Re-imagining school science for the Anthropocene

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This paper makes an argument for the need to re-imagine science education in the compulsory school sector to better meet the needs of young people growing up in the Anthropocene. It argues that connecting emotionally and imaginatively with the natural world; being able to see systems and appreciate complexity; and knowing something of the history and philosophy of science should be key features of an education designed to prepare students for today's world. It is time to re-think how curriculum is organised – and the role of science within the curriculum – rather than tweaking the edges.

The current situation

In New Zealand, as well as internationally, in recent years there has been a strong focus on strengthening the role of science in society. This has meant schools have been expected to provide pathways for future scientists and to develop a level of "scientific literacy" for everyone. This citizenship role is emphasised in the current *NZ Curriculum* document that states,

> In science, students learn about the natural, physical world and science itself so that they can participate as critical, informed and responsible citizens in a society in which science plays a significant role. (MoE, 2007, p17).

Despite these aspirations, and the development of various strategies designed to support them[1] concerns remain about the effectiveness of science education in New Zealand. In the *2017 National Monitoring Study of Student Achievement in Science* only 46 percent of principals rated the school's provision of science at Year 4 as either "good" or "very good". There was also no significant improvement in the overall average scores for Year 4 and Year 8 students between 2012 and 2017. New Zealand's participation in two large international studies – *the Trends in International Mathematics and Science Study (TIMSS)*, and the Programme for *International Student Assessment (PISA)* also does not indicate significant improvement in achievement over time. The central concern of this paper is not, however, about *improving* science education. It is about *re-thinking* what an education that aims to equip students for today's world might look like. How might school best prepare students to grapple with the complex problems, such as climate change, associated with the Anthropocene?

[1] For example an emphasis on learning about the Nature of Science, the development of a set of "science capabilities", pedagogical approaches such as inquiries into socio- cultural issues etc.

It can be argued that the modernist view of science with its Cartesian divisions between people and nature, mind and matter etc. has led to many of the problems we are now facing. As Anne Salmond maintains in *Tears of Rangi: Experiments across worlds:*

> In New Zealand, as elsewhere, shifts towards atomistic ways of being, anthropocentric models and extractionist habits of mind have been associated with fragmentation in social networks, growing inequalities between rich and poor, incarceration of many young people (especially young Māori men), market failures in housing and finance, and the degradation of fresh water, land and maritime ecosystems. (Salmond, 2017, p.414).

Perhaps it is time to pay closer attention to the growing body of literature that understands humans as being inextricably linked to, and part of, the natural world (Judson 2010, Capra 1996) as opposed to the modernist view of science which positions humans outside nature. This latter view of science is still deeply embedded in Western thought and prevalent in many science classrooms (Osborne, 2007). This is despite a paradigm shift that, according to some scholars, took place in many branches of science during the 20th Century – a shift from mechanistic, reductionist thinking to holistic, complex, systems thinking. (Capra 1996, Funtowicz & Ravetz 1993). If the modernist view of science, with its Cartesian divisions between people and nature, is implicated in the ecological crises we are now facing (Salmond, 2017) and the view of science commonly portrayed in science education no longer accurately reflects science itself (Tytler & Symington, 2006) then it calls into question the role of science in the school curriculum. If science education was re-imagined to focus on students connecting with the natural world, and appreciating complexity what might it look like?

An alternative curriculum

The rest of this paper sets out some ideas for re-imagining science education. It proposes a new curriculum that does away with the siloed learning area called “science” – where students learn *about* the natural/ physical world and science itself – to a more integrated curriculum where students *connect* emotionally and imaginatively *with* the natural/ physical world and appreciate its complexity. They also learn about the history and philosophy of science. In this proposed curriculum students will be encouraged to explore various ways of making sense of the world – including through science. Before detailing what such a curriculum might look like four reasons are provided for the proposed switch in focus.

Reason 1: Importance of connecting emotionally and imaginatively
An emotional connection to nature along with some depth of knowledge about it, leads to the development of a sense of place. (Judson, 2010). Across the disciplines, this sense of place is considered important in various ways. In the ecological education literature (and central to this paper) it is argued that a sense of place can provide the emotional bond that can inspire people to live sustainably. In the New Zealand context, a sense of place is particularly important to Māori, and is said to contribute to a sense of individual and collective identity (Penetito, 2009). Perhaps a close emotional connection with the natural world could help not only protect the planet but also contribute to the development of a more genuinely bicultural society.

As well as being a valued outcome, emotional engagement is also a powerful pedagogical tool. Research suggests that emotional engagement benefits learning. Experiences that create an emotional reaction are not only better remembered (Willingham, 2008) but also support better reasoning (Claxton, 2015). In discussing the importance of emotions in learning Glasser (2002) goes as far as to say:

> Feelings and emotions are the glue that inextricably marries "facts" and "values." They bind the world that is, with all its splendour and terror, to the world of our hopes, dreams and imaginations. Feelings and emotions are the source of our ideas, inspiration and creativity: they are what enable us to reason deeply and they are what impel us to act. (Glasser, 2002, p.xviii)

Reason 2: Importance of the ability to discern and appreciate complexity (systems thinking)
Appreciating the complexity of the natural world, involves seeing it as a complex system – rather than as a collection of individual elements. A system is an interconnected set of elements that is coherently organised in a way that achieves something. (Meadows, 2008). Systems can be simple, complicated or complex (Sumara & Davis, 2006). Most biological systems are incredibly complex – "they are dynamic, self-organising, and adaptive networks of interactions" (Falk et al., 2015, p148). They often involve systems nested within systems. Changing any part of these systems can affect the behaviour of the entire system – often in unpredictable ways.

The term "systems thinking" is used in the literature to describe an approach to understanding systems that involves engaging with the complexity of the system, rather than reducing it to discrete elements. (Sommer & Lucken, 2010). Systems thinking foregrounds relationships, connectedness and context. The emergence of systems thinking challenges the fundamental analytical thinking that was central to a modernist view of science. The key difference between systems thinking and analytical thinking is a shift in the relationship between the elements of the system and the whole. In systems thinking, the elements of a system can only be understood within the context of the whole. "Nature is seen as an interconnected web of relationships, in which the identification of specific patterns or "objects" depends on the human observer and the process of knowing."(Capra, 1996. p 40.) In this way systems thinking is similar to many indigenous ways of knowing. (Knudtson and Suzuki, 1992).

Systems thinking is important because it provides hope of new insights into dealing with the major problems of our times. It has the potential to help us know *differently* – to see new possibilities – and to engage more authentically with other ways of knowing. (Davis, Sumara & Luce-Kapler, 2008).

Reason 3: Importance of knowing something about the history and philosophy of science

The idea of including knowledge of the history and philosophy of science in this proposed curriculum was borrowed from the Pūtaiao document (Ministry of Education, 2009). As explained in that document, the aim of including the history and philosophy of science in the curriculum is to enable students to "examine science from the outside, in order to study its characteristics as a product of human culture" (Ministry of Education, 2009, p128). From the outside, students can learn about the benefits science has brought to society but also its role in the historical marginalisation of indigenous cultures and people. Science can be seen more easily as a particular way of making sense of the world, rather than as a reflection of the world as it really is. In studying the history and philosophy of science, students are provided with opportunities to learn the stories of science – the successes and failures, new discoveries and changing ideas. They also consider the ethical and societal dimensions of science.

Reason 4: Importance of breaking down the subject silos in the curriculum

This is probably the most controversial of the ideas for a re-imagined curriculum. At a purely pragmatic level, removing a siloed school subject called "science" and replacing it with a trans-disciplinary theme called "our world" or something to that effect, would signal that science learning and teaching needs to radically change. The experience in New Zealand, of introducing new ideas or approaches into curriculum (for example, the inclusion of the Nature of Science strand into the science curriculum) is that these new ideas are interpreted through the existing sense making systems of teachers. This means the ways the ideas play out are often very different from the original intent.

If the focus is on developing students who can appreciate the complexity of systems, then it seems to make more sense to organise curriculum in a way that is freer and less bounded than the traditional siloed “disciplines”. This proposed curriculum focuses on the learner, rather than the subject area. Students are encouraged to make sense of their worlds in a range of ways.

An alternative curriculum in practice

The final section of this paper explores some ideas of what such a curriculum might look like. In doing so, I have drawn heavily on Kieran Egan’s theory of Imaginative Education and Gillian Judson’s approach to ecological education (which builds on Egan’s theory). In Kieran Egan’s theory of Imaginative Education, emotions and imagination are central to effective learning. Egan argues that as learners see possibilities through imagination, they become emotionally engaged and connect value or significance to what they are learning. Imaginative Education is structured around the idea that children at different ages use different “cognitive tools” to make sense of their world and this means different pedagogical approaches are particularly powerful at different ages (Egan, 1997).

The curriculum proposed here is divided into 3 stages which cover the years in the current NZ curriculum where science is a compulsory subject[2].

- Early primary (5- 8 year olds approximately) focuses on building an emotional connection to the local environment.
- Middle/ senior primary (9-12 year olds approximately) builds on the emotional connections already established and begins to foreground systems thinking.
- Junior secondary (13-14 year olds approximately) builds on the previous stages and introduces the history and philosophy of science.

Early primary

At this stage, the focus is on building an emotional connection with the local environment – to learn to love it and feel comfortable in it. Children are given regular and frequent opportunities to engage all their senses in exploring the local environment. They might lie on the ground and feel the grass tickle their skin, feel the wind on their faces, smell the leaves, taste drops of rain, make “sound maps” of the different noises they can hear, look for changing patterns etc.

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[2] This proposed curriculum does not cover senior secondary school where the subject is currently optional and arguably has a different purpose.

Back in the classroom teachers use a range of developmentally appropriate strategies to further engage students emotionally and imaginatively in the world. Judson (2010) suggests that story and mental imagery are particularly powerful tools at this stage. Stories allow children to experience the world through another person's experience, introducing different perspectives. Mental imagery also allows students to imaginatively explore different perspectives. Here is an example of what is meant by mental imagery.

> *When teaching about flowers, one could imagine emerging from the cold ground, pushing towards the light, bursting with a kind of ecstasy in the warmer air, turning with passion toward the sun, feeling the rush of sap, then experiencing the horror of the returning cold, and shrivelling back underground, (Egan, 1997 p 61-62)*

Children could close their eyes and imagine being the flower – perhaps even acting it out as the story is narrated. The possibilities are endless and well within the current capabilities of junior primary teachers.

Middle/ senior primary

During these years there would still be a focus on building an emotional connection with the natural world but students would be encouraged to go deeper through *slow looking,* a strategy developed by Shari Tishman, a Senior Research Associate at Project Zero. Tishman defines slow looking as "a way of gaining knowledge about the world. It helps us discern complexities that can't be grasped quickly, and it involves a distinctive set of skills and dispositions that have a different centre of gravity than those involved in other modes of learning." (Tishman, 2018. p 2). Slow looking encourages students to observe details, to defer interpretations, to appreciate complexity, to shift between different perspectives and to "see the system". The focus is on understanding how things are now. In this way slow looking introduces systems thinking.

To gain benefits from this approach it is necessary to put aside time for slow looking, teach students strategies, structures and tools to support their looking, and to cultivate the disposition to look slowly.

During these years, students would also be encouraged to start interacting with environments that are more distant from them both in location and time. What is our school's local environment like compared to that of a school in another part of the country or the world?

What was our place like when our parents or grandparents were growing up? What has changed?[3]

Students will also carry out a range of inquiries that will be supported with thinking routines designed to explore complexity[4]. Traditionally many educational approaches, especially in science, are aimed at simplifying complexity but here students will be encouraged to engage with complexity – making close observations, considering alternative outcomes, developing a tolerance for uncertainty. In particular, students will explore the organisation of ecosystems. They will focus on nature's processes such as the water cycle, the carbon cycle, the nitrogen cycle and, the waste cycle as described by Alan Peacock (2004). Students should be challenged to critique simplistic, reductionist representations of these cycles and engage with their complexity.

According to Egan, during this stage of development, students are often interested in the limits of reality, and in the human origin of knowledge. During this time, students will also explore what we know about the biggest and smallest components of the universe and the the diversity of living things. They will find out about the things that are too small or too distant to be observed, and how we know they exist. It is also the time for the stories of science discoveries and inventions.

Junior secondary

During this stage of schooling, students will build on many of the practices from earlier stages but will also learn about the history and philosophy of science. They will compare and contrast different ways of understanding the world and gain an understanding of how science itself is changing. They will engage with ethical and social issues. There will also be a focus on the stories of cutting edge new science, especially in contexts directly relevant to young adolescents such as the human body, "gut bugs", nutrition, diabetes etc.

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[3] In his book, *Feral,* George Monbiot argues that as we become disconnected from out natural environment we risk not noticing changes that are happening. One way of helping children see changes could be to get them to listen to stories of how things were in the past.

[4] See for example
http://pz.harvard.edu/sites/default/files/Exploring%20Complexity%20for%20ISV%202017%2006%2023_CreativeCommonsLicence.pdf

Potential advantages of this curriculum approach

Pragmatically, one of the advantages of this suggested curriculum is that it could be implemented in schools, right now, within the parameters of *NZC.* There is no requirement within the existing document for schools to structure curriculum around learning areas. In fact, the document states that "wherever possible, schools should aim to design their curriculum so that learning crosses apparent boundaries" (Ministry of Education, 2007, p38). The requirement is for the principles of *NZC* to "underpin and guide the design, practice and evaluation of curriculum at every stage." (p37). The principles referred to are high expectations, Treaty of Waitangi, cultural diversity, inclusion, learning to learn, community engagement, coherence and future focus. All of these apply to the proposed curriculum.

Not only would the proposed curriculum meet the requirements of the existing *NZC* framework, but at least at the early primary stage, the curriculum could be implemented without the need for extensive professional learning and development for teachers. At the Middle/ Senior primary level some good resources with the stories of science would need to be developed. There would also need to be some professional learning and development around systems thinking and complexity but this would also be achievable. For many secondary teachers this approach would require a major shift in thinking and their identity as science teachers. The provision of good resources and professional learning and development, especially about the history and philosophy of science, would be important.

This proposed curriculum supports students to form an emotional attachment to the natural environment, and then later to explore it through a range of lenses. As Knudtson and Suzuki, argue in *Wisdom of the Elders,*

> Respect for other ways of knowing, humility about the potential of our technologies, and love for each other and all other life-forms are all essential in searching for a way to live and flourish in balance with the natural world. (Knudtson and Suzuki, 1992, p. xxxi).

This curriculum aims to develop people who both see themselves as part of the inter-connected web of relationships that make up nature, rather than outside it, and to develop a flexibility of mind that can appreciate complexity. The bottom line, for me, is that we need to know *differently* to have any hope of facing the planetary challenges ahead of us – and the need to address these challenges is too urgent not to try something different.

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