CHAPTER 2

Re-thinking Science Education for the Anthropocene

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This chapter argues that the arrival of the Anthropocene era requires a substantial re-set of science education. It makes a case for re-orienting school science education so that meta-level understanding of science is foregrounded over science's "content," its modes of inquiry, and/or its internal social practices. This would be quite unlike the school science curriculum we know today, but, given science's role in the Anthropocene, this is the chapter's main point.

All academic disciplines have four broad features. First, they all have discipline-specific ways of thinking and discipline-specific frameworks for developing and evaluating new knowledge. Second, they generate "products"—concepts, principles, or tools—that although they come from, and may later be changed from within the discipline, can be used by people from outside the discipline. Third, members of the discipline participate in discipline-specific ways of interacting with each other as they work together to generate, evaluate, and distribute new knowledge. Fourth, all

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disciplines are located in, and influenced by, particular historical and cultural contexts. They exist alongside, and in contrast to, other ways of thinking, doing, and knowing. Although not everyone who is involved in a discipline masters all of these areas equally, the discipline as a whole embodies and it is defined by all four of them.

School curriculum development usually involves selecting knowledge from a "parent" academic discipline and then "re-contextualising" it for educational purposes (Bernstein, 2000; Deng, 2007). These purposes can change over time as education systems respond to developments in the wider social, political, and economic contexts they are enmeshed in. In general, however, each "subject" of the traditional academic curriculum draws on the above four features of its parent discipline. In the curriculum context, these features are "weighted" differently in relation to each other, based on currently prevailing ideas about the educational purposes of that curriculum area. The science curriculum for schools usually emphasises, in different proportions, science's four broad features: first, the *epistemic* aspects of science—the specific forms of intellectual inquiry that scientists use to develop, evaluate, and justify new knowledge; second, the *ontological* aspects of science—its "products" or "content," which can include facts, laws, algorithms, principles, or tools; third, the social and rhetorical strategies scientists use when they *interact with each other as scientists*; and fourth, a *meta-level understanding* of science's role and location in the wider social, cultural, political, and economic context in which it developed.

Over the roughly 150 years or so of science education's existence, science's "products" have been the main component of most school science curricula. Generations of reformers have argued for a more "balanced" curriculum, for greater emphasis on one or more of the other aspects of science, but in general, this has had little impact on classroom practice (DeBoer, 1991). For example, science education researchers have argued strongly that deep understanding of science's "products" is impossible without an understanding of the inquiry processes that produced them (e.g., Newton et al., 1999; Duschl & Osborne, 2002; Osborne, 2014; Kind & Osborne, 2017). Other researchers have advocated pedagogies designed to "socialise" students to think, act, and interact "like scientists" (e.g., Driver, 1983; Driver et al., 1994; Driver & Oldham, 1985; Tobin, 1990). Still others have argued for greater emphasis on developing a meta-understanding of science, through studying its history, philosophy, and sociology (e.g., Matthews, 1994), and there is a large body of work advocating a focus on socio-scientific issues (e.g., Zeidler et al., 2005; Zeidler

& Nichols, 2009) and/or developing scientific "literacy." However, it is fair to say that mainstream science education research, informed as it is by cognitive science, continues to focus largely on addressing the intractable issue of how to support students to achieve "real understanding" of science's "products." Intertwined with all this, influenced by wider trends, there have been calls for science education to be made more "inclusive," "engaging" or "relevant" for more students, and the last couple of decades have seen an increased emphasis on skills, competencies, and what Biesta (2012) calls the "learnification" of education.

This is a complex fruit salad of ideas. However, as a long-term observer of this field, I have found it hard to discern any consensus on the question of the *educational* function/s science is supposed to serve through its inclusion in the school curriculum. A multitude of different purposes for school science are espoused, including providing foundational science knowledge for students headed for science-related careers; providing students with science-related knowledge they might need in everyday life; developing sufficient scientific "literacy" for active citizenship; and empowering students by providing access to "powerful knowledge." These purposes are all very different, and each implies a very different curriculum: however, all are oriented towards acquiring and storing away certain kinds of *knowledge*. This predilection for turning everything into "stuff to be known"[1] seems to be a feature of science education. However, it isn't always clear how acquiring this knowledge is supposed to be *educative*, in the sense meant by Dewey (1938).[2] Having a sense of this is, it seems to me, important for curriculum designers as they decide how to select from—and balance—the four aspects of science outlined above.

None of these issues are new (Gilbert, 2011), but my purpose in rehearsing them here is to suggest that recent events and trends outside education, specifically the coming of the Anthropocene, throw these issues into very sharp relief. In this chapter I want to argue that the "new times" we are now in require us to re-frame science's role in the school curriculum. Substantial change is needed, change that is difficult to even imagine, let alone think about productively and practically. However, for reasons I'll come to shortly, I think there is a moral imperative to attempt this work. In this chapter, I explore whether emphasising the fourth,

[1] David Perkins calls this predilection "aboutism" (see Perkins, 2009, p. 5).

[2] Dewey defined "educative" experiences as those that foster ongoing intellectual growth by building the capacity to think in deeper, more complex, more abstract ways.

meta-understanding aspect of science could provide an appropriate frame for the kinds of education we now need. But first, why is change necessary? What exactly *is* this thing called the Anthropocene? And what does it have to do with education?

The Anthropocene is the name now being given to the advent of a new geological epoch, beginning roughly with the Industrial Revolution and the industrial-scale use of fossil fuels, in which human activities came to have a major influence on the earth's physical processes. The term is derived from the Greek: "anthro" meaning "human," and "cene" meaning "new" (geological era) and was coined to signal the termination of the earlier Holocene era. Burning carbon sequestered over hundreds of millions of years by living processes from the atmosphere has vastly increased atmospheric carbon dioxide levels, which has in turn triggered an ongoing increase in mean global temperatures. This is expected to have a major impact on world sea levels, weather systems, and ecosystem stability, which will affect the habitability of the planet for humans and have major implications for human social, political, and economic life. These processes are now well under way (Kress & Stine, 2017; Scranton, 2015; Klein, 2014; McNeill & Engelke, 2014; Hansen, 2009).

As widely discussed elsewhere, collectively we have not managed to put in place measures that could reverse or delay these trends, nor have we developed strategies for adapting to or mitigating their likely effects (Flannery, 2005; Hamilton, 2010; Jamieson, 2014; Oreskes & Conway, 2014). The scientific consensus is that unless we reduce carbon emissions by 45% (from 2010 levels) by 2030, we will exceed 1.5 degrees of global warming, deemed as the upper limit for a habitable planet. According to some scientists, "abrupt" change, that is, change that is so rapid that humans and other natural systems do not have time to adapt, is likely, possibly within the next decade (IPCC, 2018; 2022). It is no longer controversial to say that we are sleepwalking towards disaster, that current practices are destroying the lives of our children, and that anyone who is under sixty years old today is likely to witness the radical de-stabilisation of life on earth. The impacts are likely to be felt first and most by the world's poorest and most marginalised peoples. Most countries are in a state of policy paralysis, at least partly because actually addressing the issue will require major sacrifice, major curtailment of our current economic activities and lifestyles. It isn't at all clear who should bear these costs and/or how they should be distributed. And now, a good thirty years after the science on climate change first became clear, it could well be too late to reverse or delay its effects. If this is the case, then actions additional to those directly related to reducing carbon emissions become important. Any world-improving action—maintaining functioning democracies, functioning legal systems, functioning communities; instituting humane immigration policies; strengthening all human systems, including education—can now be considered climate action.

So what does all this have to do with the school science curriculum? Wouldn't the "topic" of climate action be most appropriately located in the social studies curriculum? Should students be taught the *science* of climate change? Or should climate change action be made a new and distinct curriculum area in its own right, as some are advocating?[3] In what follows, I outline why I think the coming of the Anthropocene requires us to re-set science education. Then I set out why I think a useful place to start this work would be to emphasise meta-level understanding of science over its other three aspects.

Being "in crisis" seems to have been a feature of science education since its inception, (DeBoer, 1991; Aubusson, 2013; Toscano, 2013). Each time a new crisis is identified, reports and new research are commissioned, new approaches to teaching are recommended, and new curricula come into effect. Vocabulary from this work finds its way into policy rhetoric and sometimes classrooms, but usually things continue much as they always have. However, the Anthropocene, because it disrupts fundamental features of the historical period in which science education developed is, it seems to me, the "crisis to end all crises."

Education, science education, and science itself, in their present forms, are products of, and deeply connected to, Western modernity's core assumptions and economic conditions. Modern education was forged in the transition from agriculture-based economies and societies to predominantly urbanised, industrially oriented ways of life. The development of mass schooling was important for its role in producing the human resources—and consumers—modern economies need. The "subjects" of the modern school curriculum, including science, were developed to support the growth of modern capitalist economies/societies. Science is deeply connected to that growth, both in the positive sense of what it has made possible, and in the negative sense of its contribution to the crisis we now find ourselves in (Patel & Moore, 2017). But this period in history, characterised by some as "carboniferous capitalism" because its success has

[3] For example, Everth and Bright (2022).

rested on the "cheapening" of nature (Patel & Moore, 2017) and the burning of fossil fuels (Newell & Patterson, 2010), is coming to an end.

As has been well-canvassed elsewhere, this has major implications for the planet and for human social and economic life. But there are also *intellectual* implications, discussion of which is also well under way. For example, some scholars are attempting to set out a new paradigm of "post-carbon" social theory, to re-work "old" (modern) conceptions of society, politics, and the economy for the new times (e.g., Newell & Patterson, 2010; Irwin, 2010; Urry, 2011; Elliott & Turner, 2012; Klein, 2014). Commentators in science-related disciplines talk about the shift to what they refer to as "postnormal times," a world in which things are no longer certain, simple, or stable (if they ever were); instead, uncertainty, complexity, chaos, and contradictions are the "new" normal (e.g., Sardar, 2010; Ravetz, 2011; Slaughter, 2012).

For Bruno Latour, a major figure in the sociology of science, the Anthropocene heralds a major intellectual shift in science itself. In his 2013 Gifford Lectures, he argues that the Anthropocene challenges scientists to think in completely new ways about science—what it *is*, what it is *for*, and what (and who) it should *engage* with (Latour, 2013).[4] He says that scientists need to see nature, not as an "object of enquiry," something we are apart from, or something to be tamed, but rather as something we are deeply *engaged with*, part of, and inextricably entangled with. Rather than investigating nature's "entities" as things-in-themselves, scientists should be exploring what he calls the "crossings," "borders" or "conversations" *between* science and nature. This of course requires completely new ways of thinking: new forms of inquiry, new tools, and new practices. It also requires a new relationship between science and politics (Latour, 2018).

All this, if we accept it, has major implications for education, for science education, and for science itself. If modernity's key concepts no longer apply, then what should education's purpose be? Do we still need (or want) public education? What role, if any, should science play in education? Is it defensible to continue to include science in the school curriculum, given science's contribution to the activities and thinking that produced the Anthropocene? Should we be *reproducing* this kind of thinking? If we think school science could have an educative function in the Anthropocene, what would this look like? How might this differ from

[4] See also: http://www.modesofexistence.org

what it does now? How, if at all, should science intersect with other curriculum areas?

These questions are incredibly difficult to address, mainly because our thinking is structured by a set of conceptual categories that are *part of the problem*. Our thinking is colonised: we can't think outside these categories. All we can do is, to use Derrida's (1991) term, to put them "under erasure," signal that they are problematic, that they may eventually need to be "erased," while at the same time continuing to work with them, because we don't (yet) have an alternative thinking system.

So, given all this, and looking at just one of the above questions, I want to suggest that school science *could* be educative in the Anthropocene context, but only if it is significantly re-framed. However, in considering this re-framing, I don't think we should "throw the baby out with the bathwater": I think we have to work with what we have. In the remainder of this chapter, I attempt to sketch out a curriculum design that foregrounds the meta-understanding aspect of science, maintaining the other three aspects, but in reduced form and with different purposes. This approach doesn't look at all like the school science curricula we are familiar with, which is the central point of this chapter.

Focusing on the epistemic aspects of sciences—that is, its products and/or the way scientists work together as scientists—is useful if our purpose is to *reproduce* these aspects of science, to enculturate or discipline students into the discipline as it is now. These approaches, if they are successful, structure students' thinking in particular ways which, unless they are also exposed to other ways of thinking, make it very hard for them to "see outside" these ways of thinking, and they foster the belief that there is one "right" way of thinking. However, if the aim is to expand students' capacity to think in *different*, more complex ways, or to expand our collective capacity for change, then this isn't such a good strategy.

Change usually doesn't come from the centre of an established discipline (Kuhn, 1970). More often, it comes from the periphery, generated by outsiders who are critical of, but also fluent in, the discipline. Changemakers are often people who are "bi-cultural," people who have participated sufficiently in more than one disciplinary context to see "how things work," what matters, and how the two contexts are similar/different. In other words, they are often people who have developed meta-level understanding. So, if our goal is to build the capacity for change and/or more complex thinking, then fostering meta-understanding, ideally of multiple contexts, seems to me to be a productive strategy.

I'm using the term meta-understanding here to mean a view of science "from above": an understanding of how scientific knowledge has been built in a particular social, political, historical, and cultural context, by particular kinds of people, using particular ways of thinking, particular practices, and drawing on sets of assumptions which differ from those used in other ways of thinking. Advocacy of approaches designed to build meta-understanding isn't new. As mentioned earlier, many reformers have argued for teaching science via a focus on its history, philosophy, and sociology; on socio-scientific issues; and/or on the development of scientific "literacy." And the "nature of science" initiatives that have been added into school science programmes in many countries were intended to encourage critical thinking and meta-understanding of science. However, in practice, none of these initiatives has produced the kind of change expected by their proponents. Perversely, many of these initiatives have generated new and additional sets of propositions students need to "know about"—that is, they have been incorporated into the "aboutism" referred to earlier (Lederman, 2007; Hipkins, 2012). Reformatting these initiatives as yet more knowledge for students to acquire is to (obviously) miss their point, but, importantly for the present purposes, it is unlikely to be *educative* in the Deweyan sense. Because these initiatives haven't worked as intended, and given the present situation, I think something bolder is needed. So, in the remainder of this chapter, I want to make the case for an approach to achieving meta-understanding that uses the concept of deconstruction. This, to people steeped in science and science education, will seem very weird indeed.

The deconstruction concept is commonly used in the humanities and social sciences and sometimes found in education, but for reasons that are probably obvious, it is unfamiliar—and likely to be unwelcome—in science-related contexts. But, as I've tried to show here, science education and science itself are different activities, with different goals. If we follow Dewey's idea of education's purpose as being to foster intellectual growth, to build the capacity to think in ever-deeper, ever more complex, abstract ways, then science's function in the school curriculum is simply to be one of several contexts or "vehicles" educators can use to foster intellectual growth. Science education's primary purpose is to *educate*, not to "communicate" or "to deliver" science (although it may do that). Science education *isn't* science, and, following from this, we wouldn't expect to see a one-on-one mapping between science and science education. So, while deconstruction might not be an appropriate technique to use in science itself, I want to argue here that it could be appropriately used in science *education*.

Deconstruction's purpose is change, particularly in relation to idea-systems, and in situations where these idea-systems are seen to be oppressive. Deconstruction is a process for trying to break out of, and see beyond, the conceptual categories that, at a deep level, structure the way we think. The aim is to look *below the surface* to see how these conceptual categories work together as a system, and how this system becomes possible by excluding or disallowing certain other categories. Deconstruction is different from analysis or critique: its aim is *not* to take apart or knock down the existing categories, but to work *with* them in new ways. Its purpose is to make visible the unacknowledged material that lies between, beyond, and underneath the existing categories, and to then to use this material to think outside these categories (Culler, 1983; Grosz, 1989; Lather, 1991; Davies, 1994).

Deconstructive work is done, not at the level of specific ideas, forms of inquiry, or social practices, but at the level of discursive practices. Discursive practices are systems of thought that emerge from certain sets of ideas, forms of inquiry, and social practices, under certain wider (political and institutional) conditions (Foucault, 1972, 1978). Many different discursive practices exist alongside each other. Each produce "truths" that "work" in the context of that set of discursive practice, within its boundaries, and when its rules are followed. Discursive practices include ideas, forms of inquiry, and social practices, but these are not the focus. What is in focus is the way discursive practices are a medium for wider power relations, and how they work, not to represent reality, but to actively *produce* it. Deconstruction involves exploring how sets of discursive practices "work": it looks at the assumptions they rest on; the practices that define them; the people who participate in them; the political, institutional, and disciplinary structures they are embedded in; the metaphors that organise them; and, importantly, it looks for what *isn't* there, for what or who is excluded, disallowed, or illegitimate.

Science is a discursive practice. It produces particular kinds of knowledge, involves particular practices, rests on particular assumptions, is participated in by people who think in particular ways, and it is part of a wider system of power relations. It produces "truths" that "work" well in this context. Enculturating the students into these discursive practices is useful if the goal is to reproduce them. But, if we accept Latour's argument that the Anthropocene's arrival challenges some of science's deepest assumptions, then this no longer seems defensible.

What might a deconstruction-based approach to building meta-understanding look like in practice? Exploring this fully is outside the scope of this chapter: my purpose here has been to make a case for why it is necessary. However, in other work (many years ago now) I have mapped out in some detail deconstructive approaches to the teaching of first genetics, and then later, animal behaviour, and human evolution for use by high school biology teachers (Gilbert, 1997). I think it is possible to do this work, and I think it could generate the kinds of educative experiences students need to prepare them for life in the Anthropocene. Perhaps now, given today's context, this kind of work might be more palatable to science educators than it was two decades ago. Perhaps.

Science education, it seems to me, has a really important role to play as we transition into the Anthropocene, arguably more so than other curriculum areas. Science and technology are routinely depicted *as* the future, as what will "save" us from the problems we face. But, while technological mitigations for climate change will undoubtedly be developed (Kolbert, 2018), thinking this way sends us down *one* particular pathway to the future. This is dangerous because, while scientific work has identified the Anthropocene's development, scientific ways of thinking and activities have undoubtedly contributed to it. It is important that we are able to think within *and* outside the "science as the future" pathway, to imagine *other* possible pathways to the future. As the Futures Studies scholarly literature tells us, channelling our thinking in particular ways, along particular pathways, effectively closes off other options. Science and technology don't, in themselves, shape our future: developments in science and technology are guided by human values, choices, and actions (Slaughter, 2012). As the futurist Riel Miller puts it, the future isn't something that just "happens" to us: every one of us "*create[s]* the future/s through the choices we make *every day … starting now*" (Miller, 2006, p. 3). Building on this, the educationist Keri Facer points out that,

> [t]his perspective changes the dominant metaphor for our orientation toward the future. Rather than envisaging ourselves walking forwards into a future in which choices are laid out before us and from which we must choose, carefully selecting paths to avoid risks and fears. Instead we might imagine ourselves walking backwards into an unknowable future, in which possibilities flow out behind us from our actions. (2013, p. 9)

Science education for the Anthropocene should build the intellectual capacities needed to *create* the futures we collectively *want*. It should aim to support the capacity to work *within* current pathways, but also to stand *outside* them. If we can't find ways to see out of the well-worn rut of existing conceptual categories, it is highly likely that we will continue to sleepwalk towards climate catastrophe. We probably have about a decade to wake up and do this work. But, on the other hand, it could well be that it is already too late for the kind of rather abstract strategies proposed here, and that a more productive contribution to the planet's future might be to join the type of activism proposed by the Extinction Rebellion (2019) movement.

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