Chapter 17
Looking Back and Looking Forward

Abstract This concluding chapter recaps some of the major insights of the earlier chapters of this book. It also points out how these insights can be used to supplement the science education literature on the nature of science discussed in the first chapter. The result is a more philosophically grounded science education literature. Such integration holds promise for strengthening both science education and philosophical approaches to the nature of science as well as providing a more in-depth understanding of scientific knowledge. Additionally, the chapter discusses some of the major areas where further research would be helpful. Although it is often a bit risky to do so, this chapter also makes some suggestions as to how some of the needed research might be fruitfully conducted and it speculates on what some of the results of such research might be. The goal of the chapter is not to offer precise predictions of how things will turn out, but rather, to encourage further research and helpfully gesture to good starting places for such research.

At the end of a book it is often helpful to take a look back at what has been accomplished before looking forward at what still remains to be done. We have worked to develop a philosophical foundation for better understanding debates in the science education literature which have an important epistemological dimension—particularly, but not limited to, the debate concerning NOS and debates about the goals for science education. The development of our philosophical foundation utilized an explanatory approach. As was fitting, we began with the heart of epistemology—an exploration of the general nature of knowledge. Next, we turned our attention to specific features of scientific knowledge before considering challenges to the possibility of our having scientific knowledge at all. As we saw, although many challenges to our having scientific knowledge are worth taking seriously, none provides grounds for thinking that we truly do not, or cannot, have scientific knowledge. Finally, we moved beyond the individualistic aspects of scientific knowledge to some of its social aspects. We discovered that science is a powerful epistemic system which is capable of generating a wealth of knowledge despite the limitations of the people who make up the scientific community. In some ways science is greater than the sum of its parts.

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17.1 The Explanatory Approach and Shifting Focus

Throughout the development of our philosophical foundation for understanding important debates in science education our explanatory approach has yielded several insights into the nature of scientific knowledge. This explanatory approach has also suggested a shift in focus when it comes to understanding NOS.

First of all, we saw in several chapters that there are reasons for thinking that a shift from focusing on scientific knowledge to focusing on *evidence* and the *justification* evidence provides for scientific claims would be helpful. In many cases where we speak of "scientific knowledge" plausibly we really mean sufficient evidence for thinking that a particular set of scientific claims are true (or approximately true to a specific degree). Often, we are not careful to distinguish between knowledge and justified belief—as we saw in earlier chapters this could be because it is very difficult to say exactly what knowledge is. We have seen reasons for thinking that our focus in science is not really on knowledge in the strict sense at all, but rather on the sort of evidence, and methods of gaining that evidence, which can justify us in believing that particular scientific claims are true. Plausibly, this insight concerning the features of our scientific inquiry is helpful for better understanding NOS.

Additionally, this shift in focus helps to make the tentative nature of scientific knowledge clearer. It is considerably easier to understand how a theory that we are justified in believing to be true is tentative even though it is based on strong evidence than it is to understand how it is that a theory we *know* to be true is tentative.

The proposed shift in focus can also help to connect our understanding of NOS more clearly with the role that verisimilitude (truthlikeness) plays in science. As we noted in earlier chapters, science is often more concerned with verisimilitude than truth simpliciter. This suggests that what really matters for scientific inquiry is the evidence we have in support of particular claims and theories rather than possessing knowledge of them. Shifting our focus to evidence rather than knowledge would better account for this aspect of scientific inquiry.

Furthermore, earlier in the book we drew an important distinction between the attitude of acceptance as a working hypothesis and full acceptance/belief. Once this distinction has been appreciated the plausibility of shifting from a focus on scientific knowledge to a focus on evidence and justification in scientific inquiry becomes even clearer. Belief is a necessary condition for knowledge, however, in many cases some of the hypotheses which make up our current scientific theories are simply accepted as working hypotheses—they are not fully accepted/believed to be true. So, although we have ample evidence for accepting these theories we cannot count as actually knowing the theories because parts of our current theories are not believed to be true. With respect to these theories we fail to satisfy a necessary condition for knowledge—we lack the requisite belief. This is not a problem at all though, if we are concerned with evidence and justification rather than knowledge.

Moreover, the proposed shift in emphasis would not even require us to stop using the term "scientific knowledge". This is good because we have seen that there are practical reasons for continuing to use the *term* "scientific knowledge" even

if our focus were to become more explicitly evidence-centric. One such practical reason is that talking about theories and claims which are justified or reasonable to believe in light of the evidence may lead to the mistaken thought that many of our best scientific theories and laws are "just theories". This sort of "just a theory" thinking may lead to misconceptions about strongly supported scientific theories.[1] Additionally, continuing to use the term "scientific knowledge" may help with the problems which arise when one fails to distinguish well-supported facts in science from things that one merely believes.[2] Hence, there are practical reasons for continuing to use the term "scientific knowledge" even if we shift our focus in the currently suggested way. A reasonable way of doing this is to make clear that the term "scientific knowledge" signifies scientific claims or theories for which we have sufficiently strong evidence for justifiedly believing they are true (or approximately true) whether or not the other conditions required for knowledge are met. Continuing to speak in terms of scientific knowledge is perfectly fine so long as we keep in mind that what we are really interested in (and talking about) is *evidence* for claims and whether we have sufficiently strong evidence to be *justified in believing those claims*.

17.2 Building on the Foundation of the Explanatory Approach

Although the explanatory approach to scientific knowledge developed here has helped elucidate some philosophical concepts and theories, the study of which may aid in facilitating improved understanding of NOS, much work remains to be done. Throughout this book we noted several philosophical debates that are still ongoing as well as numerous areas where additional research would be valuable. It would be cumbersome to recall each of these points here. Yet, it does seem that we should at least briefly consider a few key areas where further research would be especially pertinent before concluding our discussion. Some of this research is primarily in the field of education, some primarily in philosophy, and some primarily in psychology. However, as this book has hopefully made clearer, research in each of these disciplines can profit from dialog with the others. In fact, the first area where considerably more research is required is a straightforwardly interdisciplinary endeavor—models for optimizing the distribution of cognitive labor. As we have already seen, modeling cognitive labor and determining how to optimize the division of that labor already prominently draws on research in artificial intelligence, economics, computer science, and philosophy. It is plausible that with additional research we might come to better understand the best ways to organize

[1] See McCain and Weslake (2013) for discussion of this and other misconceptions which lead some to object to well supported scientific theories such as evolution.

[2] See Kampourakis (2014) for discussion of this problem.

our scientific practices so as to maximize the amount of scientific knowledge we can generate with our limited resources.

Related to this issue, further research needs to be done with respect to biases and illegitimate heuristics. We have seen that there are various errors of reasoning which humans tend to make fairly systematically. It would be worthwhile to explore the sorts of errors that we fall prey to more fully as well as strategies for how people can learn to better avoid these errors. Although this would not directly affect the division of cognitive labor, it holds the potential to greatly improve our chances of making the best use of our cognitive resources.

Another area worth exploring is the nature of understanding. Specifically, it would be particularly helpful to carefully examine what exactly is required in order to truly understand a theory and to use that theory to enhance understanding of phenomena. Going along with this, research into how best to facilitate increased understanding of scientific theories and improved skills in utilizing that understanding through education would be very useful.

Finally, an area of research that is of particular relevance to our discussion in this chapter is the educational benefits of implementing the recommended shift in focus when it comes to understanding NOS. It seems plausible that shifting our focus slightly to place more emphasis on evidence and justification instead of knowledge may help lead to less confusion when it comes to understanding scientific knowledge. Research into the effects of teaching students about science via the sort of evidence-centric approach advocated here could help illuminate the benefits (and costs) of such an approach. It is research that; hopefully, this book has shown is worth doing.

References

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