be unaware of philosophical debates about the interaction between science and values. To prevent them from unconsciously adopting a false conception of science that may have misleading and even dangerous consequences, it is important to make them aware of the ways in which values and interests are involved in scientific research (Koster and De Regt 2020). A structured way of introducing the issue is to start by distinguishing between the various stages of scientific practice, in which values may or may not be involved. In particular, one can identify three distinct stages of scientific practice: (i) the stage in which the choice of research topics and methods take place, (ii) the stage in which the research is carried out, and (iii) the stage in which research results are applied. It is quite easy to convince non-philosophy students that values and interests play a role in the first and third stage. But what about the second stage, the stage in which scientists actually conduct research and that might be called the 'heart' of science? Do values and interests also play a role in this stage? To discuss these questions in a

course for non-philosophy students, it is best to present examples of actual scientific research (see Koster and De Regt 2020).

A suitable example for students in biology is the case of the so-called *homo floresiensis* (Koster and Kupper 2020, pp. 22–24, 32–35). In 2003, hominid fossils of remarkably small size were discovered, leading to a major controversy in which two different groups of scientists defended opposite hypotheses. One group claimed that the data concerned a new hominid species, *homo floresiensis*. A second group, however, defended the hypothesis that the remains belonged to an ordinary *homo sapiens* that had been deformed by disease. The arguments of both groups were based on the same set of fossils and on sound results of scientific research, but their interpretations of the evidence were influenced by interests related to prestige, status and money (see Koster and Kupper 2020). In this case the acceptance of either hypothesis (a decision that belongs to the second stage) is underdetermined by the empirical evidence, which leaves room for such ‘external’ influences. By discussing examples such as this, in which values and interests influence scientific research, students become familiar with the idea that it makes sense to raise critical questions about the value-free view of science. In order to gain more depth, it is helpful to introduce the distinction between epistemic and non-epistemic values. By highlighting the role of non-epistemic values in relation to the case of *homo floresiensis*, students in biology will become aware of the importance of this subject for the practice of their own scientific discipline, and will be stimulated to discuss the (il)legitimacy of such value influences.

In a course in philosophy for students in the social sciences, teaching on the relation between science and values will be different. Since their origin in the nineteenth century, the social sciences are obsessed with the philosophical problem of naturalism: Do the social sciences differ from the natural sciences, and if so how? Next to naturalism, questions of normativity are prominent in the social sciences. Students in the social sciences are trained to ask questions about, for instance, the way social rules, cultural norms, and political values are part of their research. Therefore, the value-free view of science, so common among non-philosophy students, is far less self-evident for students in social science.

Because many research projects in the social sciences have a political dimension, a particular question related to the value-free view of science is of great importance: To what extent is social science influenced by a political perspective? To answer this question, and thus to gain more insight into the practices of the social sciences, students should reflect on the distinction between epistemic and non-epistemic values and discuss the ways in which these values may play a legitimate or illegitimate *role* in (social) science. Here one may invoke Mark Risjord’s interpretation of Longino’s distinction between constitutive and contextual values. Constitutive values are conducive to the aims of science and are necessary for conducting scientific research, while contextual values belong to the social and cultural environment of scientific practices and shape these practices in a ‘random’ way (Risjord 2014, pp. 18–19).

Employing the distinction between these two roles, Risjord (2014, p. 19) formulates the Moderate Thesis of Value Freedom: “Science is objective when only epistemic values are constitutive of scientific practice; [non-epistemic values such as] moral and political considerations must always remain contextual.” The Moderate

Thesis of Value Freedom thus recognizes that non-epistemic values can play a role in science, but states that this role should never be constitutive. By examining whether this requirement of scientific objectivity has been met in actual cases of social-scientific research, students acquire a profound insight into their own discipline. However, the Moderate Thesis of Value Freedom can be contested. A case in point is the United States Census: the constitutional mandate to count the population every ten years. The census determines not only the allocation of federal funding for enterprises such as education and law enforcements, but also the number of seats each state will occupy in the House of Representatives. The outcome of the census is thus highly politically relevant. Conducting a census and thus counting people is not a straightforward process. One issue concerns *how* people should be counted. Traditionally two methods have been applied for counting: (i) by going door-to-door, and (ii) by mailing questionnaires to each household. Each method has predictable advantages and disadvantages. Going door-to-door, for example, results in a relatively high response, but is much more expensive than the use of questionnaires. Whichever method is used no census is perfectly accurate. It can even be predicted in which way a method causes a census to either undercount or overcount the population. Choice of a method is thus not free from politics, and since one *must* choose a method, political values play a constitutive role in determining the census. So in this case the Moderate Thesis of Value Freedom does not apply: non-epistemic values penetrate the heart of the practice of the social sciences (Risjord 2014, pp. 15–20).

These and other examples of contemporary issues in social-scientific research stimulate students to reflect on the nature of their discipline. Questions about objectivity and reflexivity can also be raised. However, for students in the social sciences these questions will not be about fundamental issues in epistemology and metaphysics, but will rather discuss possibilities of professional and institutional control to prevent bias and unreliable outcomes as much as possible.

4 The dilemma-oriented learning model

In the previous sections we have discussed approaches for teaching philosophy of science to non-philosophy students in an effective and attractive way, given that the main learning objectives are (1) the development of skills to critically reflect upon the nature and status of science in general and (2) an in-depth understanding of the underlying framework of a specific discipline in particular. How can our findings be translated into concrete teaching practices? In this section we answer this question by presenting a specific teaching format, the Dilemma-Oriented Learning Model.

The Dilemma-Oriented Learning Model (DOLM) is a teaching format that is geared towards improving reflective skills of students (Aalberts et al. 2012; Koster and De Regt 2020). The model has been developed especially for non-philosophy students, to enlarge their capacity for reflective judgment. DOLM starts with a dilemma involving ‘high potential issues’ or ‘ill-structured problems’: problems that “cannot be described with a high degree of completeness or solved with a high degree of certainty” (King and Kitchener 1994, pp. 10–11). These dilemmas refer

to complex issues and problems, which have the potential to make students aware of underlying frameworks. Accordingly, they are well-suited for teaching philosophy to non-philosophy students. An example of a dilemma for students in movement sciences is: What kind of exercises are most suitable for young football players? (Borge and McNamee 2017). Students may be confronted with two types of exercises: a technique-oriented approach and a game-oriented approach, linked to the motor paradigm and the action paradigm respectively. In the first approach, attention is first given to physical condition and technique by doing ‘isolated exercises’ such as headers and Cooper tests, and only then to tactics and insight into the game. A game-oriented approach focuses on exercises within the game and thus within a ‘meaningful context’. By analyzing these different approaches, students become aware of the underlying conceptions of movement associated with the two paradigms. In DOLM attention is paid to the way in which misconceptions related to initial underlying frameworks can gradually be replaced by conceptions that are part of more productive underlying frameworks (cf. Reydon 2021). An example of a dilemma, relevant for law students, is: Can a political party be legally forced to treat women and men equally? (Veraart 2011). Analysis of this dilemma can create awareness of at least two different, underlying political-philosophical views on multi-cultural societies: respect for diversity versus the right to equal treatment. A third example, for students in the biomedical sciences, is: How to choose between conventional medicine and homeopathy? (Aalberts et al. 2012). This dilemma confronts students with diverging views on the nature of reality, claims about possible biases, characteristics of explanatory mechanisms and questions of what can be considered as sound evidence.

However, discovering elements of underlying frameworks is far from easy. DOLM helps students to reach this aim in a three-phase process: In the intuitive phase (A) students choose on the basis of their own experiences and views, and subsequently discuss their choices and arguments with fellow students. For instance, when asked to make a choice between conventional medicine and homeopathy, they may refer to their personal (positive or negative) experiences with homeopathic remedies or to what they have been taught by their professors. In the scientific phase (B) they take into account (typically divergent) scientific information, as well as their discussions with fellow students and their critical reflection on the scientific literature. Here students will, for example, critically evaluate claims of evidence-based conventional medicine and reconsider criticisms regarding so-called implausible principles of homeopathy and its lack of explanatory power. In this phase it turns out to be helpful to teach students how to understand and evaluate scientific reasoning (Vaesen and Houkes 2021). In the philosophical phase (C) students consider philosophical approaches, with a focus on elements of underlying frameworks, in particular specific argumentative patterns and scholarly perspectives. The dilemma regarding conventional medicine and homeopathy compels the students to think about the question “What is good science and what is bad science?” To reflect on this question, various philosophical accounts of science will have to be studied and applied to the case at hand. In the review phase (D) students look back on the whole process and reflect on their choices and reasoning. Each phase involves processes of clarification (how the problem and the dilemma is to be defined and how relevant

information is to be gathered), of weighing (the ordering and presentation of information and arguments), and of making or reconsidering choices (in the last case choices may be revised or further substantiated).³

DOLM meets the demands mentioned in Section 2: DOLM is *dialogical*, as students acquire insight by discussing the main topics and questions with their fellow students. Moreover, it is *functional*, by offering insight in the way elements of underlying frameworks influence one's own discipline, and *thought-provoking*, since students are challenged to rethink fundamental assumptions by reflecting on topical and exciting examples from scientific practice. Finally, it is *structured*: DOLM is characterized by a systematic learning process (see Koster and De Regt 2020).

5 Conclusion

What makes teaching philosophy of science to non-philosophy students different from teaching it to philosophy students, and how should lecturers in philosophy adapt to an audience of practitioners of a field of study that they are reflecting on? We have answered this question – posed in the call for papers for this topical collection – by means of a comparative analysis of the demands and conditions for teaching philosophy of science to the different types of students, focusing on learning objectives and didactic approaches. For philosophy students, knowledge of philosophy of science and its history is intrinsically valuable and an *aim in itself*. Hence, the subject matter can be presented in an abstract and theoretical way, with attention to the historical development of philosophical ideas. By contrast, courses for non-philosophy students aim at supplying *tools for reflection* upon their own discipline and future professional practice. Accordingly, it is advisable to teach philosophical ideas by applying them to concrete examples from (contemporary) scientific practice (cf. Green et al. 2021; Kleinhans 2021).

We have illustrated our analysis with a case study of how the topic of science and values may be taught to non-philosophy students. The philosophical debate about science and values supplies tools that can be applied to concrete and contemporary examples; for example, the discovery of *homo floresiensis* for students in biology, or the determination of the United States Census for students in social science. By discussing these examples, the student's thinking process will advance from a pre-reflective stage ('of course science is value-free'), via quasi-reflective thinking ('epistemic values are allowed to play a role in science, but sometimes even non-epistemic values influence scientific practices such as hypothesis-testing'), to fully reflective thinking ('even non-epistemic values can play a constitutive role in science, but this doesn't necessarily entail that science is not objective'). Thus, students develop their understanding of the role of underlying frameworks, thereby gaining in-depth insight in their own discipline.

³ See Aalberts et al. (2012); Koster and Boschhuizen (2018); Koster and De Regt (2020) for further details.

Finally, we have discussed the question to what extent the different learning objectives do require different teaching formats. While courses for philosophy students typically use traditional teaching formats such as lectures, tutorials and close-reading sessions, we have suggested that philosophy courses for non-philosophy students will benefit from alternative teaching formats. As an example we have outlined the Dilemma-Oriented Learning Model (DOLM), a teaching format that is explicitly designed to equip non-philosophy students with reflective skills.

In sum, we have argued that teaching philosophy of science to non-philosophy students requires a fundamentally different approach compared with teaching philosophy students. While this may not be a surprising conclusion by itself, it is not immediately clear how exactly the difference can and should be made. We have answered that question on the basis of a comparative analysis of the learning objectives of the respective courses and the background of the students. For non-philosophy students the aim of acquiring insight in underlying frameworks within their own discipline is crucial. A teaching approach based on contemporary, applied philosophy, and using concrete examples, will allow students to reach this aim and equip them with valuable reflective skills.

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Declarations

Conflicts of interest/competing interests none.

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