The place of values in the aims of school science education

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Abstract

In this chapter, we begin by discussing what the aims of science education should be. We pay particular attention to the science education provided by schools during the compulsory period of education and consider what the values of such education should be. We examine how the science curricula in Australia and England have changed in recent years, and consider what the effects of this might be on student understanding of science and engagement with it. In both countries, there has been a shift towards 'hard science', away from a consideration of the nature of science and the contexts in which science is undertaken. We argue that these shifts may be counterproductive if the intention is to increase the numbers of students who choose to study science once it is no longer compulsory. We are of the view that school science education needs more education for social justice, socio-political action and criticality and give examples of how teachers might interpret curriculum statements in ways more likely to advance student engagement with science as well as an understanding of it.

Introduction

Debates about the aims of school science education are perennial (e.g., Reiss & White, 2014), particularly in the West. In this chapter we review these arguments, situating them in current global circumstances including rapid technological advances, a continuing demand for workers with STEM (Science, Technology, Engineering and Mathematics) qualifications and the increasing acknowledgement of the deeply worrying effects that humans have on the Earth's ecology, and indeed its future. Part of our argument is that decisions about the aims of school science education are inevitably decisions about values in education in general and values in school science education more specifically. This means that for a country, a group of schools, an individual school or a classroom teacher to come to a view about the aims of science education in the classroom is to have made a judgement, implicitly or explicitly, about values.

One of the intentions of this chapter is to make more explicit the role of values in decisions that are made about the nature and content of school science. We note that one's understanding of what should be the aims of science education depends on whether one gives more weight to the overall aims of education, with science education playing a part within that, or to the aims of science, with science education playing a part within that. We place ourselves firmly in the camp that sees science education as playing a part within the overall aims of education.

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We pay particular attention to the science education provided by schools during the compulsory period of education. We are mindful of the fact that much learning of science takes place elsewhere and at other times of life – and we are passionate about the importance and potential of these out-of-school sites for science education. Nevertheless, in many international contexts, schools are in a unique position in that in an increasing number of countries they typically cover 90% or more of each cohort for ten or more years, are staffed by learning experts and exist in a social structure that presumes that these learning experts have the right to undertake their jobs so as to enable learning about a broad range of knowledge, skills, and dispositions. This is in contrast to the focused and highly contextualised experiences that other sources (e.g., science centres, zoos) might additionally provide.

Current global circumstances

The current global landscape is characterised by rapid technological advances within a highly connected and globalised world that is nevertheless deeply fragmented. Increasing numbers of people in a rapidly increasing proportion of the world's countries are able to communicate almost seamlessly in real time across the globe and an increasing proportion of the world's population has virtually instantaneous access to information, goods, services and each other via the internet. With such advances comes increased accessibility, travel, job mobility and the rise of technologies such as Artificial Intelligence. But at times it seems that our cultural evolution is unable to keep pace with this rapid technological change, which manifests, as has long been noted (Beck, 1986/1992), in greater uncertainty about what the future might look like and increased concern at these changes. Such concern is indicated by a rash of dystopian novels such as Margaret Attwood's The MaddAddam Trilogy (published in 2003, 2009 and 2013) and Naomi Alderman's *The Power* (2017), and such films as *The Hunger Games* series (2012, 2013, 2014 and 2015), *Under the Skin* (2013), *The Divergent Series* (2014, 2015 and 2016), *Interstellar* (2014) and *Ex Machina* (2015).

Increased technological advances and the movements of goods, services and finance have escalated competition at local, national and global scales, which has placed increased emphasis in education on comparing national capacities with measures such as TIMSS and PISA as well as national standardised testing, such as NAPLAN in Australia and SATs in England and Wales and the USA. Greater pressure from political and economic forces on education has repeatedly returned to the question of what education should be preparing students for and therefore what the aims of education in general, and school science more specifically, should be.

Government agendas provide insights into the political and economic aims of nations and how these aims might affect educational aims and practices. For example, Australia's National Innovation and Science Agenda aims to "drive smart ideas that create business growth, local jobs and global success" (Australia, 2017) because "innovation and science are critical for Australia to deliver new sources of growth, maintain high-wage jobs and seize the next wave of economic prosperity … Innovation keeps us competitive. It keeps us at the

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cutting edge. It creates jobs. And it will keep our standard of living high" (p. 1). Furthermore, there is a presumption that "Too few Australian students are studying science, maths and computing in schools – skills that are critical to prepare our students for the jobs of the future. We also need to create an environment that attracts the world's best talent to our shores" (p. 4).

In the USA, "the nation's capacity to innovate for economic growth and the ability of American workers to thrive in the modern workforce depend on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility that lie at the heart of the American dream" (Achieve, 2009, p. 1).

STEM curricular responses

Many governments are responding to these global developments by placing greater emphasis on school STEM courses in what seem to be increasingly desperate attempts to fend off competition from beyond their country's borders. Bencze et al. (2018, p. 74) argue that:

> STEM sales campaigns rely on a common neoliberal tack; namely, disaster capitalism (Klein, 2007). In other words, in order to infuse neoliberal priorities, capitalists may capitalize on natural or manufactured disasters. STEM education promoters often, for instance, appear to adopt salvationary rhetoric – claiming that STEM education should allow individuals and jurisdictions (e.g., states/provinces, countries) to be saved from economic disaster; and, indeed, to prosper, especially in terms of jobs and associated products and services, in the face of increased international economic competitiveness from other countries, like India and China ...

In the UK, and despite consistent economic data on the importance of the service and creative industries, there is a government fixation on the importance of STEM education for manufacturing and future prosperity. For example, in 2014, the Education Minister, Elizabeth Truss, in the staccato prose that seems to be favoured by certain UK politicians, said:

> We're one of the top countries for research citations in subjects like physics or maths. We have one of the strongest science research communities in the world. And we know this is vital for our national future. Maths is becoming ever-more important to the economy. More and more sectors rely on technology – and more companies require people with advanced analytical and research skills if they're going to compete. So we need a strong education system. Because tomorrow's world relies on today's pupils. (Truss, 2014)

In this and similar government pronouncements from other nations, education and innovation are seen as a means of economic survival and transferability. Political agendas

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speak of education as a way of preparing students as ‘marketable commodities’, able to enhance national economic and innovative competitiveness in a global climate.

Education is feeling the pressure of such a view of students. Indeed, the next generation of students is facing an uncertain future with suggestions that a large proportion of jobs in the future are yet to be invented or designed, as present ones disappear, in large measure as a result of increasing automation (Rainie & Anderson, 2017). As a consequence, education systems will need to adapt to prepare students for change in the workplace. This increased pressure can be seen in the political agendas for a number of nations. Rather than a focus on preparing ‘scientists’, the focus is on preparing students for the jobs of tomorrow by enhancing students’ STEM capacities. For example, from the USA:

> Our nation needs an educated young citizenry with the capacity to contribute to and gain from the country’s future productivity, understand policy choices, and participate in building a sustainable future. Knowledge and skills from science, technology, engineering, and mathematics—the so-called STEM fields—are crucial to virtually every endeavor of individual and community life. All young Americans should be educated to be ‘STEM-capable,’ no matter where they live, what educational path they pursue, or in which field they choose to work. (Achieve, 2009, p. vii)

In Australia, *The Melbourne Declaration* specifies the broad goals for schooling in Australia and suggests that:

> In the 21st century Australia’s capacity to provide a high quality of life for all will depend on the ability to compete in the global economy on knowledge and innovation. Education equips young people with the knowledge, understanding, skills and values to take advantage of opportunity and to face the challenges of this era with confidence. (Ministerial Council on Education, 2008, p. 4)

The goals for education suggested by the Declaration argue for a youth that is confidently equipped for the contemporary challenges of a globalised world. This aim aligns with the National Innovation and Science Agenda, referred to earlier, which advocates increased innovation for sources of growth, creation of jobs, economic prosperity, global competitiveness and the maintenance of high standards of living (Australia, 2017).

The aims of education

Despite the recent emphasis on STEM for national prosperity, a number of aims continue to be proposed for education (cf. Biesta, 2009; Reiss & White, 2013), for all that there is now less confidence that we know what makes for a good education. Indeed, Kress (2000) argued that whereas the previous era required an education for stability, we now require an education for instability. Such a scenario would require considerable provisionality and open-endedness about any precise, subject-specific set of aims. Generally, in writings about

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the aims of education and in curriculum documents, we can discern two broad groupings (Reiss, 2007). First, those where the intention is to develop the individual for her/his own benefit; second, where the intention is to develop individuals so that they may collectively contribute to making the world a better place, though in recent years this global aim has shifted more towards national interests.

Acknowledging the historical and cultural context of any attempt to discern the aims of education, contemporary philosophers of education have examined what these might be. Chief among the suggestions are: autonomy, well-being and justice.

Autonomy as an aim in education

To be autonomous is rationally to decide things for oneself. It may be objected that no person is an island, that our decision making is influenced by our historical past and social present. While this is true, the argument for autonomy still holds. If you choose to read philosophical writings rather than popular romance fiction, for example, the reasons are likely to be due in large part to your parents, schooling and friends but that doesn't mean that you lack agency or act with diminished autonomy in reading them.

It is widely accepted within liberal traditions of education that education should intend students to achieve autonomy. Of course, there are degrees of autonomy and different conceptions of autonomy. It is generally held that rational autonomy is displayed by individuals who act intentionally, with understanding and without external controlling influences that determine their actions (e.g., Haworth, 1986), although there is increasing sensitivity to the Eastern and feminist positions that too strong an emphasis on rationality may be both discriminatory and illusionary. Nonetheless, an optimistic belief in rational autonomy would mean that a society in which a sufficient proportion of its citizens had achieved rational autonomy would function successfully. For example, it is not rationally autonomous for me to routinely choose to deceive and steal as even a cursory analysis should convince me that this is neither fair to others nor likely to lead to a flourishing society.

Other terms, such as self-determination or authenticity, have much in common with rational autonomy. To be self-determined is to make personal decisions that are authentic, or true to oneself. This argument might be taken as assuming that we are born with a self that is waiting to be unveiled and that social and cultural conventions constrain or distort an individual. From this perspective, the purpose of education would include challenging social and cultural constraints of the authentic self.

However, social and cultural constraints are powerful, and education is fundamentally a product of societies. An educator may urge students to pursue their dreams and exercise self-determination and authenticity, and yet the students are still be 'measured' and 'judged' by an education system that replicates the hierarchical structures of the society in which it is embedded. The students are still constrained by the system that educates

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them in terms of standardised testing and academic rankings. This complexity is challenging for students and educators alike.

Education for autonomy should therefore aim to balance rationality with authenticity and self-determination. It is possible to lead a self-determined or authentic life by devoting time to consuming chocolates or playing video games online 24/7. However, rationality would temper these desires with pragmatic decisions about one's health as well as social and cultural conventions such as employment and the need for social engagement. This raises questions about the relationship between what is good for an individual and what is good for a society and, in particular, how individuals make decisions about their well-being in the light of societal paradigms.

Well-being as an aim in education

The idea that education should try to enhance people's well-being (sometimes expressed as human flourishing) is closely allied to the notion that education should enable people to act autonomously. However, we can easily imagine situations, such as are found in introductory textbooks on medical ethics, when well-being and autonomy are opposed. Suppose, for example, an adult injured in an accident urgently requires life-saving medical treatment that can only be delivered by injection but attempts to reject it because they are terrified of needles. Most of us would favour trying to persuade the person to accept the treatment but if that proved unsuccessful giving the treatment without the person's consent (i.e., overriding the person's autonomy) on the grounds that there is a greater good than autonomy in this case, namely the preservation of life.

This example further highlights the complexity of decision making for well-being due to uncertainty (cf. Rennie's chapter in this volume). Values exist within and outside an individual. However, uncertainty complicates decision making about an individual's well-being due to competing values. As an aim for education, what role do schools play in preparing individuals to be aware of this complexity and the problematic nature of decision making, such as what is 'right' or 'wrong' for a given situation related to a person's well-being?

Justice as an aim in education

Education can also be seen as striving for justice. There are various conceptions of justice but they have in common an emphasis not only on the actions of individuals but also on the consequences of individuals' actions and social structures on relationships between individuals and on the distributions of resources between individuals. Here, values play a complex and important role in determining which resources or actions are valued, for and by which people (cf. Fitzgerald and Abouli in this volume). This raises issues about whose values matter more than others. Recent years have seen an increasing acknowledgement of

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the importance of environmental justice, helping to decentre humans, thus giving more consideration to the interests of other species.

Social justice is about the right treatment of others (what Gewirtz (1998) characterises as the relational dimension of social justice) and the fair distribution of resources or opportunities (the distributional dimension). Yet, complexity exists in determining what counts as 'right' treatment and also what might count as fair distribution when competing sets of values exist. For example, it may be accepted by some that an unequal distribution of certain resources can be fair provided other criteria are satisfied (e.g., the resources are purchased with money earned, inherited or obtained in some other socially sanctioned way – such as gambling in some, but not all, cultures). At the other extreme, it can be argued either that we should ensure that all resources are distributed equally or that all people have what they need. Such distributions might be achieved through legislative coercion, social customs or altruism on the part of those who would otherwise end up with more than average.

Justice as an aim of education is complex, despite educators' widespread enthusiasm for 'social justice', especially when the values which influence decision making are not explicit or cannot be examined with much objectivity. What role do teachers and schools play in educating for justice and how can teachers be supported to think about their own values and the way these values are portrayed to their students (cf. Cooper and Loughran in this volume)?

The possible aims of school science education

The above arguments are about the aim(s) of education in general. We shall now attempt to demonstrate the implications of these arguments for determining what the aim(s) of science education should be. Of course, categorising possible aims of school science is problematic. Although separated here into discrete aims, this classification is not without limitation as there is considerable overlap and interdependence between categories. In addition, different stakeholders bring individual lenses and values to bear on decision making about what school science should look like and consist of. Global and national values also play a major role in what become 'new expectations' for how teachers and students 'should ideally' work in classrooms. Teachers and students need to reconcile top-down imperatives with their own values and aims for school science. Therefore, changing global and national prerogatives has serious implications for schools, teachers and students through the potential misalignment of respective stakeholders' values. What does this mean, then, for the way teachers and schools plan for science learning and teaching? The answer depends on whose values are considered.

Supply of future scientists

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In revisiting the aim of school science as way of supplying future scientists, we need to consider the changing face of scientific work in the 21st century. A professional scientist can be considered to be one who is employed in a science or science-related career. As a global citizenry, we value the role scientists play and thus place value on students choosing science as a vocation.

The practice of scientific research has seen dramatic change over the last few decades. This has presented opportunities and challenges for scientists, such as: increases in interdisciplinary collaboration (Luke et al., 2015); a rise in team-based work on large projects, geographic distribution and virtual communities; new organisational structures (Cummings & Kiesler, 2014); and a rise in new and alternate approaches for funding, such as entrepreneurial and crowdsourcing (e.g., Wood et al., 2011). Also on the rise is the emergence of an emphasis on STEM 'capacities', 'skills' and/or 'attributes' as ways of working towards an uncertain future. As a previous Australian Chief Scientist argued:

> Our nourishment, our safety, our homes and neighbourhoods, our relationships with family and friends, our health, our jobs, our leisure are all profoundly shaped by technological innovation and the discoveries of science. (Office of the Chief Scientist, 2013, p. 5)

Indeed, the need to provide pathways for future scientists (and people with expertise in mathematics, engineering and technology if STEM in its interdisciplinary form is truly valued) still persists as an imperative of many science courses. However, the nature of this preparation may be changing. With the emergence of policy agendas, such as the examples offered early in this chapter, in addition to the changing accessibility to information via the internet, we see an increased emphasis on teaching 'skills' and 'capabilities', such as the capacity to find relevant information, critical thinking, and problem-solving skills to comprehend scientific concepts and to enable the ability to work with data and evidence. Greater emphasis has been placed in learning theory on the student as the constructor of knowledge, rather than as a passive recipient of facts and concepts; however, whether this is a reality of schooling is another matter.

The broadening of science education to focus more on skills, capabilities and dispositions may also be in response to the calls for more humanistic approaches to science education, such as the 'science for all' movement. And it could also be in response to criticism towards science education that caters for the few (who may become scientists) at the expense of alienating a large majority (who are unlikely to).

With the suggestion that three-quarters of the fastest growing occupations will require STEM skills and knowledge (Becker & Park, 2011), school science courses will need to prepare students for a range of skills and capacities rather than just aiming to develop conceptual understandings. However, the increased focus on STEM in education policy does not necessarily translate into greater development of capacity, partly due to the lack of consensus as to what STEM teaching, STEM skills and STEM capacities might look like in a primary and secondary setting and how to develop them. While there is a growing number of STEM schools and STEM centres in schools, they often feel and look a lot like traditional

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sites of school science. This illustrates the problematic way in which global imperatives, such as the push for a greater focus on STEM, might translate into practice within schools when there are different values at play.

Another argument for the development of more skills-based rather than overly conceptual-focused science curricula is the changing state of career progression. A person may have several career changes over the course of a lifetime, and it is difficult to see this tendency reversing. The movement to skills- and capacity-based science courses, particularly in a climate of rapid technological evolution, could be a way of indirectly preparing students for a multiplicity of potentially different future careers in science-related fields, as well as creating a citizenry with skills and capacities to survive and diversify in an uncertain future. However, the nature of what these courses might ideally look like is unclear. For example, what sort of practical work is most appropriate for specialised (e.g., biomedical sciences) or generalised science degrees? How much should science degrees teach about the nature of science?

Furthermore, there may be a danger of going too far the other way, of alienating or not adequately preparing those with a fascination (or at least interest) in the content of science who might have otherwise chosen to pursue a career in science. We admit that this possibility is under-researched but we want to acknowledge the possibility that there is a minority of students who do not want anything other than an overly conceptual-focused science curriculum. There is also increasing acknowledgement that skills, like conceptual understandings, need to be developed within specific contexts; science courses that focus on the process of science and on building up generalisable skills (e.g., Warwick Process Science, developed in the 1980s) may do their students a disservice compared with courses that retain a solid grounding in scientific knowledge and understanding.

Scientific literacy

Emerging from the ‘science for all’ movement has come a desire to embed science learning in relevant and authentic contexts in order to nurture a greater awareness of the nature and uses of science in students’ everyday lives. The notion of ‘scientific literacy’ has emerged as a common aim of school science curricula, and although debate as to the meaning of the term persists (Roberts, 2007), sufficient agreement allows for it to be used beneficially.

Goodrum, Rennie, and Hackling (2001) have suggested several qualities of scientifically literate individuals – people who:

- are interested in, and understand the world around them
- engage in the discourses of and about science
- are sceptical and questioning of claims made by others about scientific matters
- are able to identify questions, investigate and draw evidence-based conclusions
- make informed decisions about the environment and their own health and well-being.

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This definition aligns with that of Hodson (2008), who further elaborates the importance of an individual's capacity to use their scientific literacy for future individual and societal benefit, by suggesting that the:

> Use of the term "universal critical scientific literacy" carries with it a commitment to a much more rigorous, analytical, skeptical, open-minded and reflective approach to science education than many schools provide and signals my advocacy of a much more politicized and issues-based science education, a central goal of which is to equip students with the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern. (p. 2)

Internationally, many curricula are becoming more sensitive to developing this kind of scientific literacy, through explicit inclusion of strands that require consideration of the nature of science – for example, the nature and history of scientific knowledge development, the nature of scientists' work, the tentativeness of new scientific knowledge and the social, cultural and value-laden nature of science. This way of thinking is perhaps becoming more evident through the use of the word 'science' to describe ways of thinking, knowing and doing, rather than just a static body of knowledge.

Perhaps the argument that to be an educated person in the 21st Century is to understand something of science should also be included within the scientific literacy category. This is the 'science as culture' argument; that science is as worth studying in itself, as are, for example, literature and the arts (cf. Kind & Osborne, 2017). Unfortunately, most school science courses don't do a very good job of introducing science as culture. They are short on history and culture and they typically omit, beyond the mundane, some of the parts of science that the cultural argument would surely deem important (e.g., the origin and end of the Universe, the theory of relativity, the uncertainty principle and quantum theory, nanoscience, what it is to be human, feminist science, ethnosciences), principally on the grounds of difficulty – as if school literature courses would omit Shakespeare and Emily Dickinson and school art courses Duchamp and Picasso on the grounds that they were difficult.

Individual benefit

Another aim of school science is for individual benefit or utility. Elmose and Roth (2005) caution that we live in "a risk society, characterized by the unpredictable consequences of techno-scientific innovation and production and by increasing complexity" (p. 11). Hence, science education should equip and benefit students in ways that have positive impact on their lives and help them navigate an uncertain future. This might include gaining employment and understanding how to maintain and make decisions about their own health and wellbeing through, for example, healthy eating (e.g., knowing about the nature of nutrients, composition of foods and the science of food preservation and cooking) and health care (e.g., being able to understand the nature of illness, especially in light of issues

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like increasing antibiotic resistance and increased incidence of diseases such as cancer, diabetes and dementia). More broadly, educating for utility across the STEM subjects could also benefit students who need to make decisions about which goods and services to purchase, be able to discern potential 'scammers', especially in an online environment, and make other informed decisions that could influence their wellbeing.

The capacity for science education to help individual students may be greater than is sometimes supposed. In a moving account of a science programme they introduced in an orphanage in Rwanda, Perrier and Nsengiyumva (2003) used 'hands-on' approaches to connect the manual, emotional and intellectual dimensions of the young people with whom they worked. These children had lost their parents as a result of the 1994 genocide; almost all of them had witnessed extreme violence and the great majority had thought they too would die. Perrier and Nsengiyumva's paper is full of accounts of young people developing (recovering is probably a better word) self-esteem, confidence and curiosity while undertaking such comparatively routine scientific activities as: building the five Platonic solids; studying the ascent of water when a candle is placed above water, lit and covered by a plastic mineral water bottle; and identifying insects. This study is particularly salient given the world-wide increase in the number of refugees and refugee camps since it was written.

Citizens who are able to make informed decisions make them not just for individual benefit, but also in light of their role in the greater global economic marketplace. Can the components of this electronic device be recycled? Does buying this brand of clothing support ethical production standards? Are the workers paid an appropriate salary? Do they have good working conditions? Is the fabric sourced from sustainable or low impact materials? Does the palm oil in this product contribute to the extinction of wild organisms? Does buying these eggs support ethical chicken farming? Do I need new shoes or can the old ones be repaired? What will happen to them when I throw them away?

In a review of the knowledge actually used by members of the public (i.e., non-scientists) to function effectively in particular settings, Ryder (2001) concluded that the amount of formal scientific knowledge needed was relatively limited. How much content knowledge should young people be equipped with to enable them to face an uncertain future? Which values will determine the conceptual emphases? These questions are not unproblematic. Constructing a science curriculum on the basis of what science members of the public need may result in less emphasis being paid to content knowledge and more to ways of accessing and evaluating scientific knowledge, including procedural knowledge, than is typically provided by school science courses.

Democracy

Decision making about one's actions impacts on the wider community in which a person exists, and thus the two are interconnected. Longbottom and Butler (1999) put forward the argument that "the primary justification for teaching science to all children is that it should make a significant contribution to the advancement of a more truly democratic society" (p.

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474). Longbottom and Butler seek to steer a path between positivism and post-modernism: in common with most science educators they would have students appreciate that scientific knowledge is reliable, indeed "the best we have" (p. 487), but fallible. They go on to argue that, in a way reminiscent of inquiry-based science, "children should adopt many of the critical and creative attributes of scientists (giving students the skills to seek and evaluate evidence and to take part in reasoned debate)" (p. 487).

The argument that school science education should promote democracy is related to the argument that it should be for citizenship (Sadler, 2011). In both cases there is what we might term 'weak versions' and 'strong versions'. The weak versions consist of learning about what a democracy is and what it is to be a citizen. The strong versions entail using such knowledge in action to bring about change. These strong versions are closely allied to claims that the aim of school science education should be to effect social justice or socio-political action, which we discuss below.

Building an educated citizenry is good for democracy but can be uncomfortable for certain politicians who would probably benefit from a more ignorant populace. The public may be distrustful of certain scientific 'advances' (e.g., fracking, GM crops, the use of embryonic stem cells), for all that it may be positive about others (e.g., cheaper renewable energy, new medical treatments). Levinson (2010) suggests that "distrustful publics will respond negatively to the introduction of new technologies thereby threatening the nation's competitiveness as a knowledge economy" (p. 70).

A more democratic society needs greater equity in education and discussion of the nature of knowledge development. To wade into some major scientific issues, such as nuclear power, GMOs and climate change, requires the ability to understand the nature of evidence, the social and cultural embeddedness of knowledge and what it is that constitutes a valid argument. Many issues impact in different ways on different interested parties; being able to understand different points of view and the interplay of different forces is beneficial for informed decision making. Levinson (2010) contends:

> Not only are the technical details of scientific and technological issues frequently at a level of complexity that would confound any layperson, but the interweaving of social, economic, political and ethical matters attendant on most contentious issues deepens the problems of what democratic participation can realistically mean. (p. 71)

Sinatra, Kienhues and Hofer (2014) conclude that "At a minimum, the public should be enabled to make thoughtful decisions that are informed by science. They should have the skills necessary to apply scientific evidence to science-related issues that affect their lives" (p. 135). But on whose values do we draw when selecting these skills and how do we decide which skills will be of most value for students in moving forward, particularly in contexts of uncertainty?

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Social justice or socio-political action

Recent years have seen a growth in the idea that school science education should serve to achieve social justice. Rodriguez (1998) was one of the earliest to argue for this by exploring the potential of science education to serve as a platform for resistance. Calabrese Barton, who worked with homeless children in the USA to develop more appropriate science learning, has shown that active participation in science lessons, and authentic learning about science, happens when children believe that their work can enact change and improvements for themselves, their families and their friends (Calabrese Barton, 2001). Drawing on feminist approaches, she demonstrated that many of the students with whom she and her colleagues worked, although seen in school as not achieving in science, were actually perfectly capable of high quality science work provided they were given real choice in the science they worked at.

Akin to science education for social justice is the notion of science education for socio-political action, as described by Roth and a number of his collaborators. For example, Lee and Roth (2002) provide a case study of a community-based activist project, the Henderson Creek Watershed Restoration Project, in which decisions were made about how to reduce erosion and increase the oxygenation of the water. Lee and Roth carefully discuss the issues that arose in the work. While some of these were narrowly scientific, many were not. There were, for example, the interests of landowners to consider; horse owners and home owners have their own interests aside from those of anglers and others. Lee and Roth concluded:

> As part of living and doing research in this community, we have come to realize that not only are out lives enmeshed with research, but that in everyday pursuits of people, science is irreducibly enmeshed with politics, farming, activism, and so forth. (pp. 44-45)

Larry Bencze and Steve Alsop (2014) have edited a collection of accounts that focus on exploring activism within science and technology education. There is also now a journal *The Journal for Activist Science & Technology Education* and a growing number of progressive authors are being used to frame science education for activism, including John Dewey, Michael Foucault, Paulo Freire, Antonio Gramsci, Jürgen Habermas, Dona Haraway, Sandra Harding and Ivan Illich. Alsop and Bencze argue that there are four main ways in which a more radical approach to science and technology education should be framed:

- Science and technology education should be critically reworked in relation to contemporary economic, social, ecological and material conditions;
- Science and technology education should be critically reworked as political practice;
- Science and technology education should be critically reworked to support learners as subjects in change and not objects of change;
- Science and technology education should be critically reworked as moral and ethical praxis.

The broadening of the aims of science education to include social justice and socio-political action has gone hand-in-hand with a reconceptualisation of scientific literacy. Roth and Lee

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(2002) argue that scientific literacy can be conceived of as a property of collective activity rather than individual minds; indeed, that it characterises interactions irreducible to characteristics of individuals. Roth and Calabrese Barton expand on this vision and through a range of case studies argue that “critical scientific literacy is inextricably linked with social and political literacy in the service of social responsibility” (Roth & Calabrese Barton, 2004, p. 10).

Criticality

Internationally, there is a growing focus on the value of critical thinking, where ‘critical’ can be taken to mean being analytical, logical, open-minded, rigorous and questioning, along with having a degree of scepticism. Critical thinking enables greater awareness and reflection about issues through the ability to rationally analyse and make judgements about arguments and evidence to formulate reasoned decisions. *Criticality*, however, situates the learner as an active participant within their environment as one who is required to: think critically with analytical reasoning (critical reason), understand oneself critically (critical reflection) and act critically (critical action) (Dunne, 2015). Criticality as an aim of education therefore would ideally lead to critically thinking individuals who are able to act with purpose and autonomy within the world around them (Barnett, 1997).

Given the uncertainty of the global landscape, especially in the context climate change, increasing human population, global connectedness and rapid technological evolution, criticality appears to be an essential capacity. Development of critical thinking skills is often touted as an essential aim for higher education but is seldom an outcome (Arum & Roksa, 2011; Dunne 2015). Increasingly, the push for developing capacities such as critical thinking is filtering down into schools (see, for example, the General Capabilities of the Australian Curriculum). However, developing criticality requires thinking about one’s epistemology and recognising the impact of values, social and cultural influence, and personal bias. Developing this capacity to take a critical look inwards and self-reflect is difficult for most people.

The notion of criticality in education as compared to critical thinking draws on the work of Freire (1972), who saw teachers as agents of praxis who were capable of helping transform conditions in society through nurturing students to think and act critically. Hildebrand (2001) likewise argued in favour of what she termed ‘critical activism’ in science education, urging participation in science (doing science) and participation in debates about science (challenging science).

Socio-scientific issues, argumentation, consideration of ethical issues (see, for example, Jones’ and Buntting’s chapter in this volume) and the role of values (see, for example, Corrigan and Smith, 2015) have been encouraged in science education to “foster critical thinking skills, decision-making, argumentation, reflective judgement and moral development” (Tidemand & Nielsen, 2017, p. 44). However, including such apporaches may be daunting for teachers if they feel they do not have sufficient knowledge or capacity to respond to student questions. Furthermore, Tidemand and Nielsen suggest that teaching of

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SSIs in secondary school contexts may not lead to enhanced critical thinking skills as it requires teachers to move beyond content. Yet doing so is challenging and problematic as it requires criticality of, and within, the education pipeline in which teachers operate. For example, how does one balance curriculum coverage with skill development in the light of increasing standardised testing and examinations along with increasing teacher accountability, etc.?

Teaching for student criticality also requires of teachers the capacity to reflect "critically on their own stance and recognize the need to avoid the prejudice that comes from a lack of critical reflection" (Oulton et al., 2004, p. 420). Yet, if criticality is not being nurtured in pre-service teacher education and is not necessarily required of teachers with regards to working within their own educational contexts (how many teachers lament the overemphasis on administrative tasks in faculty meetings as compared to robust and critical discussions about learning and teaching within the school?), when might capacity for criticality be nurtured and valued?

The examples in the sections above on science for social justice, socio-political action and criticality may inspire but they may also overwhelm or even dishearten. After all, not all science teachers work in ways that allow the inclusion of extended projects. Neither do they all feel they have the capacity or confidence to engage with socio-scientific issues in the classroom, for example. Furthermore, even the most enthusiastic attempts to make a science curriculum relevant for one's students may fail (e.g., Tobin, 2002). However, it is possible that much classroom-based teaching and modelling may, and over shorter time spans than extended projects require, contribute to science for criticality.

Conclusions

Values are being taken more seriously in science (Elliott, 2017). The contributors to this book collectively argue that they need to be taken more seriously in science education – both in the classroom but also, and equally importantly, in the multifarious decisions about curriculum, pedagogy and assessment that are made before a teacher walks into their classroom.

As with any attempt to categorise, the above analysis of the aim(s) of school science education simplifies; things are generally messier than when they are reduced to arguments on paper. There are respected science education researchers and practitioners who write validly about science education who cannot easily be pigeon-holed into the above classifications, and there are those who straddle more than one category. Our purpose in classifying the aims of science education into discrete categories, albeit problematic, is to open up discussion and invite critical reflection about one's values for science education.

Moreover, the various positions outlined above can be mapped reasonably well onto the tripartite classification of autonomy, well-being and justice discussed at the start of this chapter in relation to the more general aim(s) of education. For those readers who like to

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think in terms of n-dimensional graphs, one can imagine each of the aims of science education as a cloud mapped in a space with the following axes:

- From benefits for selected students to benefits for all students
- From benefits now to deferred benefits as adults
- From individualism to communitarianism
- From knowledge to action.

The place of values in the science curriculum depends critically on one's views of the aim(s) of science education. For example, as Hodson (2003) points out, there will be barriers and resistance to a science education predicated on socio-political action:

> Making the kind of changes to the curriculum advocated in this article will not be easy. Much that I have suggested is likely to be disturbing to science teachers, severely testing both their competence and confidence. Traditionally, science education has dealt with established and secure knowledge, while contested knowledge, multiple solutions, controversy and ethics have been excluded. Accommodating to what some teachers will perceive as loss of teacher control and direction will be difficult. Indeed, to teach this kind of issues-based curriculum science teachers will need to develop the skills and attitudes more commonly associated with the humanities and language arts. (pp. 664-5)

But then all curriculum reforms meet resistance. As Hodson and many others (e.g., Ogborn, 2002; the whole Action Research movement) point out, successful change only happens when teachers are active participants in the change process.

Finally, although we are of the view that school science education needs more education for social justice, socio-political action and criticality, we have some sympathy with more conservative analyses. Teachers, as well as students, have zones of proximal development. As others have put it:

> … it takes an inordinate amount of time – years rather than days or months – for science teachers and scientists to re-examine their own experiences, principles, and practices about science and science education and to implement coherent and consistent strategies to combat the inequalities that currently exist at all levels in our educational system. (Bianchini & Cavazos, 2001, pp. 286-7)

For reasons both of practicality and because we are suspicious of monolithic arguments, we see a role for a diversity of aims of science education. There are two main reasons for favouring, or at least accepting, a number of even incommensurate aims for science. One is that, pragmatically, attempting to insist on just one aim is unlikely to succeed. The second is the possibility that different aims may suit different audiences.

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