

Chapter 1

The Importance of Understanding the Nature of Scientific Knowledge

“Science without epistemology is—insofar as it is thinkable at all—primitive and muddled”

(Einstein 1949, p. 683)

Abstract This chapter explains and motivates the importance of understanding the nature of scientific knowledge. The chapter begins by briefly exploring some of the recent science education literature and some of the ways that the literature might benefit from stronger philosophical foundations. Roughly, it will be noted that since scientific knowledge is just a special instance of knowledge, understanding the nature of knowledge in general can provide key insights into the nature of scientific knowledge. These insights into knowledge in general and scientific knowledge in particular seem to hold promise for bolstering the effectiveness of the science education literature on the nature of science. It is because of this that it is important to understand the basics of key debates in epistemology. Also, it is noted that challenges to our general knowledge of the world around us are equally challenges to our scientific knowledge. After briefly explaining the relevance of understanding scientific knowledge this chapter provides an overview of the remaining chapters of the book.

It is clear that the knowledge gained from the sciences has an enormous impact on our lives every single day. No rational person will deny that scientific knowledge is integral to our daily lives and that in many ways it has made our lives better. Scientific knowledge and its applications allow us to cure and treat various diseases, communicate with people all over the world, heat and cool our homes, travel the world, enjoy various entertainments, and so on. Not surprisingly, science, and the knowledge it produces, is often highly valued.

As we do with many things we value, we encourage people to study the sciences to appreciate and benefit from the scientific knowledge already available as well as to help contribute to the production of new scientific knowledge. It is widely held that merely studying the content of the various sciences is not enough by itself to achieve these goals. One should also learn about the nature of science (NOS) itself. That is to say, one should not simply learn the contents of the current state of scientific knowledge, but also learn about the methods that produce such knowledge and the characteristics of scientific knowledge (Kampourakis 2016).

Emphasis on the importance of understanding NOS is not a new development—understanding NOS has been advocated as a major goal for the study of science since at least the beginning of the last century (Central Association of Science and Mathematics Teachers 1907). This is not simply a goal promoted by the educational systems of a small set of countries—understanding NOS “has been advocated as a critical educational outcome by various science education reform documents worldwide” (Lederman 2007, p. 831). Most nations regard the development of students’ understanding of NOS as a primary objective of science education (Eurydice Network 2011; Feng Deng et al. 2011; National Research Council 2012; NGSS Lead States 2013). In fact, the goal of understanding NOS is so widespread that several scholars around the world have argued for its primacy as an educational goal (Lederman 1999, 2007).

This widespread advocating of understanding NOS as a primary goal of science education prompts one question immediately: what exactly is NOS? The answer to this question is the focus of intense debate in the science education literature. According to Norman G. Lederman, and others, NOS can be best understood in terms of what Gürol Irzik and Robert Nola (2011) label the “consensus view”.¹ According to this consensus view, the way to best conceptualize NOS is in terms of a fairly small number of general characteristics such as: being based on empirical evidence, tentative, theory-laden, and so on.²

Others claim that this consensus view is mistaken. Some argue that the general features that the consensus view uses to characterize NOS are too broad.³ Others argue, relatedly, that science is simply too heterogeneous to fit the sort of model offered by the consensus view.⁴ So, although the consensus view is “the most widely adopted conceptualization of NOS”, it is not without its critics (Kampourakis 2016, p. 1).⁵

Not only does the consensus view have critics, it also has rivals. Chief among the rivals to the consensus view is the “Family Resemblance” approach to NOS. Advocates of the Family Resemblance approach maintain that “it is useful to understand NOS not as some list of necessary and sufficient conditions for a practice to be scientific, but rather as something that, following Wittgenstein’s terminology, identifies a ‘family resemblance’ of features that warrant different enterprises being

¹It is worth noting that Irzik and Nola make it clear that this view is largely the result of work by Lederman along with his various collaborators. See, for example, Abd-El-Khalick (2004), Bell (2004), Cobern and Loving (2001), Flick and Lederman (2004), Hanuscin et al. (2006), Khishfe and Lederman (2006), McComas et al. (1998), McComas and Olson (1998), Osborne et al. (2003), Schwartz and Lederman (2008), Smith and Scharmann (1999), and Ziedler et al. (2002).

²For particularly clear expressions of the consensus view see Lederman (1999), Swartz and Lederman (2008) and Irzik and Nola (2011).

³See Allchin (2011), Rudolph (2000), Irzik and Nola (2011).

⁴See Elby and Hammer (2001), Erduran and Dagher (2014), Irzik and Nola (2011, 2014), Matthews (2015), and van Dijk (2011, 2014).

⁵See Abd-El-Khalick (2012), McCain (2015), and Schwartz et al. (2012) for responses to some of these objections for the consensus view.

called scientific” (Matthews 2012, p. 4).⁶ The key idea of this approach is that we should “investigate the ways in which each of the sciences are similar or dissimilar, thereby building up from scratch polythetic sets of characteristics for each individual science” instead of trying to come up with necessary and sufficient conditions for NOS (Irzik and Nola 2011, p. 595).

Rather than attempting to adjudicate between the consensus view, the Family Resemblance approach, and other conceptions of NOS, the focus in this book will be to provide a philosophical foundation that can help illuminate this debate over the proper understanding of NOS. By exploring, and becoming clear on, core issues in epistemology and philosophy of science this book will provide tools that will help make this debate (and perhaps others in science education) more tractable.⁷

Getting clear about what “NOS” refers to is very important, and there is serious debate concerning how best to understand NOS. However, our discussion up to this point prompts another key question: why is NOS such an important feature of science education? One answer that springs to mind is simply that the better students understand NOS, the better equipped they will be to become good scientists. After all, it seems plausible that a deeper understanding of the activity you are engaged in will allow you to be better at that activity. The best chess players tend to be those who have a deep understanding of the game of chess. The best carpenters tend to be those who have a deep understanding of construction processes (measuring, leveling, framing, etc.). So, it is not unreasonable to think that the best scientists will tend to be those who have a deep understanding of NOS. More important than the benefit of simply being a better scientist is the benefit of increased scientific literacy. After all, most students will not become professional scientists, but they will all be citizens who may someday need to make decisions about socio-scientific issues. For this reason, of the several other potential benefits of an adequate understanding of NOS that have been identified it seems that 2, 3, and 4 below are the most important:

1. It is necessary for understanding the process of science and it helps with managing technological objects.
2. It is necessary for making informed decisions about socio-scientific issues (e.g. global warming, stem cell research, etc.)
3. It is necessary for fully appreciating the importance of science in contemporary culture.

⁶Also see Irzik and Nola (2011, 2014) and Erduran and Dagher (2014) for defense of this sort of view.

⁷For example, there is ongoing debate concerning what the proper goal of teaching various scientific theories, such as evolution, should be. Some, e.g., Goldman (1999), argue that belief is the primary goal of science education. Others, e.g., Smith and Siegel (2004), argue that belief, while important, should not be the goal of science education. Instead, they maintain that understanding should be the primary goal of science education with belief as a potentially desirable outcome. Getting clearer on such epistemological concepts as ‘belief’, ‘knowledge’, and ‘understanding’ can shed light on this debate over the primary goals of science education.

4. It helps facilitate an understanding of the norms of the scientific community—particularly, the moral commitments of this community and how they are valuable to society as a whole.
5. It aids in the learning of scientific subject matter—the principles and findings of particular sciences.⁸

Not only are these potential benefits intuitively plausible, empirical research has supported the link between increased understanding of NOS and the attainment of these benefits (Feng Deng et al. 2011).

Of course, given that an adequate understanding of NOS is necessary for obtaining a number of these benefits it follows that one simply cannot possess certain benefits if she has an inferior understanding of NOS. That is to say, without a proper understanding of NOS one cannot truly understand the process of science, make well-informed decisions about socio-scientific issues, or fully appreciate the importance science has in our contemporary culture. To give just one illustration of this, Kostas Kampourakis (2014) persuasively argues that one of the reasons why many people are resistant to accepting evolutionary theory (one of the best confirmed theories in the history of science) is that they fail to properly understand NOS. Specifically, Kampourakis argues that many people fail to distinguish scientific knowledge from other things that they *merely* believe, but do not really know, and this failure leads them to side against mountains of evidence by not accepting the truth of evolutionary theory. It is not difficult to imagine how this sort of tendency could lead to many uninformed socio-scientific decisions and other errors.

Now that some of the benefits of properly understanding NOS and the widespread emphasis on increased understanding of NOS as a premier educational goal have been made clear, yet another question clearly presents itself: how well do students and science educators understand NOS? Unfortunately, the answer to this question is “not well at all”. Sadly, “the longevity of this educational objective [increased understanding of NOS] has been surpassed only by the longevity of students’ inability to articulate the meaning of the phrase ‘nature of science’ and to delineate the associated characteristics of science” (Lederman and Niess 1997, pp. 1). Numerous studies have shown that students’ understandings of NOS are lacking in many areas (Lederman 2007). The findings of these studies are particularly telling because they employ a variety of apparatuses for measuring students’ understandings of NOS with the same results—students exhibit poor understanding. As Lederman (2007, pp. 838) points out, “the overwhelming conclusion that students did not possess adequate conceptions of the nature of science or scientific reasoning is considered particularly significant when one realizes that a wide variety of assessment instruments were used”.

⁸These five benefits are closely based on those put forward by Driver et al. (1996). See Lederman (2007) and Feng Deng et al. (2011) for further discussion.

Even more alarming than the fact that students lack a proper understanding of NOS is the fact that some studies, such as Miller (1963), suggest that many secondary science teachers do not understand NOS as well as students do! These results have been supported by more recent investigations to the point that it is at least safe to say, “science teachers do not possess adequate conceptions of NOS, irrespective of the instrument used to assess understandings” (Lederman 2007, pp. 852). The evidence supports that regardless of how we assess understanding of NOS, “student and teacher understandings are not at the desired levels” (Lederman 2007, pp. 861). This is a most unfortunate situation.

At this point a brief recap is in order. We have seen that there are numerous benefits both to individuals and to society as a whole when citizens possess a proper understanding of NOS. These benefits are so widely recognized that increased understanding of NOS has been almost unanimously held to be a critical educational goal for more than one hundred years. However, despite the recognized benefits of properly understanding NOS and the emphasis on this understanding as an educational objective, students and teachers both fail to possess adequate understanding of NOS. What is to be done?

Fortunately, a number of factors, which seem to aid in increasing understanding of NOS, have been identified. It seems sufficient background in the history and philosophy of science clearly influences teachers’ ability to teach science (King 1991). Teachers are not the only ones who benefit from a background in philosophy. There is evidence that students enrolled in a philosophy of science course develop a deeper understanding of NOS than students who are only enrolled in courses on scientific methods (Abd-El-Khalick 2005). Astoundingly, Mekritt Kimball (1967) has noted that undergraduate philosophy majors outscore both science teachers and professional scientists on measures designed to track understanding of NOS. This finding led Kimball to suggest that adding some philosophy courses to undergraduate science curricula may help improve understanding of NOS.⁹ Given the results of these studies it is not surprising that an explicitly reflective approach in instruction has been linked to greater success in teaching NOS (Schwartz et al. 2012). After all, philosophy is known for its employment of an explicitly reflective approach to understanding and assessing fundamental problems and theories in many domains. Of course, this is not to suggest that a grasp of the philosophical issues surrounding and interwoven with NOS will guarantee an adequate understanding of NOS. However, the evidence does suggest that some appreciation of philosophy, particularly as it is related to science, can help put one on the path to an adequate understanding of NOS. It is the purpose of this book to facilitate, at least to some degree, the initial steps on this path.

In order to help facilitate a deeper understanding of NOS, the goal of this book is to offer a comprehensive and accessible introduction to the epistemology of science—an introduction that does not presuppose familiarity with philosophy.

⁹Carey and Stauss (1968) also recommended the inclusion of philosophy of science courses in undergraduate science curricula as a means to enhancing understanding of NOS.

That is to say, I will attempt to provide an introduction to epistemology (theory of knowledge) in general as well as the particular nuances of philosophical work on scientific knowledge that will help initiate some increase in understanding of NOS on its own, and more importantly, help provide some of the tools necessary to facilitate even more in-depth investigation of NOS and the surrounding science education debate.

One might wonder, if a deeper understanding of NOS is the primary goal, why are we bothering with epistemology in general in this book? The reason is simple. Scientific knowledge is itself a kind of knowledge, so understanding the nature of knowledge in general can provide key insights into the nature of scientific knowledge. A firm grounding in the theory of knowledge can help provide a strong foundation for deeper appreciation of NOS. Additionally, other important debates in science education revolve around key concepts of general epistemology such as the nature of belief, knowledge, and understanding. The chapters in this book, while far from exhaustive treatments of the various topics, provide a solid introduction to philosophical topics that will be of particular use for science education. By exploring the basics of general epistemology as well as philosophy of science and particular challenges to our scientific knowledge, the various epistemological components of key science education debates will become clearer.

Now, it would be a mistake to think that this book, or any other single work for that matter, will provide easy solutions to debates in science education or a cure-all for the prevailing inadequacies in understanding of NOS. Rather than attempting the impossible, in this book I instead seek to aid in these endeavors by providing an accessible overview of the major components of knowledge in general and scientific knowledge in particular. In addition to explaining the nature of scientific knowledge (from the perspective of contemporary philosophy) I also explore some of the challenges that have been raised for the possibility of our having such knowledge at all. Although in many cases the relevant philosophical issues are explained and various moves in the debate are explored in a neutral manner, I do not always remain neutral. In particular, I do not simply mention challenges to our scientific knowledge in various chapters, I also argue for what I take to be the strongest rebuttals of such challenges. Additionally, I present a picture of knowledge throughout this book that, while being a picture that many scientists, science educators, and philosophers would accept, is not universally accepted. Unfortunately, universal acceptance is another lofty goal that is likely unreachable. So, instead of trying for this, I offer the reader a picture of the nature of scientific knowledge that is consistent with commonsense, is acceptable to scientists, and helps to provide a foundation for understanding NOS and gaining clarity in various science education debates. Even if the reader finds various components of this view of scientific knowledge unsatisfactory, examining the view as well as what can be said in its favor will be instructive both as a way to make clear key ideas in epistemology and philosophy of science and as a way of illuminating how alternative conceptions might be profitably explored.

The remainder of this book is divided into four parts. The seven chapters in the first part are focused on the “traditional account of knowledge”. In the following

chapter, I introduce the traditional account of knowledge. First, I distinguish between three main kinds of knowledge: acquaintance knowledge, knowledge-how, and propositional knowledge. The nature of each of these kinds of knowledge and their differences are illuminated. It will become clear that scientific knowledge is best understood as a particular variety of propositional knowledge. After clarifying the differences between these kinds of knowledge, I turn to a brief examination of the traditional account of propositional knowledge. This traditional account holds that in order for someone to have knowledge of a particular proposition three conditions must be satisfied: she must believe the proposition, the proposition must be true, and she must have justification for believing the proposition. My discussion of the traditional account of knowledge in this chapter sets the stage for the more in-depth examination of the general features of knowledge that is the focus for the remaining chapters in this part of the book.

Chapter 3 is the first of three in which I explore each of the components of the traditional account of knowledge in detail. In this chapter I investigate the nature of belief. I contrast the idea of *believing in* something with the idea of *believing that* something is true. The first notion of belief is really an expression used to signify trust or faith in something rather than the sort of belief that is a component of knowledge. Once the importance of *believing that* is made clear I briefly examine various accounts of the nature of belief. I explain why we do not need to decide which of these accounts is superior for the purpose of understanding our scientific knowledge. Further, I lay out some of the main distinctions concerning kinds of beliefs and touch on various philosophical issues that arise from the consideration of belief. Fortunately, we do not need to settle all (or even many) of these issues for our purposes. It is sufficient for the present focus to simply have a good grasp of the general nature of belief as well as of some of the various ways an account of belief might be developed. However, consideration of these distinctions and issues helps to deepen our understanding of the nature of belief, and so deepens our understanding of the nature of knowledge.

In Chap. 4 I focus on the nature of truth, the second component of the traditional account of knowledge. Although it is often taken to be obviously clear, the nature of truth is a very complex philosophical issue. I examine both traditional and contemporary theories of truth as well as realist and anti-realist conceptions of truth. Further, I briefly look at some of the major challenges for a successful theory of truth. Ultimately, I argue for a commonsensical, realist conception of truth. This conception of truth is supported by both philosophical argument as well as the recognition of its presupposition in scientific practice.

Next, I turn toward the final component of the traditional account of knowledge: justification. Traditionally, justification has been understood as having good reasons for believing that a particular claim is true. However, there are several important distinctions and debates about how best to understand justification as good reasons. In fact, one major contemporary debate in epistemology concerns whether we should keep with tradition and understand justification in terms of good reasons at all. Internalists say, “yes, one always needs good reasons in order to be justified in her beliefs”, but externalists disagree. I explain each of these views of justification

in some detail in this chapter. After explaining internalism and externalism about justification, I consider some of the major moves in the debate between these two positions. It becomes clear by chapter five's end that whether internalists or externalists are correct about justification in general, the sort of justification required for scientific knowledge does require good reasons, which I argue are best understood as evidence.

Since Chap. 5 concludes by noting that scientific knowledge requires evidence, it is quite natural that evidence is the focus of Chap. 6. In this chapter I explore two central issues of evidence. The first issue concerns the nature of evidence itself. There are two primary theories of the nature of evidence. The first claims that evidence consists of non-factive mental states and the second claims that evidence consists of propositions. I explain both of these theories and consider some of the major challenges to each theory. The second issue I explore in this chapter is that of what it takes for someone to have an item of information as evidence. Extreme views of evidence possession each have serious problems, however, moderate views face challenges too. After elucidating some of the challenges facing the various views, I argue that there are some promising ways of providing a moderate account of what it takes to have evidence.

In Chap. 7 I clarify the very important distinction between having justification for believing a proposition (propositional justification) and justifiedly believing a proposition (doxastic justification). Since justified belief is a necessary condition of knowledge, it is extremely important to understand what is required to move from merely having propositional justification to having doxastic justification. In this chapter I explore the relation that one's belief has to bear to her propositional justification in order to be doxastically justified—what epistemologists call the “basing relation”. Accounts of the basing relation fall into three categories: causal accounts, doxastic accounts, and hybrid accounts. I elucidate the general features of each of these kinds of accounts, as well as the challenges they face, in this chapter.

I begin the final chapter of this part of the book, Chap. 8, with a brief recap of what has been discovered about the traditional account of knowledge throughout the previous chapters. After making the traditional account of knowledge clear, I present a decisive objection to that account of knowledge—what is known as the “Gettier Problem”. Roughly, this problem illustrates that it is possible to have a belief that is both justified and true, and yet, contrary to the traditional account, the belief is not an instance of knowledge. In addition to explaining how the Gettier Problem shows that the traditional account of knowledge is incomplete I explore some promising responses to the Gettier Problem. Finally, I conclude by noting that even without an answer to the Gettier Problem we can use the traditional account of knowledge as a framework for understanding scientific knowledge. This is so because the Gettier Problem does not threaten the relevant components of scientific knowledge—belief, evidence, and truth. The Gettier Problem simply gives us reason to think that we should be primarily concerned with the relation between scientific claims and evidence, which holds whether or not we are in a situation where the Gettier Problem arises.

In the second part of the book I transition from focusing on the nature of knowledge in general to focusing on scientific knowledge in particular. In the first chapter of this section, Chap. 9, I examine the nature of scientific explanations as well as their relation to understanding. Roughly, I point out that good explanations are those that provide understanding of particular phenomena. In addition to examining the relationship between explanation and understanding, I also explore how understanding scientific theories is related to understanding phenomena. This examination of explanations and how they lead to understanding is very important since it is common in scientific practice to adopt a particular theory because the explanations that it produces allow us to understand various phenomena. This is also particularly important, if as some claim, understanding is the primary goal of science education.

I build upon the insights of the previous chapter when arguing for a close connection between explanation and evidential support in Chap. 10. That is to say, in this chapter I argue that the degree to which a given body of evidence supports believing that a particular proposition is true depends upon how well that proposition explains the evidence. The upshot of this is a clear conception of when we should accept claims in science that can be extended to an account of justification more generally. Thus, in this chapter I seek to demonstrate that the connection between scientific explanatory practices and the justification for any of our beliefs may be a close one. So, the process of expanding our scientific knowledge may be more closely related to the process(es) of expanding our knowledge in any other domain than one might have expected. This might be thought to have particularly important ramifications for debates surrounding the proper understanding of NOS in the science education literature.

In the next part of the book I respond to challenges to our knowledge. One way to challenge our scientific knowledge is to challenge all of our knowledge of the world around us. I explore the challenge to our knowledge posed by external world skepticism in Chap. 11. During the process of examining and responding to arguments for external world skepticism important insights are revealed. One of the foremost of these insights is that knowledge does not require evidence that makes the believed proposition absolutely certain. Instead, significant, yet fallible, evidence is all that is required for knowledge. Another insight is that the explanatory account of evidential support developed in earlier chapters helps to show that, despite initial appearances, external world skepticism is not a significant threat to our knowledge after all.

Chapter 12 centers on another way of challenging our scientific knowledge: challenging our knowledge of unobserved cases. The skeptic about induction claims that while we might observe many, many instances of black ravens this does not allow us to know that the next raven we observe will be black (or even reasonably believe that it will be, or is likely to be, black). This sort of inductive skepticism poses a major threat to our scientific knowledge as well as our commonsense knowledge of the world around us. In this chapter I argue that, again, the skeptical challenge can be overcome by carefully understanding the sort of explanatory account of evidential support that has been developed in earlier chapters.

In Chap. 13 I examine a more limited, but in some ways more worrisome, threat to our scientific knowledge. This challenge comes from empirical research which suggests we are subject to a number of biases and irrational processes when forming our beliefs. Some take this evidence of human irrationality to undercut our knowledge in general. I argue that the challenge posed by evidence of our irrationality is not a significant threat to our scientific knowledge. By recognizing our tendency to make certain systematic mistakes we can take steps to correct for the effects of such mistakes both as individuals and as groups. Thus, at most what evidence of systematic irrationality does is give us further reason for thinking scientific knowledge should be held tentatively—something that is embraced by most all conceptions of NOS.

This part of the book closes with Chap. 14, in which I discuss one of the major debates in philosophy of science, the debate between realists and anti-realists. Realists maintain that our best-confirmed scientific theories are true, but anti-realists think that we should only accept that our best-confirmed scientific theories are useful in some sense without committing to their truth (or even approximate truth). I present and evaluate the major arguments on both sides of this debate. Throughout the chapter I defend a realist stance, which allows for genuine scientific knowledge. Ultimately, I conclude that in the case of our best-confirmed theories the truth of those theories best explains their predictive success, which gives us justification for believing they are true. Anti-realist arguments do not give us reason to think scientific knowledge is beyond our grasp. While this realist stance may be controversial among science educators and philosophers of science, I believe that it is defensible. Additionally, I believe that exploring the debate between realism and anti-realism by way of defending realism can make the debate itself clearer and shed light on where those of anti-realist leanings might focus their rebuttals.

The final part of this book is devoted to important issues in the social epistemology of science. I begin by exploring how individual knowledge of scientific claims is related to knowledge within a scientific community. In Chap. 15 I explore the nature of social evidence. The most prevalent form of social evidence is testimony. In this chapter I discuss the nature of testimony and how it is that we can gain knowledge from the testimony of others. In this chapter I also examine a second kind of social knowledge, which we gain from the very commonplace, yet philosophically interesting, phenomenon of disagreement. I explicate the epistemic significance of disagreement in science. In particular I discuss how we should respond when we discover that others disagree with us about a scientific claim.

In Chap. 16 I move beyond a study of the individualistic characteristics of scientific knowledge by looking at science as an epistemic system. It becomes clear that the thoroughgoing social nature of science leads to some characteristics which make it particularly well suited for adding to the store of scientific knowledge. In particular, the social nature of science leads to a division of cognitive labor. This division of cognitive labor both makes it so that trust plays an integral role in the generation of scientific knowledge and so that scientific progress is enhanced by the scientific community hedging its bets through scientists pursuing a wide variety of research projects utilizing a variety of methods. Although the individual scientists

that make up the scientific community are not without human flaws, various social institutions in science help to make good use out of our baser motivations. I argue that while science may not be perfect, it is an epistemic system which has features that make it tremendously successful at generating knowledge of the world around us.

I conclude the book with Chap. 17. I begin by recapping some of the major insights of the earlier chapters of this book. I also point out how these insights can be used to supplement the science education literature. The result, I hope, is a more philosophically grounded science education literature. Such integration holds promise for strengthening both science education and philosophical approaches to understanding scientific knowledge. The philosophical foundation provided by this book holds promise of clarifying a number of epistemological concepts of great importance to debates in science education. This is not to say that I settle the debate concerning how we should understand NOS, or any other key debate in science education—far from it! Instead, this book provides a philosophical basis from which we can better understand and evaluate the key positions in these debates. It is my hope that this philosophical basis, by being relevant to adjudicating between positions in these debates, can also serve as a springboard for increasing understanding of NOS and other key components of science education. I also discuss some of the major areas where further research would be helpful in this final chapter. Although it is often a bit risky to do so, I make some suggestions as to how some of the needed research might be fruitfully conducted and speculate on what some of the results of such research might be. My goal for this final chapter is not to offer precise predictions of how things will turn out, but rather, to encourage further research to continue on the path to greater understanding of NOS and helpfully gesture to good starting places for such research.

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