Second Philosophy and Testimonial Reliability: Philosophy of Science for STEM Students

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Abstract: In this paper, I describe some strategies for teaching an introductory philosophy of science course to Science, Technology, Engineering, and Mathematics (STEM) students, with reference to my own experience teaching a philosophy of science course in the Fall of 2020. The most important strategy that I advocate is what I call the "Second Philosophy" approach, according to which instructors ought to emphasize that the problems that concern philosophers of science are not manufactured and imposed by philosophers *from the outside*, but rather are ones that arise *internally*, during the practice of science itself. To justify this approach, I appeal to considerations from both educational research and the epistemology of testimony. In addition, I defend some distinctive learning goals that philosophy of science instructors ought to adopt when teaching STEM students, which include rectifying empirically well-documented shortcomings in students' conceptions of the "scientific method" and the "nature of science." Although my primary focus will be on teaching philosophy of science to STEM students, much of what I propose can be applied to non-philosophy majors generally. Ultimately, as I argue, a successful philosophy of science course for non-philosophy majors must be one that advances a student's *science education*. The strategies that I describe and defend here are aimed at precisely that end.

1.   Introduction

In the summer of 2020, I was awarded a grant by the Milwaukee School of Engineering to develop a philosophy of science course for Science, Technology, Engineering, and Mathematics (STEM) students. Having to think about how to teach a philosophy of science course to a group of STEM majors gave me ample opportunity to reflect upon one of the key questions that is the subject of this special issue, namely: "What makes teaching non-philosophy students different from teaching philosophy students?" In what follows, I will attempt to offer one perspective on this question, with reference to my own experience teaching a philosophy of science course in the Fall of 2020. I will elaborate on several strategies that I have developed, including a view that I call the "Second Philosophy" approach, which consists, roughly, in emphasizing the concrete ways in which philosophical problems arise during scientific practice. To justify this approach, I appeal to considerations from both educational research and the epistemology of testimony. Additionally, I defend some distinctive learning goals for instructors teaching STEM students, which include rectifying empirically well-documented shortcomings in students' conceptions of the "scientific

method" and the "nature of science." Although my focus will be on teaching philosophy of science to STEM students, much of what I propose can be applied to non-philosophy majors generally.

2.   First Impressions and Second Philosophy

A large body of research in pedagogy and educational psychology suggests that the first impressions that students form in the classroom matter considerably (Perlman & McCann 1999; Wilson & Wilson 2007; Herman et al. 2010; Clayson 2013; McGinely & Jones 2014; Gaffney & Whitaker 2015, etc.). In general, it has been shown that first impressions develop quickly and endure during the course of an academic term. It is for this reason that practical pedagogy guides often advise educators to pay close attention to their students' first impressions of the course (Nilson 2010: 45).

The matter of first impressions is particularly pressing for the philosophy of science instructor, especially since it common for STEM students coming to philosophy for the first time to be already somewhat suspicious of the very concept of "philosophy of science." This skeptical attitude may derive from many sources. First, STEM students might reason, quite understandably, that they have already advanced quite far in their science education not having heard much about philosophy of science, and so it is likely, they think, that philosophy of science is not relevant to them or their concerns. Second, it is not uncommon for science textbooks to display a mild hostility toward philosophy, often being cast as a discipline "dealing principally with the unmanageable 'big picture' questions" (Blachowicz 2009: 311). Third, students might have heard some disparaging remarks about philosophy from some high-profile "philosophy-jeerer"—to borrow a term coined by Rebecca Goldstein in her book *Plato at the Googleplex* (2014). For example, perhaps some students have heard the quotation often attributed to the physicist Richard Feynman that "philosophy of science is as useful to scientists as ornithology is to birds." Or perhaps they have heard Stephen Hawking and Leonard Mlodinow's declaration in their book *The Grand Design* that "philosophy is dead" (2010: 5). It is difficult to determine how much influence these philosophy-jeerers have had on the overall reputation of philosophy among STEM students. But in any case, it is helpful to keep these sorts of dismissive attitudes in mind, especially early on, when introducing course material.

The best way to tackle an antecedent suspicion toward philosophy of science is to bring students to the realization that, in many cases, the problems that energize philosophers of science are not ones that are imposed *from the outside*, but rather are ones that arise *internally*, during the practice of science itself. If we can show that philosophical problems arise naturally in the course of doing science and are not simply manufactured by philosophers, then I maintain that the persuasive power of the

philosophy-jeer's proclamations will be undercut. As is well-known within the philosophical community but less so without, the philosophy of the particular sciences has flourished in the last several decades. Nowadays, it is not uncommon for philosophers of biology (e.g., Sober 1984; Okasha 2006) or philosophers of physics (e.g., Albert 1992; Maudlin 2011) to produce work that engages directly with the science, and which is largely a response to methodological and theoretical problems internal to a particular scientific discipline. As the citation record demonstrates, this excellent work in the philosophy of the particular sciences is of interest to at least *some* scientists.[1] One downside of such work from a pedagogical standpoint, however, is that it is often highly technical and presupposes a lot of background in the relevant science which cannot be taken for granted in one's students; thus often the most one can do in an introductory philosophy of science course is to gesture at its existence.

Luckily, however, many of the standard, accessible topics in the general philosophy of science curriculum are also ones that arise naturally in the course of scientific practice. Consider, for instance, the demarcation problem. According to Popper, the problem of conceptually distinguishing between science and pseudo-science is the "key to most of the fundamental problems in the philosophy of science" (1962: 42). Naturally then, the demarcation problem is frequently one of the first topics covered in an introductory philosophy of science course.

There are at least three ways in which one might introduce and motivate the demarcation problem to students. The first way—what we might call the "First Philosophy" approach—consists of presenting the demarcation problem as an intrinsically interesting, unanswered philosophical question. One might begin with something like Anthony Kenny's conception of philosophy as "thinking as clearly as possible about the most fundamental concepts" (Edmonds & Warburton 2012: xvii), one which remains popular even among those who have abandoned the idea of providing individually necessary and jointly sufficient conditions for the application of our concepts (Huemer 2015: 72-4). Then one might proceed to make the case that "science" is one of our most fundamental concepts, and so we ought to engage in philosophical reflection upon the concept and attempt to provide a solution to the demarcation problem. The second way—what we might call the "Historical" approach—consists of introducing the demarcation problem by beginning with its historical context, some of which Popper describes in his *Conjectures and Refutations* (1962): namely, a dissatisfaction with the answer provided by the received view in early 20th century philosophy of science, i.e., logical

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[1] For example, the biologist Stephen J. Gould (2002) cites Sober (1984); the biologist E.O. Wilson (2000) cites Okasha (2006); the physicist Carlo Rovelli (1996) cites Albert (1992); and the computer scientist Judea Pearl (2009) cites Maudlin (2011).

empiricism. The last way—what I call the "Second Philosophy" approach—consists of showing that the demarcation problem is simply something that at least *some* scientists *must* engage with *qua* scientist or *qua* citizen. On the Second Philosophy approach, we might provide examples to illustrate how the demarcation problem arises during scientific practice, or within the nearby domain of science policy.

In calling this approach "Second Philosophy", I am borrowing a term from Penelope Maddy's book *Second Philosophy: A Naturalistic Method* (2007). Unlike the "First Philosopher", best exemplified by Descartes, whose concern is to construct a firm foundation for scientific knowledge and whose method is that of hyperbolic doubt, the Second Philosopher, is "born native to our contemporary scientific world-view" (Maddy 2007: 14); "she begins from common sense, she trusts her perceptions, subject to correction" (14), "operates within science" (15), and "so lacks [the] motivation for adopting the Method of Doubt" (18). Here, I do not mean to endorse Maddy's "particularly austere form of naturalism" (2007: 1). But the perspective that Maddy describes is one with which many STEM students will be sympathetic. While foundational questions about the nature and methods of science, e.g., the problem of induction, have their proper place in the curriculum, the hyper-skeptical first-philosophical standpoint of Descartes' meditator seems to me dialectically inappropriate in a philosophy of science course geared toward STEM students. Thus, by employing the term "Second Philosophy", I merely mean to evoke the idea that philosophy of science, insofar as it is possible, ought to *begin* within science, even if it is not *pursued* "relentlessly from the inside" (Maddy 2007: 32).

In accordance with the Second Philosophy approach, I introduce the demarcation problem with a pair of popular articles that raise the specific question, "Does string theory count as science?". The first is a passionate article in *Nature* written by the physicists George Ellis and Joe Silk entitled, "Scientific method: Defend the integrity of physics" (2014). In their article, Ellis and Silk criticize the proposals of the physicist-turned-philosopher Richard Dawid, who argues in his *String Theory and the Scientific Method* (2013) that the canons of scientific method should be widened to include "non-empirical" methods of theory assessment. Such a proposal, Ellis and Silk argue, would break with "centuries of philosophical tradition of defining scientific knowledge as empirical" (2014: 321). The second article is a short piece in *Scientific American* and begins as follows: "Is string theory science? Physicists and cosmologists have been debating the question for the past decade. Now the community is looking to philosophy for help" (Castelvecchi 2015). The rest of the article describes a meeting between physicists, philosophers, and historians of science that occurred on December 7–9, 2015 at the Ludwig Maximilian University of Munich in Germany, largely in response to Ellis and Silk's article.

In general, concrete questions, such as "Is string theory science?", rather than the abstract question, "What is science?", are a better entry-point to the philosophical debate over demarcation criteria. Often students are already familiar with the string theory controversy, given the prominent coverage of these disputes in the popular press. Consequently, beginning a unit on the demarcation problem with the string theory debates serves to make the philosophical dispute about the nature of science seem less arcane. After having observed the trenchant disagreement among eminent physicists over the scientific status of string theory, students are liable to better appreciate the urgency of the philosophical question. In keeping with the Second Philosophy approach, students are apt to perceive that the demarcation problem can arise quite naturally for the practicing scientist. Similar learning outcomes can be obtained by examining the demarcation problem in the context of legal disputes over whether "creationism" is a science or a religion (e.g., Laudan 1982; Ruse 1982). In this way, students can appreciate the immense practical relevance of the demarcation problem for scientists *qua* citizen.

The Second Philosophy approach and its concomitant strategies are not peculiar to teaching the demarcation problem, but rather can be readily deployed to introduce STEM students to other problems in the philosophy of science. For instance, consider the philosophical problem of simplicity. Philosophers of science have spent a lot of time analyzing what scientists might mean when they judge one theory to be "simpler" or more "parsimonious" than another, and how a preference for simpler theories might be epistemically justified (e.g., Sober 2015). Now, instead of beginning with such abstract questions as "What is simplicity?" or "Why does simplicity matter?", it is preferable to begin with a specific dispute among scientists over the legitimacy of some application of simplicity.

One example that does not require much technical background is the use of "Morgan's Canon"—which is often regarded as a kind of simplicity—in animal psychology. While it is standard among psychologists to invoke Morgan's Canon to argue against the hypothesis that non-human animals can represent the mental states of other animals—i.e. the hypothesis that they have a "theory of mind"—some psychologists and cognitive scientists reject this apparent application of simplicity as illegitimate (Fitzpatrick 2008). Accordingly, one might introduce the problem of simplicity by raising the concrete question, "Does the hypothesis that chimpanzees have a theory of mind lack simplicity?" Once again, showing that the philosophical problem arises in the course of *doing* science, and is not something manufactured by philosophers and imposed from the outside, will serve to better motivate the subsequent technical discussion about the nature and justification of simplicity.

Crucially, the Second Philosophy approach can be regarded as an "inductive method" of teaching (Prince & Felder 2006), whereby "instead of beginning with general principles and eventually

getting to applications, the instruction begins with specifics" (123). An argument in favor of the Second Philosophy approach is that inductive teaching methods, including case-based instruction, are "supported by the best research on learning currently available" (127). Inductive methods facilitate educational outcomes by: i) establishing connections with students' prior knowledge or experience (123), ii) motivating students to see the relevance and usefulness of new material (125), iii) fostering a "deep" rather than "surface" attitude to learning (126), iv) promoting critical thinking skills (128), and v) enhancing students' ability to appreciate multiple perspectives on a given problem (132).

To be sure, the Second Philosophy approach works best for questions in philosophy of science about which there already exists controversy among practicing scientists; typically, these will tend to consist of methodological or epistemological questions. However, even in the case of metaphysical questions, about which the practicing scientist typically has little interest, I contend that our efforts still ought to be guided by the Second Philosophy approach. Consider, for instance, questions concerning the metaphysics of laws of nature. I suspect that we will not find many first-order disputes between scientists that turn on whether the Humean view of laws or the non-Humean view of laws is true. [2] Still, from time to time, we *can* find scientists endorsing some metaphysical view about laws of nature. For example, in a *New York Times* article entitled "Laws of Nature, Source Unknown", the Nobel prize-winning physicist Steven Weinberg is quoted as claiming that he is "pretty Platonist" about laws of nature, and that he believes laws of nature are as real as "rocks in the field" (Overbye 2007). By contrast, the popular Caltech physicist Sean Carroll is quoted as claiming that "a law of physics is a pattern that nature obeys without exception" (Overbye 2007). Here, Carroll is naturally interpreted as endorsing the Humean view, whereas Weinberg is naturally interpreted as endorsing the non-Humean view. While neither Carroll nor Weinberg goes on to argue for either of these positions at length in the article[3], introducing STEM students to the metaphysical question of laws of nature by having them read this short article can help improve their initial impressions of the debate. Although the metaphysical debate about laws is somewhat remote from the practice of science and science policy, at the very least, we should demonstrate that it is something of which *at least* some scientists are cognizant, and in some cases take up one position rather than another.

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[2] Roughly, according to the Humean view, laws reduce to true empirical universal generalizations. According to the non-Humean view, laws are ontologically "over and above" the patterns we observe, conferring a kind of "physical necessity" on the states of affairs that the laws "govern."

[3] However, see the episode of Carroll's excellent podcast *Mindscape*, titled "Ned Hall on Possible Worlds and the Laws of Nature", in which Carroll discusses some of these issues in depth.

3.   Pedagogy and Testimonial Reliability

The foregoing considerations might lead one to object that the pedagogical approach that I advocate here is at best unduly deferential to the sciences and at worst a form of low-key scientism. One might insist that we as philosophy educators should strive to convey to students why the central questions in philosophy of science merit attention, regardless of whether scientists show appreciation or understanding of those problems. After all, philosophy of science is an autonomous discipline, with its own norms and history, and while our practice should be informed by relevant knowledge of the sciences, one might argue that our approach to introducing students to the core problems in philosophy of science ought to be more independent. On this view, we should not feel obligated to argue that an issue is worth caring about *because* scientists themselves care about it.

While I am sympathetic to this perspective, I maintain that there are good reasons to adopt the Second Philosophy approach, notwithstanding the above concerns. As philosophers working on the epistemology of testimony have consistently pointed out, many of our beliefs about the world are ultimately derived from the testimony of others in our social group (e.g. Fricker 2004). In an age where the amount of knowledge to be gained is now vast and increasingly specialized, it is much more difficult to take literally Kant's "motto of enlightenment": *Sapere aude!* – "Have courage to use your own reason!" (1784/2003: 54). For example, most of us are not climate scientists, and so if we are to have knowledge of the fact of anthropogenic climate change, we will ultimately have to derive that knowledge from the collective testimony of the climate science community. Moreover, even within knowledge-producing disciplines, expert practitioners will need to rely upon the testimony of their colleagues, e.g., trusting that the results of an experiment were reported honestly and accurately (Fricker 2002). But given that testifiers are sometimes unreliable or dishonest, we must—and in practice *tend to*—judge testimonies by the competence of the testifier (Harris 2012) and the extent to which the testifier is perceived to be well-disposed toward us (Sperber et al. 2010).[4]

Of course, in the philosophy classroom we strive to provide students with direct arguments for and against various claims. We don't merely *tell* students that there are good arguments against some claim; we *present* the arguments for their own consideration. Still, there will remain instances in which students must assess the instructor for testimonial reliability. And given that a kind of hostility to philosophy has been expressed by some well-known science popularizers, it is crucial for the instructor early on, when first introducing some problem in philosophy of science, to manifest the

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[4] I owe these last two references on the epistemology of testimony to Levy (2019).

appropriate markers of testimonial reliability. As I have suggested, starting a new unit with some specific controversy from *within* the practice of science itself or the adjacent arena of science policy is an effective way of ensuring testimonial uptake. In beginning with an extended discussion of some concrete question from scientific practice or science policy, one demonstrates one's familiarity with the first-order details of the science, thereby signaling to potentially suspicious students one's competence. Additionally, one can demonstrate benevolence to students by portraying oneself as being motivated to *benefit* the scientific enterprise, including STEM students, scientists, or science policymakers, by helping to solve these problems. Rather than styling ourselves as *outsiders* intervening on science, casting judgment on its epistemic credentials, we should invite our students to engage *alongside us* as members of an overlapping community of interested and well-intentioned inquirers.

The strategies that I have advanced in illustrating the Second Philosophy approach are thus attempts to take seriously these psychological and epistemological facts about testimony. We must, by necessity, assess the testifier by judging their competence and benevolence. But as Levy (2019: 70) points out in a different context, "to some degree we have no choice but to assess both competence and benevolence by our own lights", and so "it is unsurprising that we prefer testimony from people who resemble ourselves." Showing students that many of the core questions in philosophy of science arise quite naturally during the course of scientific inquiry—and are not ones imposed by philosophers from the outside—can help students feel comfortable that their instructor is in their "ingroup" and thus a legitimate source of testimonial knowledge. While perceived testimonial reliability on its own will not be sufficient to demonstrate the value of philosophy, or to achieve key learning outcomes, as I have argued, it remains a crucial contributing factor for the attainment of such goals.

4.   Distinctive Learning Outcomes for STEM Students

In the main, I have focused on the appropriate way to frame philosophical problems to STEM students in an introductory philosophy of science course. However, to some degree the goals that we ought to adopt when teaching philosophy of science to STEM students should be different than what we might hope to achieve with philosophy majors. In addition to the traditional goals of transmitting to students a body of knowledge, e.g., central questions, theories, and arguments, or helping students to become clearer, more precise, and nuanced thinkers, there are some distinctive learning outcomes that we should attempt to achieve in a philosophy of science course for STEM majors. These include: i) leaving students with an accurate, lasting impression of what constitutes a philosophical problem

and how such problems might be tackled, and ii) rectifying naïve conceptions of the nature of science and scientific method that students have inherited from prior education.

4.1   Identifying and Tackling Philosophical Problems

One of the challenges with teaching philosophy to non-majors is that often students have only the faintest idea of what philosophy as an academic discipline consists in. The causes of this gap in their knowledge are likely many and varied, and I will not try to speculate here about what they might be. But one of our goals in a philosophy of science course for STEM majors should be to leave students with an accurate conception of what philosophy is. It is, of course, relatively standard to begin many courses across different disciplines by saying something on the first day about what the course consists of. But one problem with this tactic in philosophy courses is that the question "What is philosophy?" is something over which academic philosophers disagree sharply. In recent years, there has been an upsurge in edited volumes dedicated to issues in meta-philosophy and philosophical methodology.[5] The existence of such widespread and trenchant disagreement over these meta-level questions distinguishes philosophy from most other disciplines, in which the nature of the subject matter is not so controversial. Consequently, saying very much about what philosophy is early on in a philosophy course is often ill-advised. Arguably, the best way for students to come to have an accurate understanding of philosophy is simply to *do* philosophy. This point holds whether that course be in applied ethics or in philosophy of science. On this point of view, a discussion about the nature of philosophy is best had, if at all, *not* at the beginning of the term but at the end.

I am sympathetic to the above concerns, and to be sure, I do not advocate subjecting non-major students to difficult debates about the nature of philosophy on their first day; instead, I propose something more practical that I believe benefits students greatly. Much earlier in my career, a student once asked me the simple yet savvy question, "Do you have any strategies for how best to *read* philosophy articles?" Upon registering her question, I realized that up until that time I had not given much guidance to my students about how to approach the course readings. In keeping with the organizing principle mentioned earlier that first impressions matter, I advocate that explicit and extensive discussion about how to *read* philosophical texts ought to play a role in the curriculum.

The justification for this proposal is that there are several ways in which philosophy articles differ from the readings to which non-philosophy majors are accustomed. For one thing, students are

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[5] For example: Haug (2013), Cappelan et al. (2016), D'Oro et al. (2017), and Blackford & Broderick (2017).

often puzzled by the fact that the author of a philosophy article might explore at length lines of argument that she ultimately intends to reject. STEM students, or others who are accustomed to the standard non-dialectical/expository style of most textbooks, are especially liable to find this feature of the text perplexing. It is easy for students to become lost in a morass of objections and responses, thereby losing track of the central point of an article, e.g., the main argument that the author intends to make. Relatedly, instructors sometimes assign an article explicitly for the purposes of "teaching against it." Once again, this is a practice that, over the years, students have expressed puzzlement about. Being enmeshed in the discipline, we may take these practices for granted; however, I have found that students often find it an odd request to *disagree with* the reading. For these reasons, I believe that explicitly apprising students of the nature of philosophy articles and emphasizing the various activities that they ought to be *doing* when they read—e.g., teasing out assumptions, raising objections, etc.—will prove beneficial. Importantly, one can have these practical discussions about strategies for reading philosophical texts without taking any particularly controversial meta-philosophical stances.[6]

Furthermore, an education goal that instructors tend to have is to get students to *think critically*, which in practice often consists precisely in such things as the ability to raise objections, uncover presuppositions, evaluate competing perspectives, etc. Fostering critical thinking abilities is not only a "fundamental educational ideal" (Siegal 1989: 28) but also a crucial element of science education (Bailin 2002). Indeed, the U.S. *National Science Education Standards* (1996: 23) explicitly lists science education goals such as the "identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations." Plausibly, these science education goals can be promoted by acquiring the reading skills essential to tackling philosophical texts, which provides further support for this proposal.

4.2   Rectifying Naïve Conceptions of the "Nature of Science"

Instruction in the "nature of science" (NOS), which is typically understood as referring to "the epistemology of science" (Abd-El-Khalick & Lederman 2000: 665), has been a "perennial goal of science education" (Lederman 2007: 831). In addition to the intrinsic importance of having a proper understanding of science, views about NOS can affect one's evaluation of ambiguous scientific evidence (Sadler et al. 2004; Liu et al. 2010). However, as empirical research on K-12 and undergraduate science education has consistently demonstrated, ensuring that students attain an

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[6] One paper that I recommend is "Reading Philosophy" by Hugh LaFollette, contained in LaFollette (2020).

adequate understanding of NOS has proved elusive. The sorts of inadequacies that have been documented across a wide variety of metrics include: i) a kind of naïve empiricism, ii) a failure to distinguish observation from inference, iii) the belief that scientific conclusions are "absolute truth" rather than tentative, iv) a failure to appreciate the social, creative, and imaginative elements of science, etc. (Lederman 1992). These sorts of inadequacies are also reflected in the introductory pages of science textbooks, as Blachowicz (2009) has demonstrated. Among the many specific defects that Blachowicz (2009) identifies in an examination of over 70 science textbooks are: a depiction of scientific reasoning as involving an "unsophisticated empiricism" (318), a neglect of important theoretical considerations such as *simplicity* (321), and an insufficient appreciation of the problems that the Duhem-Quine thesis poses for hypothesis-testing (327). Unfortunately, in a recent review of over 50 years of empirical research in science education, Lederman (2007: 869) concludes that the following generalizations remain justified: "K–12 students do not typically possess 'adequate' conceptions of NOS. K–12 teachers do not typically possess 'adequate' conceptions of NOS."

What should be somewhat heartening to the philosophy of science instructor, however, is that the empirical literature on science education also suggests that "[c]onceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply 'doing' science" (Lederman 2007: 869). Researchers and science educators often recommend philosophy of science courses or training as a potential solution to inadequate conceptions of NOS among students and teachers (Kimball 1967: 111; Carey & Stauss 1968: 363; Loving 1991; Matthews 1994), with some success having been observed in empirical studies on such interventions (Abd-El-Khalick 2005).

To be sure, many of the topics that feature on a standard philosophy of science syllabus, e.g., parsimony, the underdetermination problem, the problem of induction, etc. would already address some of the deficiencies in students' conceptions of NOS. Even so, it is important for philosophy instructors to be aware of the pervasive misconceptions about NOS that students might have acquired from science textbooks or past education, and for instructors to organize their teaching of these topics accordingly. In particular, instructors ought to explicitly work to correct the oversimplifications and distortions about NOS that philosophers of science and science educators have pointed out. Importantly, it is possible to tackle these problems with the spirit of camaraderie that characterizes the Second Philosophy approach. For instance, in my philosophy of science course, I begin with an excerpt about the scientific method from a science textbook. But rather than rejecting the textbook's account of the scientific method as hopelessly misguided, I invite my students to consider how this account might be qualified and improved. So too, rather than framing, say, a discussion of the Duhem-

Quine thesis as a dramatic shattering of their preconceptions about science, I instead cast our discussion in a constructive light, as one where I am trying to deepen their prior knowledge.

5.   Concluding Remarks

In this paper, I have explored some strategies for teaching an introductory philosophy of science course to STEM students. The most important strategy I have advocated is adopting what I have called the "Second Philosophy" approach, according to which we ought to show, insofar as it is possible, that the problems that concern philosophers of science are inspired by concrete questions that arise naturally *during* the practice of science itself. In addition, I have recommended that philosophy instructors: i) explicitly teach students how to read philosophical texts, which constitutes crucial critical thinking skills, and ii) to attempt to rectify the well-documented shortcomings in students' conceptions of the scientific method and the nature of science. Ultimately, a successful philosophy of science course for non-philosophy majors must be one that advances a student's *science education*. The strategies that I have described and defended here are aimed at precisely that end.

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