Chapter 5
Political Entanglement and the Changing Nature of Science

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5.1 Beginning with a Reminder…

I would like to begin with a reminder that the research leading to the current literature on the 'nature of science' is by no means a neutral field of scholarship in science education (more specifically US-based science education). It has a detailed history, and can be situated within multiple historical, political, and social contexts that intimately shape the 'nature' of educational research (Alsop and Gardner 2017). This means that an educator's orientation to science and its entanglements (a word intended to provoke your imagination) is largely sociohistorical, and by extension political. In other words, it is very much dependent on the collective narratives, material circumstances, disciplinary/ideological landscapes, and relationships that surround science knowledges and practices. In North America for example, the relevance and importance of science and science education is intricately linked to the production of human capital (Hoeg and Bencze 2017; Bazzul 2017c; Carter 2017; Pierce 2012), and the perceived need for competitive industrialized states to promote research innovation (Ziman 2000; Mirowski 2011). Given this context, a relevant critical question is how state-approved science education works to constitute relationships to others and the world. Fundamentally challenging the very nature of the nature of science is a vital activity for critical science educators, who see science and education as crucial sites of sociopolitical engagement.

This chapter advocates that education about the nature of science include a politics of knowledge by recognizing that science is inextricably entangled with different disciplines, ways of knowing, and sociohistorical and political contexts. In times of ecological crisis engaging transdisciplinarity and politics as crucial parts of

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science is increasingly becoming an ethical imperative for multispecies[1] survival. I will develop this premise by first discussing the need to open up the discipline of science education, which includes the nature of science, to other ways of knowing. Then I will discuss how science is entangled in a politics of knowledge due to its role in modern governance and the exercising of (bio)power. Overall, I take a basic critical stance to the nature of science by viewing it as an area of inquiry into what science entails, and could possibly entail, in all of its connections and embodiments historically, politically, epistemologically, ontologically, socially, culturally, ecologically, aesthetically, as well as its transdisciplinarity. A general critical stance toward the nature of science and science education writ large, however, only partially addresses the larger and more urgent problem regarding science, education and the creation of socially and ecological just futures. Along with this critical stance a pressing concern for educators must include how communities of humans and their 'more-than-human'[2] kin, might create and preserve communal ways of living together on a damaged planet. It seems more and more relevant for science educators today to move away from nature of science as merely a distillation of what is most characteristic of science, and the idea that a handful of educational researchers, or research paradigms, can definitively outline what the fields of philosophy, history of science, and science studies combined could not – science's nature. The nature of science must be *left open* to multiple forms of ongoing thought and inquiry. Think about it for a minute: does it make sense that one of the most consequential cultural developments of human history could be distilled so easily? It is not reasonable to also think that science, art, music, history, or economy change substantially over time?

My point is not just that maintaining a *boxed-in* view of science is unrealistic, but also that such a detached and discrete perspective of science is not a good way to orient scientific knowledge and practice during ecologically precarious times (COVID-19 being an example most people could identify with) when transdisciplinarity is becoming necessary for survival. It is not that looking at what makes Modern Western Science different than other ways of knowing is useless. Rather, it is to say that finding new ways to live together in an age of rapid climate change, extinctions, and the growing distance between the Global North and South[3] means recasting science as co-extensive with diverse ecologies, culture, history, and politics. The relationships of science to everything else have always been messy (Harding 1998), and will continue to get messier as human activities such as the burning of fossil fuels and the unchecked killing of the planet's species continues to

[1] Multispecies is an inclusive term that simply means the consideration of more than one species.

[2] The more-than-human is a fluid term that refers to entities other than human in ways that abolish a hierarchical order (plants, rocks, insects, humans, soil, crustaceans, etc.). In my view, the 'more-than' aspect is a reminder that inherent to abolishing this hierarchy is a radical relationality that sees any human meaning, value, or self-understanding as fundamentally dependent on relationships where humans are just one part.

[3] The Global South and North should be understood as a sociopolitical divide along the lines of exclusions, colonialisms, racisms, and socio-economic disparity.

lead to an irreversible geological age some scientists and scholars are now calling the Anthropocene[4] (Lewis and Maslin 2015). It may now be time for science educators to question the idea of always orienting to the nature of science through mainstream educational literature. Should it not also be 'mainstream' to consider scholarship across the academy in the humanities, sciences, arts, and social sciences? If the current nature of science literature purposely ignores a wide range of contexts and literatures, it risks being painfully out of touch.

To summarize, for the nature of science to be relevant to our planet's current ecological and social moment educators should keep in mind that:

1. Science involves ever changing sets of practices and knowledges that are fully entangled with other ways of knowing, histories, social contexts, economies, and ecological relationships.
2. Characterizations of science as separate from other ways of knowing, while useful in highlighting differences, may hinder the search for different ecologically and socially just ways of living on a rapidly deteriorating planet.
3. In order for science and science education to be relevant to surviving mass extinctions, climate change, and widening poverty a more radical view of science's ethico-political potential(s) must emerge.

The growing antiquation of current NOS research, policy, and instructional approaches related to nature of science, is not because many of these paradigms originated in the 1990's, but because they do not take seriously enough the pressing wicked ethical, social, and existential problems of the twenty-first century (Carter 2011). The nature of science will seem more relevant to educators and students when it facilitates collective ways of living with the beings that share our planet. Indeed, this entire volume by Hagop Yacoubian and Lena Hansson (2020) is a testament to the idea that nature of science scholarship is most relevant when it is employed as/for justice education (see also Yacoubian 2015).

To summarize, the nature of science as it has already been articulated in the literature has a history, however due to the fact that we live in times of ecological crisis the nature of science needs to be expanded to allow for a politics of knowledge and a serious and multifaceted engagement with transdisciplinarity.

5.2 Keeping the Nature of Science Discussions Going

I'd like to begin this chapter by building on a pluralistic notion of nature of science based on what long standing thinkers on the subject were already saying in a special issue of the *Canadian Journal of Science, Mathematics, and Technology Education*. The issue was organized around Derek Hodson and Siu Ling Wong's (2017) critique

[4] The Anthropocene is a label used to describe our current geological moment where human activity will come to mark the geological and biological course of the planet for millions of years.

of the 'consensus view' of nature of science, and included six responses to their critique (Bazzul 2017a).[5] I view this special issue's value as a movement toward plurality in relation to science and its nature, and in this way one of many points of departure toward a more open and multiplicitous science.

It would be helpful to present some of the key arguments about the nature of science arising from the special issue (as I see them of course). First, while some might argue otherwise, the 'consensus' view of nature of science – the idea that there is more or less a final agreement about what science entails, how it is done, or is/isn't' – can no longer boast a relevant consensus (Allchin 2017). Second, any description of science and its nature is sociohistorically, politically and materially situated. In this vein, Steve Alsop and Sam Gardner (2017) argue that educators, scholars, and scientists leave room for engaging *the particular*, or those aspects of science that don't fit neatly into boxes. One reason being is that any consensus is historically situated – or more figuratively, one tracing of a dynamic map. Another way to attend to the particular in science and science education is to focus on the intricacies of specific local entanglements and the ethical and political possibilities that emerge. Third, both large and small scale scientific enterprise literally function as active transdisciplinary entanglements, for example in the geopolitical and technology-rich agricultural sciences, such that there is no nature of science distinct from science-in-the-making (Simonneaux 2017). Fourth, science circulates multiple narratives generated by a wide range of communities that draw from many different ways of thinking and seeing the world. This includes those important narratives that describe the overall purposes of science – narratives that are most often not conceived or decided upon by scientists. One of the most important (and 'non-postmodern') points of Jean Francois Lyotard's *The Postmodern Condition* is that scientific knowledges have powerful legitimating processes nonetheless that cannot legitimate the narratives 'about science'. No matter what, science's social, political, cultural importance, and ethos, is decided elsewhere. Fifth, any ethos or set of practices related to science are always coextensive with power relations (Bazzul 2014; Dagher and Erduran 2017). It is this point in particular that this chapter argues should be made explicit when constructing or learning about science's nature. Sixth, ways of knowing and understanding phenomena that are not deemed 'scientific' by rigid disciplinary boundaries are still absolutely fundamental to science practices and knowledge production (Berkovitz 2017). And for educators interested in the relationship between science,culture, politics, spirituality, ethics and history, this is a pretty big understatement. From this vantage point we can see the consensus view of nature of science (see also Lederman et al. 2002), along with the moves toward pluralism outlined in the paragraph above as constellation points in an evolving network of practice. It is now time for another paradigm shift for science that the field of education may be well positioned to help bring about. Science educators, as part of a larger community of caring and ethical beings, need to engage

[5] Fouad Abd-el-Khalick (2012) articulates support for this consensus, and in a way that highlights the tensions that arise when this consensus is potentially undermined.

and respond to ecologically and socially urgent contexts and imperatives in the times called the Anthropocene.

Science education might realize its potential for social and environmental transformation through philosopher Jacques Rancière's (Rancière and Corcoran 2010) theorization of politics, which involves *dissensus* in the name of equality (equality not as a simplistic excuse for ignoring difference, but as a radical democratic principle). The basic idea of Rancière's politics is that the dominant social order casts the world in ways that exclude the marginalized, which includes the more-than-human (or nonhuman). Politics is a process of disruption of what is sensible/thinkable/doable in order to realize new forms of equality. While science education can cultivate a disinterest in politics, certainly it has done this, it can alternatively be part of forms of dissensus that help make those who have been marginalized and oppressed come to count equally. Since the narratives that guide and inform science education are fluid and not decided beforehand, there is no fundamental reason why science education cannot be a force for justice in the name of equality (Tolbert and Bazzul 2017).

What makes political dissensus an interesting addition to nature of science discussions is its opposition to consensus. It may well be that vigorous debates about the nature of science become a vital part of political struggles to combat climate change, environmental racisms, destructive resource extraction, extinctions and widening social inequality. This makes sense because science has already come to play a large role in both the emergence and mitigation of these phenomena. While consensus building has an important place in the normative functioning of institutions, knowledge production, and everyday cultural life, science educators might also ask what a particular consensus excludes. What relationships, interests, or beings are not being counted equally in the social/natural world? Considering much of the planet's wildlife is rapidly disappearing, and humans are exploiting all life for the benefit of a small few ('the 1%'), can scientists and science educators ethically *not* take a strong political stance? Can science educators afford not to expand the purview, powers and reach of science (and its nature)? Accepting entanglement means there is no logical sequence for the work of multispecies justice, precisely because the work emerges in relationships. An educational community can begin by looking at what is important to their own community, make connections, and look outward. It should not look the same each time. The uses, practices, and implications of science, whilst having historical, practical, technical and contextual similarities will also contain differences, which is a major implication of Douglas Allchin's (2012) historical work.

To summarize the main points in this introduction, while some science education scholars have already tried to expand understandings of the nature of science to include considerations of broad sociopolitical contexts, I suggest that a more concentrated engagement with plurality and politics is imperative for multi-species flourishing and survival. In the next section I take a closer look at politics, power, and dissensus as contexts for science, science education and the nature of science.

5.3 Science Education, Modern Governance, and a Case for Political Dissensus

> There is no model of truth that does not refer back to a kind of power, or no knowledge or even science that does not express or imply, in an act, power that is to be exerted. All knowledge runs from a visible element to an articulable one, and vice versa; yet there is no such thing as a common totalizing form, not even a conformity, or bi-univocal correspondence. (Deleuze, in *Foucault* 1988 p. 39).

Critics of continental philosophy and staunch scientific realists may not like the epigraph to this section. Afterall, it was not written by a scientist or science educator! However, if educators cannot listen to a multiplicity of voices, I am not sure what hope there is for the future. Educational communities who want to work toward environmental and social justice should consider that the nature of science is completely coextensive with politics (exactly how should remain a contested terrain of argument), which means that science needs to be conceived and practiced as a politicized activity involving an intricately entangled transdisciplinary set of practices. While many science educators might argue that science and politics have connections, and that other knowledges are helpful to scientific practice, much of the literature and discourses of science education may not put these in relation to the current sociopolitical and ecological moment in which we are currently living.

One reason for this is that the education of scientists, and science educators for that matter, often does not include an examination of how science practices, institutions, and knowledges are necessary for the governance of both human and more-than-human bodies. However, both science and education are *biopolitical*[6] sites of engagement – where dissensus and disagreement become ways to engage distributions of power and technologies of social control. Engaging politically through science education involves aesthetic shifts – allowing something different to be sensed, seen or done. These shifts necessitate a focus on difference and relationality, and this includes the affective-political dimensions of science education (Kayumova and Tippins 2016), which are key to finding new ethical forms of communal living.

A more relational and politically relevant view of the science will involve letting go of the need for absolute descriptions of science, or what science educators like Maria Wallace (2018), following Gilles Deleuze (1994), call a *majority*[7] view of science: overarching abstractions that mask complex relationships between

[6] In short, biopolitics refers to the way modern forms of governance constitute, the conduct, values, and social life of human beings (and their more-than-human kin). Science discourses, which purport a certain amount of objectivity, are power-infused discourses that accompany the exercising of power in modernity (Bazzul 2014).

[7] Although there is not enough space to give a thorough explanation of Deleuze's view of majority/minority, majority views think with concepts already outlined while minority views attempt to make a flight away from these categories. Science, to some extent, struggles with a majority/minority dilemma as scientists attempt to work within paradigms of already accepted concepts, whilst simultaneously attempting to develop knowledges and practices that break free from accepted ways of understanding the world.

phenomena (e.g. between humans and the more-than-human). 'Majority' views are perhaps unavoidable because they serve multiple functions, but they are always incomplete. Therefore alongside majority views of science, educators who care about seeking and nurturing complex relationships with the world must also seek what might be called a *minority* view: an escape from being locked into rigid views of the world and how to engage it. Science educators need space to dream differently in-community with our more-than-human kin (Bazzul et al. 2018). This will involve not just an epistemological shift, but an ontological one. To pursue science's ecological and social entanglements, educators must also seek to *become-minor* as far they are open to complex ecological, technical, historical, social, political, ethical, and relational context they (or others) may not yet understand very well. A minority view finds itself in the *middle of something*, it does not claim to be the ending or a superior view of our shared world.

The epigraph to this chapter suggests that there are always multiple capillaries of power running through relationships of knowledge and the social order. A basic lesson of philosopher Michel Foucault's work is that objective knowledge – of which science is a huge part – is co-extensive and entwined with power relations and modern governance. If this is true, then science's integral role in governance and disciplinary power must be engaged by a wide variety of educators, scientists, and community groups. In order to understand how science and the exercising of power are co-extensive educators need to engage social theory; and Foucault's work is an effective theoretical guide to the functioning of power. One important aspect of power is that it is not just exercised 'from above' through institutions, capital, or the interests of a ruling class. It is also exercised 'from below' at the level of conduct and bodies (Foucault 1978). Think about this: how does scientific knowledge bring people to understand themselves as healthy individuals, a biological species, or a labouring subject in an economy? Modern science is not only linked to economic interests, but helps form the 'grid of intelligibility' by which people make sense of their lives. To put it in aesthetic terms, scientific knowledge helps cast what is visible and sensible, and in this way helps keep particular configurations of power, for better or for worse, in place. However, power relationships are not straightforward. It is not just a matter of determining ideological or economic agendas within a scientific project, although this is a worthwhile endeavour. An important question for science educators to ask is: What do our pedagogies allow science students and teachers to see and do? What does it enable, and how might it be disabling? If seeing and doing things differently for multispecies survival is an obvious ethical imperative for the Anthropocene, science educators will increasingly find themselves engaging contexts of political disagreement and dissensus.

There is a tendency for science educators to get hung up on epistemology. Indeed part of the 'science wars' of the 1990's consisted of 'battles' over epistemology and the limits of science. These debates pitted 'scientific realists' against 'postmodernists' in ways that oversimplified both perspectives. While a range of views exists about how much science is influenced by power, ideology, and technologies of governance, etc., it is undeniable that relationships between knowledge and power exist. These relationships do not necessarily preclude any specific epistemology, no

matter what people on either side of the 'science wars' may say. Maintaining that there is a relationship between knowledge and power, does not mean things cannot be 'true'. Foucault (2003) is clear on this: 'truth', regardless of whether something is *actually* true or not, has a relation to power. This view is quite compatible with many epistemological positions, including realisms (e.g. critical realisms, scientific realisms), which are perhaps the most appealing epistemic outlooks for science educators. Exploration of science's political entanglements is not any sort of assessment of science's 'veracity', or the 'scientificity' of its claims. Again, this is why different descriptions and deployments of science will involve many 'minor inquiries', rather than one overarching truth about knowledge, science, politics and the social world.

Science's entanglement with politics, a vital part of its nature in precarious times, may be thought of as the exercising of power over life, what many critical scholars refer to as biopolitics. Biopolitics is wide-ranging term used to characterize the exercising of (bio)power, and also resistance to this (bio)power (Hardt and Negri 2000), in the lives of both human and non-human life, however I use the term here mostly as it relates to human bodies (see Thomas Lemke's (2011) comprehensive overview of biopolitics).[8] It is helpful to think about power relations using Michel Foucault's (1982) work on subjectivity and governmentality, where knowledge/science, along with the various techniques of subjectification (the constituting of individuals as governed subjects), circulate the effects of power. Essentially, power flows along multiple capillaries and this directionality is always two fold. Like the flow of electricity, the exercising of power always meets with resistance. If there is no resistance, there is no exercising of power. This means a situation of absolute domination and docility, political or otherwise, ceases to be a power relationship. The exercising of freedom and ethical reflexivity naturally becomes very important within this conception of power, especially when thinking about how education brings students into spaces where they must consider how to lead ethical lives (Bazzul 2017b).

Scientific knowledges and discourses, including discourses of science education, carry the effects of this power to a greater extent than other discourses because they purport to objectivite. In the case of science education this objectivity is doubled, as the very fact that state institutions have sanctioned curriculum resources and policy also adds an objective quality. The exercising of power, is used to constitute subjectivity by working to 'conduct the conduct' of individuals; however this power is both 'accepted' and resisted. Therefore power works to actively constitute the subjectivities of individuals 'from above', and individuals collectively function to constitute the institutions, organizations and strategies of power 'from below'. Figure 5.1 is a simple diagram that helps illustrate these basic attributes of power. The diagram is not meant to define or represent power, but to provoke educators to think about it.

[8] Biopolitics is also a useful frame for understanding modern science and ethics (Bazzul 2015a), as well as the production of labour and science education (Bazzul 2017c).

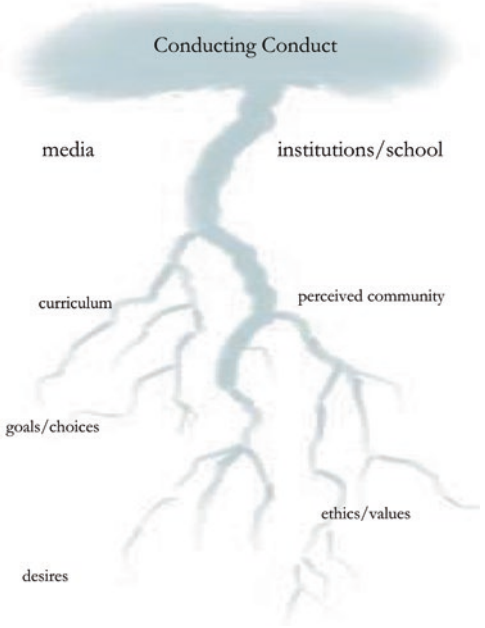

Fig. 5.1 Illustration of power based on the work of Michel Foucault (1978, 1982)

So how is thinking about power important to science education? If we take a slightly broader perspective, all ecologically dangerous and socially unjust conditions, from colonialisms to capitalist economic systems, involve the widespread exercising of (bio)power, which is subsequently met with (bio)political resistance from below. Sandra Harding's (2008) book, *Sciences from Below: Feminisms, Colonialities, and Modernities* documents some of the ways activists in India have helped shaped agriculture science and science policy, as well as how citizen groups have altered the direction of medical research (e.g. autism). Science research and science education are both entangled with the exercising of biopower and the (bio) political resistance to this power. The way science-related ethical issues are introduced and taken up in science classes, can be attached to interests that forward a particular agenda or configuration of power such as neoliberalisms and/or 'naturally' associated a scientific mindset with the Global North (see Bazzul 2015a). Modern governance takes both the population and the individual as objects of intervention in terms of 'who to let live' and 'who to let die' (Bazzul 2014; Foucault 1978). Historically, the co-development of the biological concepts of a 'milieu' and population genetics with practices of modern governance, from census statistics to eugenic programs, demonstrates a parallel story of the co-emergence of scientific knowledges and forms of social control (Rose 2009; Murphy 2017; Canguilhem 2001; Pierce 2012). The interests of the state and corporations, more and more eclipse the needs of communities. Science needs to play a role in larger cultural, geological, ecological, and political 'plays'; therefore imagination is absolutely

necessary. How science constitutes students and teachers as 'subjects of knowledge' is still an underrepresented research area in science education (Blades 1997).

Another question that arises is what kinds of scientific discourses carry the effects of power? Practically speaking, it is helpful to look to those discourses that attempt to intervene in how individuals come to understand their own conduct, values and relationships. Science discourses that constitute the activities, purposes and ethical considerations of life, such as those of biology, tend to lend themselves to social, political, and institutional prerogatives. However, educators should also examine sciences like physics and geology, because they orient humans to things like resources and land. Other helpful considerations for educators include how:

- the biological sciences bring people to see their bodies and the bodies of others (as racialized or genetically disposed); and how these bodies should be organized and cared for, which includes how people come to work on ourselves.
- science raises questions of collective existence, for example the appropriateness of technologies, resource development, ecological relations between various populations (human and otherwise).
- science knowledges and discourses help delineate 'how' one might think and act rationally, and ethically. What does it mean to be a science person? Says who? What else might be considered in this view?

The point is precisely for educators to discuss how science is deeply interwoven with governance and politics. This is because engagement with political entanglement, and not a blind faith in technology, is vital for our survival. This aspect of science must be seen as vital to its nature. The warrant for science education should be ecological and social justice for survival. Ajay Sharma (2012) argues as much when he argues to position Climate Change, which is a political issue as well as an ecological issue, as the central guiding phenomenon of science education. In light of this pressing new warrant for science education it would be unethical to ignore the ecological-political landscape affecting communities globally. Science educators and students need to *get real.* Yet, justice oriented scholarship in science education is often 'domesticated' or co-opted for mainstream science education, by clambering to the self-interested directives of governments and corporations (Tolbert et al. 2018).

To summarize, science is integral to modern forms of political power and governance. Due to the relationships between knowledge, power and institutions, science education that endeavours to teach for justice must not ignore this aspect of science's nature. Not only do truth discourses exercise power (independent of their actual truth value), schools that disseminate such discourses work to shape the conduct of subjects. Science education, due to its specific relationship to truth discourses, both official discourses of government and science knowledge, must pay extra attention to its own political entanglement.

5.4 Science Education and Political Entanglement

In my own teaching the Anthropocene, along with its more descriptive alternatives such as the capitalocene (Moore 2017) and the chthulucene (Haraway 2016), has become central to why students should learn about science in the first place. The Anthropocene is one potential context through which ways of knowing the world become instantaneously connected (Moore 2017); and make no mistake; facing the Anthropocene is an ethical-political task. This task should be seen as less of a choice, and more a necessity. The Anthropocene is a time when modern binaries of cultural/natural, geologic/geographic, political/scientific, and human/more-than-human are quickly dissolving. Big agriculture's razing of large forests, European colonialism and the resulting displacements and genocides, industrial-military nuclear testing, and global capitalism's disregard for life have permanently marked the geological record for millions of years to come.

It is therefore unethical for science educators and researchers to somehow render the sociopolitical/geological/environmental as secondary or tertiary aspects of the nature of scientific endeavour. Jay Lemke (2011) maintains that science education is distinctly conservative in character, and that not engaging issues of pressing concern for students is a form of *collaborationism*. Simply put, a liberal frame might be inadequate for mediating our current position (Lloro-bidart 2015). Denying the sociopolitical realities that form the backdrop of science, and vice-versa, is becoming extremely difficult to maintain. According to physicist and philosopher Karen Barad (2007), 'the scientific' must now contend with the fact that it is always already sociohistorical; and likewise the 'sociohistorical' must contend with the fact that is always already biological and geological. The Anthropocene sets the stage for exploring an entangled science, one that is more in-tune with ecological necessity. If science knowledges are integral to the exercising of (bio)power, this means that science and science education are also sites of political engagement. This is where an openness to multiplicity and the freedom to dream become vitally important.

A more radical way of looking at politics can be found in Jacques Rancière's (Rancière and Corcoran 2010) vision of politics as dissensus, disruption of the status quo, the domain of what is sensible and thinkable, in the name of equality (as outlined briefly above). Elsewhere, I have suggested that science education communities align their pedagogical approaches with social movements, such as the Indigenous grassroots movement "Idle No More", in order to commit science education to bringing about more ecologically and socially just futures (Bazzul 2015b). Of course, engaging social movements in the classroom can be difficult and sometimes risky.[9] It is much safer to engage more traditional citizenship education and non-controversial ethical issues related to science. However, traditional forms of

[9] For example, teacher colleagues in Saskatoon, Canada created a disturbance when they took their eco-justice students to support and an Indigenous rights sit-in (MacPherson 2016). There was also many that showed solidarity for the teachers, including many members of our faculty of education at the University of Regina (see open letter)

citizenship education, and 'safe-to-discuss' ethical issues very often tacitly assume a particular social, political, and historical backdrop that remains unchallenged. Citizenship education that embraces Rancière's vision of dissensus means teaching less content and more about the necessity of dissent; not for its own sake (who would want to dissent for no good reason?) but where the equality of communities, including nonhuman life, is concerned. Educational theorist Gert Biesta (2011) argues for this form of citizenship education in his figure of the *Ignorant Citizen.* This form of citizen knows less about what the state would prefer them to do (or be) as citizens, and more about disruptive actions.

Instilling an element of radical democracy also means examining how we as science educators run our own classes. Rancière argues that education for emancipation requires that educators let go of holding their explanations as forms that students must simply reproduce. Such education stultifies the creative powers of students. A basic equality runs through education communities when everyone is given the equal ability to offer a different interpretation, creation, or result (Rancière 1991). Science educators might say: 'Wait a minute! There are some works/knowledges that are more correct or better!'. Yes it is certainly true, in many ways, some works are better than others – the history of literature tells us this much. It is also true that some works fit better with traditional paradigms of established science. However, the epistemic dimensions of knowledge and science deserve much more attention from educators. Following Lyotard's (1984) *The postmodern condition: a report on knowledge*, science has a more or less egalitarian form of knowledge transfer, because there is an assumed equality between the sender and the addressee of knowledge (Bazzul 2013). As science educators we can nurture this radical equality inherent in science communication in our classrooms. At the same time, however, science students and teachers also offer unique work around the narratives, practices, contexts, and knowledges that surround and infuse science – and these are infinite in scope. Science classrooms may therefore be unique in their *dual-capability* to render an equality in communication, both at the level of communication of science among equals who engage in practices of verification and communication; and also in the validation of different situated ideas around the contexts, meanings, applications, and knowledges of science. In summary, equality manifests in science classrooms through a simultaneous recognition of equality in communication and also in the diversity of the speaker in terms of how they are embedded in the entanglements of science and life.

Although criticised for not being 'activist' enough, The US-based "March for Science" demonstration, was a careful stand taken by concerned scientists and members of the US public, along with their global allies, to defund health and climate change research by the Environmental Protection Agency and the National Institute of Health (St. Fleur 2017). Some criticized the March for only being a response to a shift in the original status quo (e.g. science is funded and therefore scientists often did not see the need to get involved in issues outside their particular research purview). Would scientists be silent if a sufficient amount of funding and a modicum of relevant policy were made available? Was the professional (largely white male) scientists' unique position as knowledge producers and experts simply

being threatened (and they were responding only to a loss of power)? While these questions are worth engaging, there was, however, a significant rupture in how scientists viewed their entanglement with the social and political world. At a basic level, there was a realization that it is the sociopolitical backdrop that determines what science gets done, and more importantly if it gets done at all!

As stated above a dissensus view challenges the taken-for-granted notion of consensus, which, as I suggest, might include 'consensus' around what constitutes science and its nature. This is not to negate consensus building as a key process to the everyday work in which communities engage. Research into socioscientific issues (Sadler 2011; Zeidler and Nichols 2009) is exemplary for classroom teachers and students to learn the difficult work of coming to a community consensus around socioscientific issues – whether these activists create a breach in the domain of the sensible in the name of equality is however another question and would depend on context. This is because consensus building often happens after certain considerations, positions, and actors/actants are already legimated – thereby concluding or bypassing the process of politics of equal inclusion (if we continue to use Rancière's definition). Politics enters the field when occluded groups, their claims, and the basis for these claims attempt to achieve equal consideration by breaking with what was hitherto sensible, visible or thinkable. How are decisions made about science related issues concerning how communities live? How are the ideological and material frames of these questions already decided beforehand? Whose ideas and viewpoints are never considered? How is power exercised through science so as to render certain actions commonsensical? Disagreement achieves politics when it causes a reshaping of what can sensed or thought in the name of equality (Rancière and Corcoran 2010). Case in point, scientific consensus on climate change has not been enough for governments and corporations to take significant action. Simply put, science and science education must disrupt the status quo, and realize its many political entanglements as a fundamental part of its practice.

In summary, science education might align itself with political movements so that it is a force for survival and justice for diverse communities. "Staying neutral" might be a tragically unethical goal for science education. Staying oppressively disengaged will not achieve the kind of ecologically and socially relevant science 99.9% of people in the world desire.

5.5 Conclusion

It may be much more important for science educators to dwell on the precarity of our current global moment that renders all (singular) personal and collective strategies, green consumerism, personal responsibility, pipeline protests, as inadequate responses to the onset of the Anthropocene (Shotwell 2016). In these times, science, and what we think it is (its nature), needs to be part of a revolution in thinking and material organization on planet earth. And like geographer and ecologist Jason Moore (2015, p. 2) warns: "Modes of thought are tenacious: they are no easier to

transcend than the "modes of production" they reflect and help shape". Indeed educators will teach and research in increasingly dire times that make older contexts for constructing knowledges and pedagogies seem embarrassingly antiquated to our current moment (can we not see that just with the events of 2020). What the onset of the Anthropocene shows is that radical ontological shifts in our thinking are immanent, both in terms of the ways diverse educators are coming together to challenge categories and knowledges that position our shared worlds as something to be consumed by capitalism and ongoing forms of colonialism.

Nature of science for justice must radically open up what science means, and give a big space for politics in increasingly intricate ways. I consider the following summary points essential to this endeavour.

- Any nature of science research, like any history or philosophy of science research, is socially, culturally, politically, historically, and even materially situated – and therefore open to interpretation and criticism. Always.
- In light of the situated nature of science, a move toward plurality, transdisciplinary and relationality makes more sense in twenty-first century contexts and the need to search for communal life with our more-than-human kin.
- Scientific knowledge is heavily entangled in modern forms of governance of individuals and populations. This manifests in the exercising of power to conduct the conduct of individuals (biopower), and also resistance to this power (biopolitics).
- Citizen roles/activities as usual, while useful in broaching ethical topics, often leave the social fabric, what is thinkable and doable, in place.
- Engaging politics, as forms of dissensus in the name of (multispecies) equality, is a necessary way for science to contribute to just futures and realize its vast entanglement in the world, as part of its nature.
- Science classrooms are very fitting spaces to engage questions of collective existence because of the influence and input science has over an ethics and politics of life itself. Science education's potential for cultivating values of equality may be underestimated.

So where to begin recontextualizing an entangled and pluralistic nature of science? It could simply begin where you are: what is culturally, materially, historically and politically entangled and urgent. Why not? Who says? Overall, it should look messy, with connections leading disagreement and even conflict: but also to exciting and productive questions and projects. Innovative work already underway can be seen in the way nondominant knowledges and communities are beginning to be engaged in science classrooms (Bang et al. 2012). Engaging marginalized communities includes engaging gender diversity and sexuality (Fifield and Letts 2019), Indigenous knowledges and methodologies (Cajete 2000); and communities of colour experiencing long-standing poverty and environmental racism (Morales-Doyle 2017; Mensah 2011; Kayumova et al. 2019). It also means engaging other ways of expansively thinking about our shared world such as arts and aesthetics and science fiction (Gough 2017); or Black and Indigenous futurisms (Okorafor 2018; Dillon 2016). My hope is that educators move in solidarity to bring about the shifts required to

deal with collective living in the Anthropocene. Now is the time to expect more from the sciences and from the potentially dynamic field of science education.

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