Science Education and the Metaphysics of Measurement

MAURIZIO TOSCANO

Melbourne Graduate School of Education, The University of Melbourne

Abstract

'Science' grounds the meaning and significance of the practices, values and norms of the scientist. 'Science' also grounds the work of the science teacher and allows her to distinguish herself from other educational disciplinarians. 'Science' doubly blesses the science education researcher, for she inherits 'Science' both as an indirect object of inquiry and the means of legitimating the methods of that inquiry. Is it possible then, that despite the differences between the respective works of the scientist, the science teacher and the science education researcher, each may be measured against the common ground of 'Science'? This paper explores this question by taking 'Science' here in its metaphysical sense. The paper aims to respond, aphoristically and poetically, to the question of what, if anything, should secure the meaning of science, science teaching and science education research. It will do so by drawing upon the later philosophical writings of Martin Heidegger.

Keywords: Science Education, Metaphysics

The Worlds of Science and Science Education

It appears that great contribution to philosophy by existential philosophers over the past two centuries or so have failed to penetrate attempts to understand the nature of science as it pertains to science education. Science education, like the sciences, is still burdened by the metaphysical search for the kind of certainty that the existentialists have long asked us to abandon in favour of a more robust acceptance of plurality and personal commitment. Coming to understand where this metaphysical tendency comes from becomes a worthwhile philosophical project in itself. But it is a project that first demands of us a thorough exploration of the metaphysical terrain of science itself. And yet, the very object of our inquiry – science – introduces here, at the beginning of our inquiry, the first great hurdle.

It is important from the outset to draw a distinction between philosophical work that contributes to that broad field we might refer to as philosophy of science, and that much narrower – and perhaps more neglected area – of philosophy of science education. It might be assumed that if one were to foster and nurture philosophical inquiry and debate in the former area; then the results of that philosophical work would trickle down into inquiries into the philosophical aspects of science education. This assumption is reasonable if we take 'science' as something which is common to both 'the sciences' and 'science education'. That is, 'science' is something that scientists are in the business of producing and practicing, and 'science' – as the set of such practices and products – is what is of concern to the science teacher in the classroom. For most then, 'science' and 'science education' are joined at the hip by 'science'.

A distinction between these two 'sciences' is not a denial of the significant overlap between 'the science' of 'the sciences' and 'the science' of 'science education'. Any overlap is surely made possible by the overlapping ontologies of these disciplines – what Heidegger would have referred to early in his writings as 'regional ontologies' (Heidegger 2002/1938). An atom *is* for the scientists, as much as it *is* for the science teacher (or the science student for that matter). If photosynthesis is a process that exists in the biology classroom, then it exists there by virtue of its first being present in the biology laboratory.

But we should be cautious about making such a hasty identification of overlapping ontologies. There is a danger here of falling prey to the tendency to consider only – to borrow a phrase from Wittgenstein – the 'surface grammar' of science rather than the 'depth grammar' of science (Wittgenstein 1953; p. 109, §664). The research chemist uses the word atom in her work, for sure; but its place in the linguistic practices of the laboratory may be very different to the usage of the term 'atom' in the chemistry classroom. The ontology of the scientist – which includes such entities as atoms – consists not of discrete objects with properties, but rather a complex set of things that are made meaningful and useful when understood within the vast complex of practices and relationships that exist in the laboratory. What is true of the science laboratory is also true of the science classroom. A casual observer could be forgiven for thinking that the 'atoms' under discussion in the chemistry classroom are the same as the 'atoms' in play in the language games of the chemist.

There is another way to bring clarity to our understanding of how the ontologies of science and science education can at once have entities in common and yet also have entities that are unique to the practices and relationships that constitute each discipline. What we are trying to capture here is analogous to the distinction von Uexküll draws between the 'environment' beings find themselves in and the *umwelt* of each being within that environment (von Uexküll, 1987). Although the ant and the snail occupy the same physical environment, the *umwelt* (or 'world') of the snail is very different to that of the ant. For example, the *umwelt* of the ant encompasses its social being in the world, whereas the snail is confined largely to an *umwelt* defined in part by its solitary progress with its home on its back. Just as at every turn we *could* encounter entities in an 'environment' common to both the ant and the snail; a perspective that instead properly considers the intimate attunement of each being to its environment reveals worlds that belong uniquely to each being: belonging not in the sense of possession, but by way of adaptive attunement. The perspective afforded to us by the idea of *umwelten*, shifts out gaze away from mere 'matter' to 'what matters'. The world of the ant takes in what matters to it – as a social being that acts on and in its world – and not merely what is available to it as an environmental resource. It is possible, then, for an ant that is lost, for it to remain in its environment, and yet by virtue of its lack of attunement to its being in that environment socially, no longer has access to its original social umwelt.

The philosophical framework we choose to distinguish between the 'science' of the laboratory and the 'science' of the classroom shapes how we interpret our encounters with and our access to 'science'. But it may also be the case that our encounters with science and our access to science have determined the boundaries between these two worlds. So, when the Australian Chief Scientist, Ian Chubb (2013), calls for giving teachers and students greater access to the 'world' of science and scientists in an effort to stem the flow of students away from science subjects at school, which 'world' of science is he referring to? Could it be, like the parable of the snail and the ant, that he is promising teachers and students access to the 'environment' of scientists without considering whether it is even possible for students and teachers to access the *umwelten* of scientists? If both the work of scientists and science educators are to be measured up against 'science', what is this 'science'?

The answers to these questions hinge upon the question of whether there is a single, unified, independent 'environment' of science 'out there' – an environment that is as sure as the ground upon which snails crawl and ants walk. For the realist Rom Harré (2002; p. 20) the 'human umwelt' is such a realm, for while it distinguishes between the world accessible to humans and the world accessible to non-humans, it makes no distinction between the world of the scientist and the science educator. If we hold to this position, then, the only 'science' available to us is the science we associate with the exploration and expansion of the *human umwelt*. And since it is the scientists, whom through the use of conceptual and physical instruments are responsible for this task, the human umwelt becomes univocally the 'science' of the scientists. This is certainly consistent with and reinforces the view that the ontology of the sciences is prior to that of science education.

However, the question concerning the distinction between science and science education is more than simply an ontological question – that is, one that asks after what *is*. For it is clear that the *human umwelt* has significance to scientists and science educators far beyond providing an ever-expanding catalogue of the things available to scientific minds and instruments; otherwise we would see no reason to distinguish an 'environment' from an *umwelt*. The dual nature of science as that which provides "what is" but also "what matters" to us is captured well in Heidegger's conception of metaphysics as *ontotheology*. As he puts it:

> If we recollect the history of Western-European thinking once more, then we will encounter the following: The question of being, as the question of the being of entities, is double in form. On the one hand, it asks: What is an entity in general as an entity? In the history of philosophy, reflections which fall within the domain of this question acquire the title ontology. The question "What is an entity?" simultaneously asks: Which entity is the highest entity, and in what sense is it? This is the question of God and the divine. We call the domain of this question theology. Tis duality in the question of the being of entities can be united under the title ontotheology. (Heidegger, 1976, p. 499; quoted in Thomson 2005).

Questioning the metaphysical basis of science and science education is not merely an academic exercise. For if we take a stance towards science that gives priority to the umwelt of the sciences ahead of that of science education, then we run the risk of negating or neglecting the possibility of science education having its own claim to a world of science that is related to but autonomous of the world of science set up by scientists. Scientists have always had a direct or indirect influence on shaping the educational landscape of science education. And where once their influence was felt through their input into policy, curriculum, and assessment; in an age where the metaphysical 'truth' of science no longer holds sway, scientists have taken to trying to re-construct both science teachers and science students. They frame teachers as lacking knowledge of the cutting edge developments in science – the latest breakthroughs from the front-line of science, without which teachers' work becomes anachronistic. The students of science are shaped by a rhetoric that has them 'disengaged' with science – the story if of a generation that has somehow strayed from the path of interest and commitment to the values of science.

The prioritizing the science of the sciences ahead of a distinctive umwelt of science education gives priority to the world of science in two ways. Firstly, it gives priority to the ontology of science. The entities of the science classroom must first come into being in the science laboratory; only later can they be transported into the classroom and become a part of the discourses and practices of science education. In this view, it is not the case that scientists and science educators share a common environment but differ in their umwelten: instead there is only the umwelt of the sciences. The science of the sciences – with its epistemology, praxis, etc – stands in an a-priori relationship to the science of the classroom. This second aspect of prioritizing the science of scientists captures the notion that this kind of scientific science is the ultimate source or origin of the very possibility of the entities of the science classroom existing. Thus, the science of the sciences functions ontotheologically for science education – providing an answer to the question of what *is* and also the question of what is *the source of the being* of those entities which are.

That Which Gathers a People

In his recent series of Gifford Lectures, Bruno Latour examined Natural Religion; contending that the 'Nature' in 'Natural Religion' constituted an entity that gathers a people in much the same way as a deity or deities would in any other religion, rendering Natural Religion a pleonasm (Latour 2013). His project was motivated by his concern that Nature, as it is conceived and appropriated by scientists (and those who accept the scientific view of nature directly or indirectly), is insufficiently secular to meet the demands of the current age – the Anthropocene – in which 'Nature' is no longer a mere backdrop to the affairs of human actors, but a an agent that shapes and is shaped by human beings' inter-connectedness with it. Latour's project is not a negative one – not simply a post-modern critique of the metaphysical tendencies of science. For Latour looks to James Lovelock's Gaia as a candidate for an entity that might gather a people in the age of the Anthropocene in an entirely secular – and I might add non-metaphysical – way. The relationship between humans and other agents in the world called forth by Lovelock's Gaia is of the kind that existentialists have championed for centuries as a way of being in and with the world. Latour sees Gaia as an entity that does justice to the plurality of agents in the world; the reciprocity between the actions of these agents; and the sense in which we are drawn into a condition of necessary attunement with other beings.

Along the path of his argument, Latour sketches out the features he thinks are common to all entities that gather a people: for instance, in the sense that the entity Nature gathers Naturalistic scientists, or the entity we call the Christian God gathers the Christian people. The four broad characteristics he ascribes to such entities

are: exteriority, unity, animation and indisputability. It may be possible, then to use these features to examine the degree to which the metaphysical foundations of the science of scientists and the science of science education differ, and if so in what ways. The aim here is to consider the possibility of differentiating between 'science' of scientists and 'science' of science educators on the basis of their respective metaphysical foundations. Latour's analysis of the 'entities that gather a people' may be useful in this regard if we read the 'gathering of a people' in a metaphysical light. This requires a further argument that I shall return to later in my discussion of the metaphysics from a Heideggerian perspective. Suffice to say that it is possible for a people to be gathered by entities that promise the kind of certainty and stability that existentialists have long eschewed. So, there is merit in applying Latour's framework if only to examine the possibility of transcending the metaphysical tendencies that science fulfils in different ways for both scientists and science teachers.

What is particularly striking about Latour's analysis of the sciences, and pertinent to the question of what kind of science is accessible to science teachers and their students, is the degree to which the entity that gathers scientists – Nature – is also the site of a tension that scientists themselves have failed to properly acknowledge. Latour highlights the tension by revealing the contradictions that arise from the four features when we factor in scientists' relationship to Nature. Firstly, for scientists, Nature is entirely exterior. Nature stands apart from us; the entities that make it up and processes that occur in it (like tsunamis and osmosis) are not dependent on the whims, fancies or subjectivity of human beings. Yet, when we consider how Nature is accessed, we realize that it is the complex network of practices of the scientists that make Nature appear as it does. The development of instruments, the dissemination of results, debates at conferences, fieldwork, etc., all bring Nature into the light of human consciousness. Secondly, scientists take Nature as unified, so that the complexity and variety of processes are assumed to be unified under the laws of nature. But the degree to which the multiplicity of processes in nature can be reduced to laws of nature is often overstated – the broad conformity between models of Nature and Nature itself break down at the microscopic level of attention to detail. Thirdly, the Nature of the scientist is inert: Nature is not animated – it does no act. And yet we are confronted with the overwhelming impression that nature is full of activity and animation, with everything expressing its own kind of agency. Finally, Latour contends that scientists would have it that Nature was indisputable – one cannot argue against the brute reality of Nature. But this is based on the products of science more so than the process of science. Every indisputable 'fact' is the result of a great deal of controversy and debate within the scientific community.

We see from this account that Nature, as the entity that gathers scientists, is characterized by being exterior to humans while also being accessible from inside the practices of science; nature is unified under a set of laws but is still flexible enough for divergence from these laws at the scales at which it is investigated by scientists; nature is physically inert but the agencies of entities that make it up proliferate through the work of science. And finally, it is only by virtue of the dynamic and controversial nature of the scientific methods that we encounter facts about Nature as incontrovertible. Latour labels these two dimensions the Epistemological and Critical versions of Nature, respectively, and argues that scientists find it difficult to accept that the entity under which they are gathered has these contradictory aspects, and furthermore that it is difficult for them to accept the necessity of the tension between these contradictory aspects. Nature, as it gathers scientists, has neither one nor the other countenance, but both.

With this picture in mind, we can begin to see the points of convergence and divergence between the science of the sciences and the science of science education. If science is taken as our encounter with Nature, then it is easy to see how scientists and science educators can be thought to share a common – or largely overlapping ontology. If our encounter with Nature is an epistemological one, then both scientists and science educators have an equal claim to accessing a common Nature. For Nature is equally exterior to both the practices of scientists and non-scientists. Nature, as unified and inanimate, cares not for how scientists work collectively to approach it, nor how teachers choose to teach about it. Nature stands as indisputable regardless of how humans might choose to distinguish between the science of the laboratory and the science of the classroom. This epistemological view of science and Nature is consistent with the view that scientists and science educators inhabit the same 'environment'. But is a shared commitment – a gathering under – this epistemologically dominated entity sufficient to say that the scientist and the science educators measure up against the same 'world' of 'science': the same umwelt? And more importantly for contemporary debates about students' (dis)-

engagement with science: what kind of access to the umwelt of scientists is possible for those gathered within the umwelt of science education; and vice versa?

Perhaps the answer to the question of access to the science of scientists (or science educators for that matter) is found in the Critical approach to Nature. That is, by searching for points of distinction between the practices of scientists and science educators from a critical perspective. The more we examine the companions to the four elements of exteriority, unification, in-animation and indisputability, the more the unwelten of scientists and science educators disentangle. In the science classroom, the Nature that emerges from, and is constructed by, the practices that occur therein is not the Nature that resides inside the practices of scientists. To borrow a phrase from Thompson, the practices that take place in the science classroom simply do not afford the construction of meaning and interpretation that is possible in the discourse of the scientific community. Likewise, the kind of multiplicity that arises from scientific practices is different from that which results from pedagogical practices in the classroom. The vast literature on scientific conceptions, mis-conceptions and conceptual change points to a differentiation between what scientists and teachers take as the relationship between the Critical and Epistemological dimensions of Nature. The degree to which Nature is animated or de-animated by scientists and non-scientists is not easily determined. Much like the question of how indisputable we would have Nature be, the degree of animation permitted is a function of how much priority is given to the epistemological stance.

If we accept that both scientists and science educators have access to the same 'environment' through their common encounter with Nature through the Epistemological stance; and if we accept that the practices of science and science education are sufficiently different (from a Critical perspective) to constitute different umwelten; then how do we construct or negotiate any meaningful exchange between scientists and science educators (or non-scientists more broadly)? Were scientists and science educators to have vastly different epistemological commitments, would the question perhaps not be so urgent or so important?

There are two avenues for overcoming the impasse created by having scientists and science educators measuring up to the same epistemological view of Nature while disagreeing precisely about how Nature emerges from within their respective practices. The first pathway is one in which there is a more robust commitment from each party to the uniqueness of their respective metaphysical stances. And that commitment may come from a greater acknowledgment of the fact that what constitutes the worlds of science and science education is the necessary tension between the epistemological and critical dimensions of science. While scientists and science educators would like to see themselves as gathered by Epistemological Nature; they cannot deny the reality that what defines them as scientists and science educators (and what distinguished one group form the other) is the capacity to hold these contradictory aspects together: both in what they take to exist and what they take to matter. Such an approach would do away with the view that the science of the scientists somehow has priority over the science of the science classroom. The second approach is to question that very role that the entity of Nature plays in both the worlds of the scientist and the science teacher.

Beyond Metaphysics

If we apply Heidegger's ontotheological view of metaphysics to the questions of what constitutes the proper 'science' of science education, then we begin to see that the 'science' of the science classroom, if it is to function metaphysically, must serve two inter-related roles. Firstly, it must provide an account of what *is* in the world; and secondly it must set up a being which, to use Heidegger's phrase is the "highest being". The latter is provided for by Nature if we take Nature to have the four characteristic features of exteriority, unity, under-animation and indisputability described by Latour. Moreover, it is by virtue of the epistemological character of, or construction of Nature that it can serve this role as well for science educators as for scientists.

Latour points out that scientists in practice do not take Nature merely as that which is exterior, unified, under-animated and indisputable. Nature is also that which is disclosed by the practices of scientists and is, therefore, interior, multiple, animated and controversial. But unlike the theological dimension of science, which the scientist and the science educator could be said to share, there are likely to be vast difference between what is considered interior to the practices of scientists versus the practices of science educators. It is also highly unlikely that the multiplicity in interpretations in the science classroom is going to be that same as that

encountered in the laboratory; and nor will the entities in the classroom be animated in quite the same way across these contexts. Furthermore, we should not expect scientific controversy in the classroom to be identical with that in the scientific discourse of scientists. Both the 'science' of the scientists and the 'science' of the science classroom share a metaphysical structure that bifurcates our theological and the ontological approach to Nature. Both conceptions of science share a common theology that is grounded in empiricism. Yet we can distinguish them by the practices and relations they afford since each results in a different umwelt.

But there is another aspect to Heidegger's thinking about metaphysics that may be more pertinent to our attempts to deal with the metaphysical commitments or tendencies of both the sciences and science education. And that is Heidegger's suggestion that historically the distinction between the ontological and the theological has manifested – shown up as it were – differently in particular epochs. More importantly for Heidegger (with respect to the Western philosophical tradition) within the epoch of pre-Socratic Greece, people had no need for metaphysics. In polytheistic Greece, people were not gathered under a particular entity as a way of securing certainty in an uncertain world. For the pre-Socratics, being was associated with *phusis*: a way of being that arises, lingers and withdraws through one's attunement to the world. Heidegger saw this pre-metaphysical epoch disappear as it gave way the Philosophic Greek, Christian, Modern and Nietzschean/Technological epochs. In each of these subsequent epochs, the ontological and the theological aspects of truth and being were expressed in different ways, but nonetheless, all were committed to metaphysics (see Wrathall 2011; p. 212 ff).

The need for scientists and science educators to find certainty and stability in and through a cognitive construction of Nature (as Epistemological Nature say; or Critical Nature; or even a combination of Epistemological and Critical) continues this metaphysical tendency. Moreover, we could look to Heidegger's historical account of the truth of being to see the recurrence and preservation of particular ontotheological assumptions in scientists' or science educators' views of Nature. For instance the pure exteriority of Epistemological Nature sits comfortably within the ontotheological framework of Modernity with its separation of subject and objects and the strong commitment to understanding Nature so as to have cognitive or physical control over it. We may also see something of the impulse of the technological ontotheology in scientists' concerns and strategies around trying to optimize the human resources available to the machinery of that industry we call science.

The point is not that any particular metaphysical foundation to science or science education is preferable to another, or that the ontotheology that is characteristic of one epoch is any better than that of another. What is important is the acknowledgment of a plurality of ways of disclosing being. That is, recognising that we are gathered under different kinds of entities: there is no single 'science' against which we can measure the truth of the work of scientists, science educators and science students alike. Or as Mark Wrathall puts it:

> Heidegger believes that our highest, postmetaphysical dignity is to be disclosers of different understandings of being, none of which can be understood as getting closer or further away from the ultimate truth or reality. (Wrathall, 2011; p. 242)

It is with kind of plurality in mind that we should ask how science education measures up to the metaphysical promise of science.

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