CHAPTER 16

Resurrecting Science Education by Re-Inserting Women, Nature, and Complexity

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Introduction

I am a female Pākehā[1] New Zealander who has worked in science education for four decades, first as a high school science teacher and later as a university teacher and researcher. However, I have never really "belonged" in science or science education. In earlier years, this was just a feeling; however, it was a feeling I set out to explore in postgraduate study, first in linguistics, then feminist theory, political theory, and science education. Here I again found myself on the margins, an outsider to the intricacies of academia, but by then I had decided to see this marginality as a strength, a space from which to see things differently. I have a long-standing interest in what we now call "diversity issues" in science and science education, but I am critical of conventional strategies for attracting women and/or other marginalised groups into science. I am old enough to have seen the same strategies rolled out repeatedly with little discernible effect on the problem. In this field the issues tend to be conceptualised at the surface-level, and the "other" question in science

[1] The Māori word Pākehā is used in New Zealand to describe the descendants of the European settlers (mainly British) who have come to New Zealand over the last 150 or so years. Māori are Aotearoa-New Zealand's *tangata whenua* (indigenous 'people of the land').

[2] By the "other" question, I mean work exploring how science *conceptually* excludes or "others" certain major classes of human. See, for example, the work of Evelyn Fox Keller (1985, 1992).

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has received little attention.[2] In this chapter I want to argue that the coming of the Anthropocene could—and should—change this. Picking up the editors' invitation to think differently about science education as it is now, this chapter's starting point is that science-as-we-know-it can't provide solutions to the issues we now face because it is part of the problem. Re-imagining science education for the Anthropocene needs to involve much more than improving public understanding of science, especially climate science, or political activism, conceived of within the current conceptual system. This chapter argues against these strategies. Proposing deconstruction as a frame for envisaging—and resurrecting—science education for the Anthropocene, it advocates a pedagogical approach based on deconstructing science-as-we-now-know-it. The chapter argues that if we are to think our way out of the situation we're now in, we need to "unpack" the conceptual system that led us into it.

The Anthropocene

The term Anthropocene came to prominence in the first years of the twenty-first century, when the atmospheric chemist Paul Crutzen proposed, at a geologists' conference, that planet Earth has left the Holocene and entered a new geological epoch that is defined by the effect of human activities, not just on other living things, but on the Earth's deeper physical processes. This new epoch, dubbed the Anthropocene (from the Greek "anthro" meaning "human"), is the result of the widespread burning of fossil fuels since the time of the Industrial Revolution in Europe. Burning carbon sequestered over hundreds of millions of years from the atmosphere, via living processes, has vastly increased atmospheric carbon dioxide levels, which has in turn triggered a steady rise 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 (Hansen, 2009; Klein, 2014; Kress & Stine, 2017; McNeill & Engelke, 2014; Scranton, 2015). These changes are already happening, but, as widely discussed elsewhere, we have not yet 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). Many now argue that we are in a "climate emergency"—that urgent action is required if we are to avert abrupt catastrophic change.

The Anthropocene discourse originated in science. Groups of scientists, using scientific language and evidence, used the term to persuade non-scientists to put in place policies and protocols to address its causes. However, the concept was quickly taken up by scholars in the arts, humanities, and social sciences. Analysis of the intellectual implications of the Anthropocene is now well underway. Arguments are being made for new "post-carbon" philosophies (e.g., Irwin, 2010) and for new social, political, and economic theories (e.g., Elliott & Turner, 2012; Klein, 2014; Newell & Patterson, 2010; Urry,

2011). However, some scholars argue that, because the crisis we're now in is a direct consequence of capitalism, Capitalocene is a more appropriate term (e.g., Moore, 2016).

The Anthropocene's arrival has significant implications for education (and science education in particular), but scholarly exploration of these implications is only just beginning (the present volume notwithstanding). This chapter looks at how the Anthropocene challenges science education and explores how it could catalyse change. However, first it examines how the Anthropocene is portrayed by scientists in their interactions with policymakers, arguing that the story they tell is not a helpful basis for re-imagining science education.

The scientists' Anthropocene story emphasises evidence-based predictions, targets, and demands for urgent action. This rhetoric is accompanied by apocalyptic stories of collapse if something isn't done, or alternatively, by "it's already too late" stories. While there are good reasons for using this language in this context, this construction of the Anthropocene, if it is picked up and used "as is" in education, has several problems.

The first problem is that this story constructs the Anthropocene as an engineering and/or a policy problem that can be solved using existing ways of thinking. This construction misses the point. The Anthropocene names a new epoch in the history of planet Earth. The term was invented to denote a significant rupture with the past. It signals the advent of new systems and processes that quite possibly will not be comprehensible using current ways of thinking. However, more importantly for the present purposes, the circumstances the Anthropocene names have been *caused* by actions that arise from and are informed by current ways of thinking. The second problem with the scientists' Anthropocene story is that it reinforces the widely held idea that science and technology *are* the future: they are what will "save" us from the problems we face. But science and technology don't, in themselves, shape our future: they are guided by human values, choices, and actions (Slaughter, 2012). And while technological mitigations for climate change will undoubtedly be developed (Kolbert, 2018), thinking this way sends us down *one* possible pathway to the future, closing off other options (Facer, 2013; Inayatullah, 2008).

The third problem with the prevailing climate change story is that it is profoundly anthropocentric and Western-centred. It exists in a filter bubble which puts humans front and centre and reifies their agency. Humans are constructed as separate from nature, active, autonomous subjects who can make meaning about, act on, and master an essentially passive nature. This draws on—and reproduces—the thinking system that is the source of the problem. The story also expresses the interests and worldview of particular humans in particular countries, obscuring the interests and worldviews of other groups of humans, as well as those of non-human living things and the non-living things with which/whom we share planet Earth (Haraway, 2016). It obscures the fact that most of the world's humans play a very limited role in

contributing to climate change,[3] and it reinforces the idea that while we live "on" planet Earth, we are not part of it, that we are entitled to take what we want and to conquer and control it.[4]

A fourth aspect of the prevailing Anthropocene story that is unhelpful is that it sets up either/or choices. *Either* we succeed in saving the planet and human life on Earth can continue, *or* we don't and humans (and a great many other species) are totally eradicated. There are of course other possibilities. Catastrophic events causing mass extinctions of other species have happened many times in the Earth's history.[5] Humans on planet Earth have experienced catastrophic events before and survived, often inventing completely new ways to be human. This could happen again, and it is possible that this could actually be positive.[6] Completely new ways of thinking about what it means to be human could emerge, ways that we can't imagine from within existing thinking systems. The prevailing Anthropocene story allows only two possibilities—success or failure. If we don't do X, Y will inevitably follow. Why only two possibilities? What *other* possibilities are we avoiding thinking about in the present circumstances? What other possibilities can we *not see* in the present circumstances? Can we think *outside* the prevailing story?

In this chapter I argue that these "urgent action or collapse," "science will save us" stories are underpinned by the set of assumptions that have created the problem[7] and, because of this, they aren't a helpful basis for re-imagining science education. Using these stories uncritically will produce science education with a focus on teaching students *about* climate change, engaging them in "climate action," and/or encouraging them to "contribute to the cause" by considering science-related careers.[8] These approaches will reproduce the thinking systems that have produced the problem. In the current circumstances, this would be deeply *mis*-educative, in the sense meant by Dewey

[3] According to a recent Oxfam study (Gore, 2015), 50% of the world's carbon emissions are produced by 10% of the world's population.

[4] This is in contrast to the reciprocal relationship with nature assumed by many non-dominant groups of humans (e.g. Kimmerer, 2013).

[5] A well-known example of such a catastrophe is the asteroid strike sixty-six million years ago that sparked global firestorms, followed by a nuclear winter-like cold (caused by the smoke), that caused the mass eradication of 75% of the planet's species, including the dinosaurs. A new, radically different, world order eventually emerged: the age of mammals and birds replaced the age of the dinosaurs (Lee, 2020).

[6] At the time of writing, we are in the grip of the global COVID19 pandemic. While at this point in time it is hard to see the positives, there are, in my country anyway, perceptible shifts in thinking. There is talk, not of going "back to normal," but of a "new normal" in which deep expertise and "essential workers" are newly appreciated while misinformation and social inequalities are not. The ubiquity of international travel is being challenged, as are many long-held assumptions about educational "delivery.".

[7] These assumptions are outlined later in the chapter.

[8] See, for example, https://educatorsdeclare.org/resources/.

(1938).[9] Other stories are needed, stories that allow us to see science, the Anthropocene, and ultimately science education differently. Drawing on work in the philosophy and social studies of science (not science itself), in the next section I explore two alternative Anthropocene stories.

Seeing Science and the Anthropocene Differently

Bruno Latour, in his 2013 Gifford Lectures, argues that the Anthropocene's arrival is a significant challenge to science-as-we-know-it. It requires a major shift in how we think about science: what it *is*, what it is *for*, with what and whom it should *engage*, and how it should do this (Latour, 2013).[10] Building on his long-term work on how scientists think about—and "do"—science (e.g., Latour, 1993), Latour argues that scientists need to rethink their relationship with nature, to see it, not as something to be tamed, objectified or "deified," something we are "apart from," but rather as something in which we are inextricably entangled, embedded, and connected. This shift, he argues, will require completely new ways of thinking, new tools that allow us to investigate nature, not as a set of "entities" to be understood and controlled, but as constructed and reconstructed in reciprocal relationships with science (and scientists). He argues for a focus on this relationship, on the spaces or "crossings" between science and nature.

Donna Haraway, on the other hand, argues against using the Anthropocene concept (or the Capitalocene) to think our way out of the situation we're in. She argues that both discourses assume—and reproduce—the binaries of Cartesianism[11] and using them can only, as she puts it, "end badly." For her, both terms too easily lead to cynicism and defeatism, to "game over, too late" thinking (Haraway, 2016). Instead, she proposes a new concept, the Chthulucene,[12] as a positive way forward. In her new Chthulucene age, human entanglement with all other living and non-living things on earth is acknowledged, not denied.

> Unlike the dominant dramas of Anthropocene and Capitalocene discourse, human beings are *not the only important actors* in the Chthulucene, with all the other beings able simply to react. The order is reknitted: human beings are

[9] In *Experience and Education* (1938), Dewey argues that "educative" experiences are those that open up possibilities for active, ongoing intellectual growth, that is, the capacity to think in increasingly complex, abstract ways. M*is*-educative experiences, on the other hand, constrain, distort or arrest intellectual growth (p. 25).

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

[11] The next section has an explanation of Cartesian binaries.

[12] The term Chthulucene, invented by Haraway, is derived from the name of a Californian spider (*Pimoa cthulhu*), which in turn comes from the language of the Goshute people of Utah (Haraway, p. 31). For Haraway the Chthulucene signifies entanglement, everything's connection to everything else.

> with and of the earth, and the biotic and abiotic powers of this Earth are the main story. (Haraway, 2016: p. 55)

Haraway's Chthulucene concept denotes a new way of thinking, a new way of doing/making things. It rejects anthropomorphism and the *anthropos*, the autonomous, rational, outcome-focussed possessor of agency and knowledge. Instead, subjectivity, knowledge, and agency are seen as emerging in multi-species collaborations, in what she calls "sympoiesis," or "making-with," a process of breaking down and re-making the old, using it in new ways, to do new things. For her:

> The unfinished Chthulucene must collect up the trash of the Anthropocene, the exterminism of the Capitalocene, and chipping and shredding and layering like a mad gardener, make a much hotter compost pile for *still possible* pasts, presents, and futures. (Haraway, 2016: p. 57)

Latour, Haraway, and many other contemporary theorists[13] make a strong case for the urgent need to find ways to think *outside* the old paradigms, to develop new modes of thinking that can allow new ways of doing things to emerge. However, this is incredibly difficult. Our thinking has been formed, structured, and colonised by the existing conceptual frameworks, to the extent that it appears as though this is just "how things are," that this is "all there is." Anything that can't be shoehorned into the existing frameworks can't be thought. Because it is unrepresentable, "uncomputable" (Bridle, 2018), the "left-over" material is treated as though it doesn't exist. It is invisible to the system, unwanted "excess" or "waste" (Irigaray, 1985, p. 30). We can't simply reject and/or replace the prevailing conceptual frameworks: we are part of them, and we can't think outside them. All we can do, to use Derrida's (1991) term, is to put them "under erasure": signal that they are problematic, that they may eventually need to be erased, while at the same continuing to work with—or around—them.

These difficulties are further compounded in educational contexts. A key goal of education is to foster intellectual growth, traditionally achieved by exposing learners to increasingly complex forms of knowledge. Knowledge is generally regarded the "raw material" for thinking: we "think with" knowledge (Willingham, 2019). But, if the knowledge we are exposed to "formats" our thinking in certain very specific ways, our intellectual growth is channelled and constrained in ways that make it very difficult to think "other-wise." Moreover, whatever—or whoever—was "excess" to this knowledge is excluded right from the start. These are of course not new problems: however, attending to them is now urgent as we try to imagine what being educated might look like in the Anthropocene.

[13] For example, Braidotti (2013), Barad (2007).

The purpose of this chapter is to oppose the use of the prevailing Anthropocene story in our attempts to re-imagine science education. Instead, drawing on the alternative readings proposed by Latour, Haraway, and others, I want to make the case for an approach that is based on deconstructing science-as-we-now-know-it. In the next section I outline how I plan to use the term deconstruction and provide an example of how science-as-we-now-know-it could be deconstructed. I then propose a pedagogical approach based on deconstruction, arguing that this approach, unlike business-as-usual science education, could be genuinely "educative."

Deconstructing Science-As-We-Know-It: How Women, Nature, and Complexity Were Left Out

The deconstruction concept, while common in the humanities and social sciences and occasionally found in education, is rarely used in science-related contexts. Deconstruction's purpose is change, particularly in relation to idea-systems, and in situations where these idea-systems are seen to be oppressive. It is a process for trying to break out of, and see beyond, the conceptual categories that, at a very deep level, structure the way we think. Deconstruction involves looking below the surface of a conceptual system to examine its key concepts and how they work together to form a coherent narrative. It also involves looking at what these concepts were built on or from, and what has been excluded or disallowed to make the system work. Doing this, its protagonists argue, is enough to produce change (Grosz, 1989; Lather, 1991; Davies, 1994). Deconstruction is different from analysis or critique. Its aim is *not* to take apart, refute, or destroy existing conceptual systems: rather, it is to *work with* these systems, but in new ways. The purpose is to open up spaces between the existing categories from which it is possible to see the system—and think—differently. In what follows I draw on scholarly work in feminist theory, political philosophy, economic history, and the history and philosophy of science to attempt a deconstruction of science-as-we-know-it. This material forms the background to the pedagogical approach that follows.

The development of capitalism and then science over the last five hundred years or so has produced a very specific way of thinking about—and organising—the relations between humans and the rest of nature (Patel & Moore, 2018). The success of both capitalism and science rests on the idea of humans as separate from—and superior to—nature. This idea first appeared in Western European thought in the 1600s and is an organising principle of much of modernist thought, including the sciences, politics, economics, and the other social sciences. It is so embedded in modern thought that it seems self-evident, obvious, and "natural." However, while it is an abstraction, invisible to most, this idea has deep material effects. It has affected how humans have thought about, organised, and dominated each other, how they have lived on planet Earth, and how they have affected other living and non-living things, including, now, the Earth's fundamental geological processes. One of these

effects is to exclude, at the conceptual level, women, nature, and complexity from this thought system. This removes their agency and power, and allows them to be, as Patel and Moore (2018) put it, "cheapened" to serve the interests of a particular class of humans. The human-nature split idea has been hugely successful for this class of humans, but it has also produced the planetary emergency we now face.

The idea of humans as not-nature originates in the work of the seventeenth-century philosopher René Descartes (1596–1660).[14] For Descartes, reality is made up of "thinking things" (*res cogitans*) and "extended things" (*res extensa*). Humans are "thinking things," and nature is made up of "extended things." However, for Descartes, not every human was a "thinking thing." Specifically excluded were women, indigenous/colonised peoples, slaves, and servants. For Descartes, these classes of person were not fully human, but part of nature. "Thinking things" are rightfully the masters and possessors of nature (which includes those considered not fully human), and nature is something to be controlled, dominated, and known. Thinking, in Descartes' schema, is reason, the exercise of "pure intellect." It is the functioning of a mind defined by its ability to radically separate itself from the bodily substrate that nourishes and supports it *and* from the matter it contemplates. At around the same time, Francis Bacon (1561–1626), a philosopher widely characterised as the "father" of modern science, was arguing that understanding nature is achieved by "attending to" or "courting her" so that "she reveals her secrets." This understanding, he thought, would allow man to exercise his rightful dominion over nature (thought of as feminine).[15]

Bacon's empiricism—looking for patterns in nature—and Descartes' rationalism—pure reasoning in a mind radically divorced from nature—are foundational to modern science. However, the thinking on which these foundations sit (and the implications of this thinking) is only really visible to historians and/or philosophers of science. The invisibility of science's conceptual foundations to most working scientists, science educators, science policymakers, and the general public has allowed science to be widely thought of not only as "representing" nature, but as if it *is* nature, while scientists are thought of as "not-nature," able to master, control, and use it. This view of science, originating as it does in the Baconian/Cartesian worldview, is based on some important exclusions. One of these, important for the present purposes, is that only "thinking things" can be the "subjects" or "knowers" of scientific knowledge. All non-thinking things—that is, the classes of human listed earlier, non-human living things, and non-living things (soils, rocks, rivers, oceans, weather, and so on)—are thought of as part of nature and therefore

[14] The following account of Descartes' thinking draws material from Lloyd (1993) and Tuana (1993).

[15] This outline of Bacon's ideas is informed by Merchant (1980, 2008), Keller (1985) and Lloyd (1993).

the "objects" of scientific knowledge. These "extended things" have no independent agency: they are non-rational matter, to be studied, understood, acted on, controlled, and dominated (Keller, 1985; Irigaray, 1987; Sartori, 1994).

Modern political and economic thought is founded on the same principles. Because, at the conceptual level, the abstract individual actor of the political/economic sphere is a Cartesian "thinking thing," women, nature, and complexity are excluded. As Anna Yeatman puts it "some individuals are more individual than others" (Yeatman, 1988). The rational, autonomous, choice-making individual of the modern public sphere is, at the conceptual level, a white, male, property-owning individual. All other categories of person—women, non-property-owning men, servants and indigenous/colonised peoples—are conceptually part of the domestic sphere and/or nature. They are not "fully" individual: they are part of, subsumed into, and controlled by the male head-of-household (or coloniser) who is the political/economic individual. While two hundred or so years of activism has produced formal, surface-level equality and women (and indigenous/colonised peoples) can now participate in science and public life, at the deepest conceptual level, they cannot "really" be the "knowers" of science or actors in the public sphere.[16] Neither can non-human living things and non-living things: like women, indigenous, and working-class peoples, they are Descartes' "extended things." conceptually part of nature.[17]

The Cartesian "revolution" was also crucial to the success of capitalism. Patel and Moore (2018), in their history of capitalism, identify four transformations that formed the world we know today and continue to shape thinking.

> First, either-or binary thinking displaced both-and alternatives. Second, [the Cartesian revolution] privileged thinking about substances, things, before thinking about the relationships between those substances. Third, it installed the domination of nature through science as a social good. Finally, the Cartesian revolution made thinkable, and doable, the colonial project of mapping and domination. (p. 54)

[16] This section draws on material in Pateman (1988, 1989); Yeatman (1988); Flax (1990); Gutman (1980).

[17] It might seem odd to argue for formal "human" rights for non-human living things and non-living things: however, in Western-influenced political systems, this is the only available strategy for redressing claims of injustice. This strategy is being actively pursued by some indigenous and environmental groups: for example, in 2017 the New Zealand Parliament officially recognised the Whanganui River as a living being with legal personhood status and is soon to do the same with Te Urewera forest and Taranaki mountain. See: https://www.nationalgeographic.com/culture/2019/04/maori-river-in-new-zealand-is-a-legal-person/. Similarly, Lake Vattern in Sweden was recently recognised as a living being with legal personhood rights. See: http://www.naturensrattigheter.se/2019/05/12/verdict-for-the-tribunal-of-the-rights-of-lake-vattern/. However, it could be argued that this strategy reproduces the Cartesianism that created the injustice.

For Patel and Moore these four transformations are far from innocent. They are "undetonated" forms of symbolic violence that reflect the interests of the already powerful and licence them to organise the world in ways that suit those interests (2018, p. 47). Patel and Moore show how the mapping of nature, organising the world into grids which then became reality, allowed it to be measured, enclosed, known, conquered, and, importantly, owned. Knowledge of nature was authored and authorised by European men, and all other forms of knowledge of nature were classified as witchcraft or folklore.[18] The privatisation of land, along with the proletarianization of human labour (turning human activity into labour that can be bought and sold) were central to capitalism's success. Nature, land, and human (and non-human) labour were turned into "cheap things" to be exploited, turned into money, then capital. This cycling of nature into money and then capital has brought us to the point in history that Patel and Moore call the Capitalocene.

Cartesianism also underpins the "computationalism" that has produced the digital technologies and the internet that organise today's world (Bridle, 2018). Bridle defines computational thinking as the

> extension of what others have called solutionism: the belief that any given problem can be solved by the application of computation. . . . Computational thinking supposes—often at an unconscious level—that the world really is like the solutionists proposes. It internalises solutionism to the degree that it is impossible to think or articulate the world in terms that are not computable. (Bridle, 2018, p. 4)

Describing its origins in the mapping of nature, meteorology, and the antecedents of today's digital platforms, Bridle shows how computational thinking now structures nearly everything, so much so that anything that cannot be computed is excluded and effectively invisible. For him, this invisibility is the most striking—and dangerous—feature of today's computational "regime." Reality has been replaced by digital models of it, which because they simulate reality by simplifying it, selecting certain elements to include and leaving others out, are flawed. Leaving out the complexities of the situation being modelled (many of which are unknown) inevitably means that models are not especially successful in predicting the future. However, Bridle argues, their ubiquity in today's world has led to an inability to distinguish between simulations and reality. Models are now so pervasive that they are effectively reality, just "how things are." They no longer stand for, frame, or shape today's culture: operating beneath our awareness, they *are* culture.[19] Bridle's concern is that as we think more and more in the channels provided by machines,

[18] Linnaeus's system for naming and classifying living things, now taken as reality, as naturally ordained, is a paradigm example of Cartesianism.

[19] Bridle here cites the extent to which knowledge is now defined by Google and relationships are now defined by Facebook.

we are losing our capacity to think deeply, or even to think at all.[20] He also worries that computationalism is constructing futures that fit *its* parameters, modelled on (a selection of) past events. Excluding the uncomputable narrows our field of possible futures: it *colonises* our futures with current thinking. This is not a good way to think about, in, or for the Anthropocene.

If, as I am arguing here, the conceptual system we are embedded in, in particular, its invisibilising of the "uncomputable," has produced the present crisis, and if it is not actually possible to think outside this system, *is* there a way forward? In the final section of this chapter I propose a pedagogical approach that I think could help to navigate these difficulties.[21] This approach draws on the work of the Belgian-French feminist philosopher and psychoanalytic theorist Luce Irigaray. Irigaray's work offers an approach that is very different from most Anglo-American feminist theory, and, while its focus is the conceptual exclusion of women, it can be used to think about the exclusion of other groups.

Reading "Between the Lines"

Irigaray argues that the conventional representation of sex and sexual difference is *not* actually a system of difference: rather it is what she calls "a Logic of the Same." Within this system there is *one* sex, *one* sexuality, *one* form of subjectivity, and so on. The category "woman" is defined in relation to the category "man" as whatever "man" is not. The result of this is that it is not possible to think of "woman" as a separate, self-defining, independent category, and it is not possible to simultaneously be a woman *and* the authoritative subject of knowledge (Whitford, 1991; Grosz, 1989). While women can contribute to knowledge, their contributions must be authorised by the "real" subjects of knowledge. Women cannot be "the one": they are always "the other," occupying a position "next to" or in support of male authority, a "substitute" for the "real thing" (Sartori, 1994).

Much of Irigaray's work focuses on how "woman" can be thought independently of "man," as a completely separate category, developed and defined by women. For her, the problem with developing a separate category is that, at the very deepest level, and from the very earliest stages, our psyche and our thinking are entirely structured by the masculine Symbolic order.[22] Women *and* men only have access to a Symbolic order structured by the

[20] See also Wolf (2018).

[21] When I started thinking about this pedagogy I had high school science education in mind. However, this model is applicable wherever the primary purpose is *educational* (in the Deweyan sense of fostering ongoing intellectual growth), as opposed to where the focus is pre-professional training and/or developing specific skills. Suitably modified, the model could be used in elementary, university or informal education contexts.

[22] The Symbolic order concept comes from Lacanian psychoanalytic theory, which posits three (largely unconscious) orders through which human existence is structured. The Symbolic is the realm of language, signs, culture, law and so on; the Imaginary is the

male Imaginary. Because femaleness is not, and cannot be, represented here, there is effectively no foundation on which a specifically female subjectivity could develop. Irigaray argues that if female subjectivity and female authority are to become possible, strategies designed to develop a female Symbolic and a female Imaginary are needed. For her, there are two aspects to this, each of which depends on, and is necessary for, the other. One involves *relationships*: developing new ways for women to relate to, and work with, each other *as women*.[23] The other involves *knowledge*: developing ways to analyse, deconstruct, and refuse the fantasies of the male Imaginary. In educational contexts, this implies developing ways to teach, while simultaneously *also* deconstructing, the traditional subject matter. To address the second of these two aspects, Irigaray proposes a strategy she calls "reading as a woman" (Irigaray, 1985). In what follows I describe this strategy and explore how it could be used to develop teaching approaches designed to make visible what is currently "uncomputable."

Irigaray's "reading as a woman" involves reading the "texts" of a given knowledge system at two levels. Drawing on the psychoanalytic concepts of interpretation and transference, she distinguishes between what she refers to as the "male" and the "female" readings of a text. In interpretation, the analyst/reader "masters" the text and is able to explain the analysand/writer's intended meaning. Interpretation, for Irigaray, is the "male" (or positive) reading of a text. Its aim is to produce coherent, transparent, and verifiable statements that can be applied to other situations. Transference, on the other hand, is a (negative) position of *non*-mastery. It involves paying attention, not to the writer's intended meaning, but to the reading's *effect* on the self of the analyst/reader. It requires the reader to recognise and identify these effects (as an analyst does). This kind of reading involves interaction between the analysand/text and the analyst/reader and it generates *new* meaning. These new meanings will be specific to the situation they were generated in, necessarily contingent, temporary, and ungeneralisable. This, for Irigaray, is the "female" reading. It involves reading "between the lines," looking for the blanks, the negatives, for what has been left out in the masculinist search for "positivity." "Reading as a woman" acknowledges that coherence is an illusion, an illusion produced by eliminating all that cannot easily be defined, quantified, and computed. Irigaray does not claim that the "female" reading is superior. She says that we should engage both, "one with the other," to develop new forms of *genuine* partnership (Irigaray, 1993a; Whitford, 1991).

realm of the ego and unconscious fantasy; and the Real is the pre-linguistic biological substrate we leave as we enter language.

[23] I don't discuss the relationship aspect of Irigaray's model at all here, but for work on this, see Piussi (1990), Cicioni (1989).

Drawing on these ideas I want to suggest an approach to science education that is based on reading the texts of science at three levels.[24] The first level is the "male" or "positive reading" proposed by Irigaray. The aim of this reading is to decode the key concepts of a particular area of science, to comprehend them as they are represented in the current paradigm, and to explore how these concepts are connected up to form this paradigm. For example, if the area of focus was genetics, this reading might focus on the meaning, significance, and connections between cells, chromosomes, mitosis, meiosis, DNA, RNA, transcription, protein synthesis, and so on, as they are understood by biologists. This first-level reading resembles current practice, but its purpose is different. Rather than being an end-in-itself, it is the groundwork on which the second and third readings become possible.

The second-level reading would look "underneath" the concepts examined in the first-level reading. It would explore the wider historical, philosophical, and cultural contexts in which these concepts were developed, and to which they contribute. It would aim to find—and deconstruct—the assumptions and metaphors on which these concepts rest, and through which they are connected to their origins. Using genetics as the example again, this reading might focus on the ways the cell is commonly represented using the metaphor of a hierarchical, command-and-control system or a corporate organisational chart. The cell nucleus, or more specifically, the DNA, is represented as "in control of" and/or "directing" cell processes. These processes are represented as the linear, one-way transmission of information that has come directly from instructions inherited on the parental chromosomes. DNA is thus the "master molecule" of life, exercising its "authority" over cell processes to provide genetic stability, much as the leader of an authoritarian organisation, government, or family might. Similarly, the relationship between the cell's nucleus and its cytoplasm is routinely represented in gendered terms. The nucleus is the masculinised "mind" or "head of household" of the cell, while the cell constituents are its feminised "body," charged with executing decisions made in the nucleus. These representations are metaphors that, while they are easily traced back to science's roots in the philosophies of Descartes and Bacon, persist in today's thinking.[25] They are a way of thinking about biology that comes from the cultural contexts in which biology developed. But embedding these metaphors into biology's conceptual system "naturalises" them. It allows the metaphors to be thought of as if they are not metaphors, but "facts of nature," which in turn disallows other possible metaphors.

The third-level reading corresponds to Irigaray's "female" or "negative" reading. Aiming to read "between the lines" of the apparent "positivity" of

[24] This three-level approach draws on the "critical literacies"/"multiliteracies" field, in which literacy is much more than simply the capacity to decode existing texts (see: New London Group, 1996).

[25] This is still the case, despite today's science's acknowledgement of the complexities of the interactions and feedback loops between internal and external cell processes, between genes and their environment, and so on.

the first-level reading, it would search for the negatives, for what is left out: in particular, the hidden relationships and interdependencies that make the first reading possible. The third-level reading's purpose is to disrupt the apparent coherence of the level-one narrative. It also aims to explore the effect of this narrative on the self of the reader (Irigaray's "transference"). A third aim is to explore how the concepts examined in the first-level reading could be read "other"-wise, and how, possibly using a kind of "science fiction" approach, these concepts might be re-presented differently, if they had different foundations. Providing an example of what this third-level reading might look like is less straightforward than it is for the first two readings. However, continuing with the genetics example, reading genetics "other"-wise might explore representations of genes, cells, and so on, not as entities acting on other entities, but as complex, fluid, continuously re-negotiated relationships of exchange, mutual construction, and reconstruction, as Irigaray herself puts it, in partnership, "one *with* the other".[26] Irigaray's "reading as a woman" is different every time it occurs. What emerges from the reading depends on the situation, the interaction between the participants, and the effects of this interaction on the participants. In the introduction to this chapter, I mentioned my younger self's "feeling" of being excluded from science. Noticing, acknowledging, and using this kind of feeling, in interaction with others, is a starting point for generating new meanings, new narratives, and new spaces to be. We can't know in advance what these will look like, but this (almost) doesn't matter. The point of reading in this way is not to replace old narratives: it is to expand our intellectual capacities for life in the Anthropocene.

For Irigaray, this deconstructive work is important because it refuses the fantasies of the masculine Imaginary. It opens up new symbolic spaces in which women, nature, and complexity can represent themselves *as themselves*, not in relation to, subsumed or defined by another, but in partnership, "one *with* the other." It seems to me that this kind of work is needed to make it possible to, as Donna Haraway puts it, "reknit" things so that humans can *conceptualise* themselves as embedded in and connected to nature, as *able to* engage in the kind of multi-species collaboration, the "sympoiesis" Haraway envisages. This work needs to begin in educational contexts, especially, but not only, in science education.

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[26] Irigaray uses biological examples in her discussion of the placenta as a space belonging to "neither one, nor the other", but "one with the other" (Irigaray, 1993b; p. 38–9).

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