Re-envisaging science education: Learning for an uncertain, complex future

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Abstract:

The Anthropocene is a time of challenge. The future is uncertain and complex as there is no single trajectory towards the future. Science education needs to change in order to best prepare learners to meet these challenges. While the goal of scientific literacy still seems relevant, its emphasis needs to shift to developing citizens who can make informed decisions about the myriad contentious issues found in society today. Such a shift including five elements in science education programmes: a far stronger emphasis on the 'doing' of science and how scientific knowledge is constructed; using an interdisciplinary approach for learning; preparation of learners to be part of an extended peer community; learning about ethics; and learning about how to take action. Consequently, learners will understand about science, be able to make informed decisions, and share power with scientists and politicians, with all working together to build life in the Anthropocene.

The 21st century will be the time people transition into a post-carbon way of life (Morgan & Matthewman, 2014). Apart from this certainty, the 21st century is a time of uncertainty and complexity because how this transition will occur is unknown and at present just a moral imperative. For learners, this means that there is no single trajectory towards the future. Therefore, learners need opportunities to consider and reflect on how a future could be framed in a manner that will result in successful learning for all (Dumont, Istance & Benavides, 2012).

While science education has potential for learners to prepare for these futures, currently there seems to be a disconnect between it and the work of scientists. This disconnect arises because scientists and scientific knowledge are in strife. People are turning away from scientists and scientific evidence with increasing mistrust and disbelief (Beck, 1992; Funtowicz & Ravetz, 1993). This turn away from science is occurring despite the way that scientists and their work have largely been responsible for the increasingly luxurious lifestyles (some) people have, longer life-spans and general well-being (Bencze, Del Gobbo, El Halwany, Krstovic, Milanovic, Padamsi …. Zouda, 2019).

How has this move occurred? Can science education be transformed to help 21st century learners prepare for an uncertain, complex future? If so, what will the purpose of science education need to become? What will the nature of science education involve when learners are engaged in science education that is appropriate for the 21st century? This paper proposes that science education has a crucial role to play in preparing learners for living in the 21st century. It will begin by exploring the issue of distrust in science and then discuss the purpose of science education for 21st century learners. Finally, the nature of a 21st century science education will be considered.

The issue – growing distrust and a rejection of science

Over the past two centuries, scientists have worked to develop explanations about our world and beyond. According to Latour, this has come about because of scientists being able to bring Nature into the laboratory and in doing so, have supposedly conquered Nature in order to tame and exploit it (Funtowicz & Ravetz, 1993). When bringing Nature into the laboratory, scientists took an isolated instance of Nature, kept it stable, unadulterated and, importantly, reproducible in order to extend our understanding. By employing this reductionist approach, Nature was rendered predictable and partially controllable. However, with the growth of knowledge produced in this way, other ways of knowing, such as common sense knowledge and inherited understandings and skills (indigenous knowledge), became less valued and scientists assumed the mantle of the 'expert' with scientific knowledge becoming the dominant and most powerful type of knowledge (Funtowicz & Ravetz, 1993).

As a result, there was a "bifurcation of nature" (Latour, 2015, p. 146), a separation of Nature and Human and this binary has endured into this century. Scientific ideas and evidence were seen as being able to offer guaranteed solutions to problems and there was little or no mention of risk, establishing a "dogma of technological infallibility" (Beck, 1992, p. 101). Scientific evidence became entangled with politics as it is used to inform policies to provide 'answers', a division of labour between politics and science that Latour refers to as the "unwritten Constitution" (Latour, 2015, p. 146). Issues were seen 'out there', well beyond the realm of people's everyday lives and consequently had little or no impact on them (Beck, 1992).

But the figurative storm clouds started to loom in the 1960s with scientists such as Rachel Carson warning about growing risks, such as those involved with wide-scale over-use of pesticides, despite their supposed benefits. As the twentieth century came to close and with the arrival of the twenty-first century, high-risk, complex issues that affect everyone's lives that have multiple but as yet unknown solutions are now omnipresent. Gone is the element of certainty that scientific knowledge had been seen to provide, and instead we are facing uncertainty, complexity and a high level of risk that affects everyone daily. The long-standing patterns of control and rationality are beginning to break down as seemingly impossible events become probable (Beck, 1992), for example the increasing frequency of 'one hundred year' floods. Due to decisions we have made using science for economic growth, we are now living with issues that potentially threaten our very existence and the risk of the wholesale destruction of Planet Earth is now possible (Beck, 1992). Nature is in ascendant and has now re-claimed the laboratory (Funtowicz & Ravetz, 1993). Consequently, science and politics are having to assume new shapes, a process that Latour (2015) refers to as a "state of war" (p. 146), that defines what it means to live in the Anthropocene.

At the heart of this issue is the relationship between science and politics. On the one hand is the positivist epistemology holding that scientists produce objective 'facts' that are abstracted from Nature, distant from people and separate from values (Funtowicz & Ravetz, 1993; Latour, 2015). On the other hand, politics is seen as involving passions, different interests and ideology. The unwritten Constitution of "science-versus-politics" then brings both together as science informs policy (Latour, 2015, p. 147). But, with increasingly complex issues, like climate change, scientists can no longer provide 'facts' that are risk-free as frontier-type science, or "science-in-the-making" (Hodson, 2011, p. 31), is uncertain and often gives rise to unexpected consequences. Latour (2015) argues that as soon as this element of uncertainty arises, a distortion of science occurs and politicians are able to introduce doubt. Due to such distortion, or "willful production of ignorance" (Latour, 2015, p. 148), scientists can no longer assume the mantle of the expert as the fragility of the scientific enterprise is revealed. Two sides in an issue (or more) then emerge and the normative practice of scientific evidence then informing policy is de-railed, leading to a paralysis that we are currently seeing with the issue of climate change. Consequently, the general public is left floundering, unsure what or who to believe – all they know is that there is no certainty, just argument. It is this state of affairs that has brought about the current distrust and turn away from science and threat of potential destruction of our world (Beck, 1992).

But Latour proposes a solution to this challenge that could end the bifurcation of Nature and Human. He asserts that what is needed is a "science-with-politics" (p. 148). This form of science rejects a positivist epistemology where scientists produce unquestionable and irrefutable 'facts' and politics distorts science. In the Anthropocene, Latour maintains that science and politics need to work together to gradually "compose a common world" (p. 149). This process will involve a bringing together of facts and values, that involves defining what is certain or uncertain; what consultation should take place; and how values should be ordered; in order to figure out the ways in which people "can stand together in a liveable form" (p. 149). Funtowicz and Ravetz (1993) concur with this bringing together of facts and values and add that different levels of uncertainty also need to be used for the evaluation of the quality of scientific knowledge involved in an issue along with the inclusion of a plurality of voices of the people involved. In this way the "interweaving of progress and fate" (Beck, 1992, p. 113), or life in the Anthropocene can be progressively framed.

The purpose and nature of science education that will meet this challenge will now be discussed.

Purpose of 21st century science education

Globally, the purpose of science education is to develop people's scientific literacy in order to produce a workforce and more recently, to develop an informed citizenry. Scientific literacy has been identified as one of the foundational literacies for 21st century learners (Education Review Office (ERO), 2018). But there is little agreement on what scientific literacy involves, apart from the inclusion of scientific content knowledge (Roberts, 2007). But due to the complexity and uncertainty of the issues facing people today and the need to move to an understanding of science-with-politics, more than scientific content knowledge is needed. What is needed is an appreciation of science as a cultural form of knowledge –

its strengths and its fallibilities in terms of variability of facts, uncertainties and ethical complexities. Consequently, the purpose of science education in the 21st century is to foster scientific literacy that develops learners who can 'manage' the uncertainty and complexity of science-with-politics and thus actively contribute to a democratic society in an informed manner. This purpose necessitates that all learners study science throughout their early childhood, primary and secondary education. It links to the slogan 'Science for All' (Fensham, 2016).

However, science education has had a dual purpose – educating people for a career in science – but it is argued that this purpose is now defunct. This purpose arose because of modernity's need for a workforce to ensure economic growth along with the belief that science and technology could solve all problems (Gilbert, 2016). But it is doubtful that continual economic growth can be maintained in the Anthropocene and if learners still need specialised scientific content knowledge, there are alternative ways of acquiring such knowledge, such as via electronic tools and new knowledge networks (Gilbert, 2016).

Nature of 21st century science education

The distrust and turn away from science infer that current forms of science education are not meeting their potential. There is declining interest in science nationally and internationally, and the latest PISA scores reveal that New Zealand students' achievement and interest in science is falling (Gilbert & Bull, 2013). These trends necessitate a transformation, a change that enables a move beyond current forms where the focus is on learning 'about' science, to one where learners can meaningfully engage with science and its complexities (Gilbert, 2016) in ways that will enable them to contribute as informed, critical citizens. This transformation requires five elements: understanding about the 'doing' of science and construction of scientific knowledge; using an interdisciplinary approach; development of an extended peer community; learning about ethics; and learning how to take action.

'*Doing' of science and construction of scientific knowledge*

Fensham (2016) argues that despite the many changes in pedagogical approaches such as Science-Technology-Society (STS), science education keeps reverting to its discipline base, that is the parent body of science itself. However, it is argued that this inertia maintains the focus on learning scientific knowledge. Instead science education needs to be transformed and consider science as a form of cultural knowledge, interwoven with society, replete with uncertainties and ethical complexities, along with the degree to which such knowledge can be applied to an issue.

Hence this re-envisaging of science education involves more than learning scientific knowledge. Instead 21st century science education is concerned with learners being able to understand how scientific knowledge is constructed, communicated and scrutinised by the scientific community. It will mean that learners can independently evaluate the validity of knowledge claims in order to distinguish between good and bad science, science and pseudo-science, as well as being able to identify the mis-use of science. Such learning involves the development of learners' ability to carry out scientific inquiry and gain an understanding of the dynamic, organic ways in which scientists work in a "constant interplay of thought and action" (Hodson, 2011, p. 105). Learners also need to develop understandings about the network of social, cultural, economic and political power relationships that underpin and sustain the scientific endeavour (Hodson, 2011). In doing so, learners will be able to appreciate how particular ideas (and people) are either privileged, marginalised or excluded and why; thus also becoming a vehicle for promoting equity and social justice (Hodson, 2011).

This re-envisaging also needs to involve learning the role that open-mindedness and scepticism play in the construction of scientific knowledge. This is key to understanding the uncertainty of science because as Hodson (2011) argues, the public mistakenly believes that scientists' arguments arise because of a lack of evidence, rather than the use of different theoretical frameworks or differing interpretations of evidence. Such an appreciation of uncertainty is crucial because as Beck (1992) claims, when uncertainty is revealed, people can be liberated from "technological patronization" (p. 109) where only the expert scientist has a voice in decision-making. Thus, through this re-envisaged science education, learners can appreciate how science is enmeshed in a complex network of power relationships in society, both affecting and affected by such relationships and the products of such networks, and hence empowered to contribute to decision-making.

Using an interdisciplinary approach

A 21st century science education needs to be interdisciplinary. Latour (2015) argues that this shift is necessary because scientists are currently fighting a war defending their construction of scientific knowledge in both spatial and temporal dimensions. In terms of a spatial dimension, science education needs to assist in the mobilisation of people so that they can make decisions about issues and ways of managing their effects. In order to do so, Latour recommends that all disciplines be brought into play so that people can appreciate not only the scientific knowledge involved, but also the economics and intricate network of power relationships that are interwoven into any complex issue (Bencze et al., 2019). Tilbury (1995) concurs with this notion, noting that any issue is multifaceted and cannot be considered from the perspective of one discipline alone. Instead many need to be utilised to appreciate an issue from historical, cultural, political, social, ethical and religious perspectives. Therefore, the boundary lines between disciplines need to be blurred, if not dissolved, using forms of integration that Rennie, Venville and Wallace (2012) believe will help learners to make connections between their learning and our globalised world in a personalised manner, such as cross-curricular, school-specialised or community-focused approaches.

There is also a temporal dimension that involves a recognition that the future is already upon us and action is needed immediately (Latour, 2015). Such learning involves an affective element where learners' optimism is nurtured, but not in terms of being able to escape from an impending apocalypse, but rather in the way in which things are "coming *toward* us" (Latour, 2015). This could involve learning from people who have already developed ways of coping in uncertain times and then thinking about and discussing how such strategies/approaches could be adopted in one's community (Monroe, Plate, Oxarart, Bowers, & Chaves, 2017). Only then can the "entangled, makeshift arrangements" that will be necessary for survival be achieved in the Anthropocene (Latour, 2015, p. 153).

Integrating arts and science could also lead to the development of learners' creativity, encouraging them to think beyond current practices. Surprisingly, science education is seen as having a role in nurturing creativity and imagination in general but also domain-specific scientific creativity, which is argued can lead to greater engagement and more effective learning in science (Hetherington, Chappell, Ruck Keene, Wren, Cukurova, Hathaway, Sotiriou & Bogner, 2019). These authors argue that creativity is not only about genius and creations that bring about great societal change but is also located in cognitive and social frameworks. Learners engaging in scientific inquiry can enhance their creativity as they evaluate their questions and answers in terms of existing knowledge, engage in possibility thinking and everyday problem-solving in original ways, as they work in collaborative groups in a dialogic manner.

Consequently, this blurring of discipline boundaries could lead to a greater emphasis on thinking about and discussing issues rather than just learning about them (Gilbert, 2016). As learners explore issues from a multiplicity of perspectives, they could gain an appreciation of their interconnectedness with the world they inhabit.

Development of an extended peer community

The nature of 21st century science education also needs to prepare learners to be part of an extended peer community (Funtowicz & Ravetz, 1993) or what Beck (1992) refers to as citizens' groups. By extending the diversity and legitimacy of people participating in an issue's dialogue, various perspectives and ways of knowing can be incorporated, such as indigenous knowledge, enriching the process of scientific knowledge construction. Funtowicz and Ravetz (1993) argue that an extended peer community can be involved beyond policy debates and quality assurance, to being part of the actual construction of scientific knowledge. They assert that this involvement occurs because people are usually involved in an issue as it affects them personally. Since the issue is an intrinsic part of their everyday life, they have specialised knowledge about it and can meaningfully contribute to the knowledge construction process. In this way a strong and competent public is created who can contribute to solving problems that involve a tension between the production of wealth and its concomitant environmental destruction (Beck, 1992).

Such a type of education can be linked to place-based education, where students study issues particular to their locality and develop an understanding of how and why such issues arose (Smith, 2007) while considering how such issues can be resolved, developing critical thinking skills. Placed-based education is personalised and relevant to individual students (Bolstad & Gilbert, 2012) as learners make connections to the world beyond their classroom (ERO, 2018), a move away from the currently used "abstract, disembodied" scientific knowledge currently taught (Gilbert, 2016, p. 193).

Learning about ethics

Because the construction of scientific knowledge is not a values-free process and the entire scientific enterprise is based on trust, 21st century science education requires the inclusion of learning about ethics. Ethics is seen as a critical examination about how and why people decide what is good/right or bad/wrong when considering an issue (Hodson, 2011). Learners need to develop understandings about ethical scientific practices and Hodson suggests that this can be achieved through case studies of scientific *mis*conduct and how scientists can be seduced by sociocultural influences to act in an unethical manner.

Learning about ethics is also necessary because achieving consensus about issues is becoming impossible in our increasingly pluralistic society. And even if consensus is reached, there is no guarantee that the decision reached will be 'right' (Hodson, 2011). Additionally, when fostering interconnectedness to dissolve the Nature-Human binary, considering the ethics of our treatment of non-humans is crucial. Consequently, Reiss (1999) proposes that learners study ethics in order to: raise their ethical sensitivity about everyday issues; increase their ethical knowledge; improve their ethical judgments; and foster their ethical conduct. Such learning could then shift individuals from maintaining their individualistic perspectives to appreciating and considering the multiplicity of views held by others. Consequently, learners could extend their use of ethical frameworks beyond an individualistic one to a "life-centred ethics" position (Hodson, 2011, p. 210) where whole ecosystems are considered, thus enhancing learners' interconnectedness.

Action-taking

Associated with mobilisation of people along with issues of equity social justice and interconnectedness, is empowering learners to be active, informed citizens. It is argued that active involvement requires learning for action-taking (Birdsall, 2010; Hodson, 2011). Both these authors propose a three-part framework that could be adopted by both individuals and groups: learning *about* action (learning how to decide on a solution and ways of achieving it); learning *through* action (planning and taking the action); and learning *from* action (reflecting on action taken to determine their value). This framework results in learners engaging in praxis as engaging in an action is not an endpoint, but instead an ongoing cycle of action and reflection, placing action taking in reflective practice (Hodson, 2011).

As students' agency develops, they will be able to use knowledge about the issue along with knowledge about taking action to identify possible strategies for mitigation and resolution of issues (Birdsall, 2010). In doing so, they will be learning how knowledge can be used to 'do' things, rather than just something one can 'get' that has come from experts (Bolstad & Gilbert, 2012; Gilbert & Bull, 2013). Instead knowledge is something that is a property of networks where connected groups of learners work together to extend their ideas beyond that of an individual alone.

This transformed nature of science education could then lead to an end of the 'state of war' between science and politics because of the existence of a strong, competent public. Then the public, armed with their understanding about science and having re-conquered the power of their own judgment, can share power with expert scientists. Subsequently, everyone can progressively build a life together in this new epoch, the Anthropocene.

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