DOI:10.6531/JFS.201806.22(4).0003
ARTICLE

STEM: Silver Bullet for a Viable Future or Just More Flatland?

Caroline Smith
University of Tasmania
Australia

Jane Watson
University of Tasmania
Australia

Abstract

This article explores contentious issues that arise from unproblematised calls for STEM (the disciplines of Science, Mathematics, Engineering and Technology) to provide innovative solutions to two existential problems of the 21st century: employment and environmental sustainability. We situate STEM as a neoliberal construct within a hyper-modernist techno-optimist future, a manifestation of Wilber's "flatland". We argue that while STEM undoubtedly plays an important role into the future, rather than being taken at face value as an unexamined good, its taken-for-granted but contradictory role is naïve and misplaced and must be subject to serious critique. We argue that in its current conceptualisation, STEM's role is inherently unable to provide the sustainability of future employment in a knowledge-based economy. We question the enthusiastic promotion of STEM as key contributor to an environmentally sustainable future as we enter the epoch of the Anthropocene, and examine the role of STEM education, in contrast to Education for Sustainability (EfS). We conclude that STEM and STEM education need to include critical and futures perspectives in order to align more fully with a flourishing economic, social and environmental future.

Keywords: STEM, Futures, Sustainability, Education.

Introduction

In recent years, both government and private investments in STEM (Science, Mathematics, Engineering and Technology) have been increasingly and uncritically advanced as the road to innovations that will rescue us from our contemporary societal ills. In particular, STEM is seen as the means to meeting our energy and resource needs in a post-industrial low-carbon future, and at the same time liberating us from drudgery through the creation of large amounts of knowledge-based work. The critical role of STEM in military research and operations is taken as read, but not discussed here.

Governments in Australia and around the world are heavily funding STEM-based industries, research and education, something Carter (2017) has called an "innovation obsession" (p.9). The hype around STEM would have us believe that future-proofing is here at last and nirvana is just around the corner. We contend that this view is somewhat naïve and misplaced, reminiscent of the movie "The Matrix" with its parallel universes.

Situating STEM in the Futures Literature

The avid promotion of STEM aligns with the recent shift towards a more fluid iteration of modernity, that is, hypermodernity—the turbocharged, digitally mediated successor of industrial culture (Smith, Fraser, & Corbett, 2017). STEM is firmly located within a techno-optimist future (Allen, 2006; McKeowan, 2017), where the continued innovative potential of humanity to adapt to changing situations with new ideas and translating those new ideas into practice is based on using the power of technology. These are the engines that will continue to drive progress and finally overcome our problems (Dean, 2016).

The Chief Scientists of Australia are particularly enthusiastic promoters of this future. The former Chief Scientist, Ian Chubb, argued for a STEM strategy, the key objective of which is "to utilise fully Australia's capacity in STEM to secure social, cultural and economic prosperity for all Australians while positioning Australia to advantage in a changing world" (Office of the Chief Scientist [OCS], 2013, p.8). Chubb also claimed that, "Investing in mathematics, engineering and science is the key to productivity growth and higher living standards for our community … The objective here is to position the Australian economy as a whole for the future" (Office of the Chief Scientist, 2012, p. 26).

Hypermodernity is the latest incarnation in the evolution of deeply-held beliefs about human exceptionalism that can be traced back to the Western worldview arising from the European Enlightenment. Here, humanity is positioned as the pinnacle of creation, liberated by technology to manipulate and consume the rest of nature at will for its own needs and gratification. Through the harnessing of fossil fuels during the Industrial Revolution, this position has come to represent all that is good and worthy in human progress and success (Berry, 1990; Milbrath, 1989). It is now what Milbrath terms the "Dominant Social Paradigm", within which increasingly large sections of humanity operate (also Shafer, 2006). This version of progress is increasingly dependent on the power of technology, which is represented as of central and vital importance. Now, STEM is framed as the vehicle to supercharge it (Smith & Watson, 2016). The Australian Government's most recent National Innovation and Science Agenda (NISA) plays directly into this, asserting that,

> *[e]xtraordinary technological change is transforming how we live, work, communicate and pursue good ideas. We need to embrace new ideas in innovation and science, and harness new sources of growth to deliver the next age of economic prosperity in Australia. (NISA, 2017, para. 1)*

STEM and Politics - a Neoliberal Project

From World War II and increasingly since the 1970s, the world has seen the further alignment of hypermodernity with the economic and political framing of neoliberalism. In the political sphere, values such as consumption, efficiency, winning, freedom, productivity, competitiveness, risk taking and power over others through the mechanisms of a free market are the hallmarks of neoliberalism: late stage capitalism (Mandel, 1975) in its rapacious global stage. Neoliberalism is now so entrenched globally that for many, it is almost impossible to envision a different world (Smith, 2007; Smith & Watson, 2016). It has become, as Monbiot (2017) puts it, "the prevailing common sense." In its vision, growth is constructed as the central good, the organising goal and value that drives ethics and morality (Bauman, 1993, 1995). However, far from a market mechanism free from government interference, Carter (2016) argues that neoliberalism is a direct result of deliberate government interventions to promote these particular values. As she puts it,

> *neoliberalism is now agenda for most national governments to the exclusion of all else … [it] is the deliberate intervention by government to encourage particular types of entrepreneurial, competitive and commercial behaviour in its citizens with the market as the regulatory mechanism. It is also the management of populations to cultivate individualistic, competitive, acquisitive and entrepreneurial behaviour. (p.33)*

Goldberg (2017) agrees, arguing that "after the fall of communism, capitalism came to seem like the modern world's natural state, like the absence of ideology rather than an ideology itself" (para. 10).

Australia's promotion of STEM as the vehicle for promoting neoliberal values is clear. As Alan Finkel, Australia's current Chief Scientist, puts it, "we exist in a competitive international environment and to compete effectively, business needs science, science needs business, Australia needs both" (as quoted in Lee & Hannam, 2015). Carter (2016) believes that its advocates do not recognise that STEM is located within a neoliberal position, nor are they aware of its problematic worldview and critiques.

For Carter (2016), there has always been a reciprocal and mutually productive relationship between the economy and STEM. In Australia the appointment of Finkel, who has strong entrepreneurial credentials, emphasises this nexus. When Finkel's appointment was announced by Prime Minister Malcolm Turnbull, Turnbull made it clear that:

> *[s]cience and innovation are at the centre of the Government's agenda and key to Australia remaining a prosperous, first world economy with a generous social welfare safety net. The Australian Government recognises the importance of science, innovation and technology to our future prosperity and economic security as a nation in a rapidly expanding and diversifying global economy … Dr Finkel is renowned for his outstanding research, industrial and entrepreneurial achievements in Australia and overseas ... His will be a vital role in shaping Australia's economic future and leading our national conversation on science, innovation and commercialisation across the research, industry and education sectors and with the wider community. (Prime Minister of Australia, 2015, paras. 5-9)*

Just More Flatland?

In focusing on technological solutions to existential problems through STEM, the fingerprint of Wilber's (1996) "flatland" can all too clearly be seen. Wilber characterises hypermodernity as a techno-rationalist flatland, a world of exteriors where the observable, empirical, measurable and material are all that there is. This world is devoid of meaning and depth, personal and cultural values are marginalised, deeper meanings of subjective consciousness are denied, and everything is reduced to surfaces, hence flatland (Burton, 2017; Riedy, 2016; Wilber, 1996). As Burton puts it, this world "tends to believe that rationality and objectivity is as good as consciousness gets" (para. 10).

STEM, with its emphasis on the objective spheres of science, engineering, mathematics and technology, embodies flatland perfectly. In its over-enthusiastic techno-optimist positioning by main stream governments and industry as the solution to unemployment woes and future prosperity and the saviour of environmental decline, we argue that STEM is highly problematic. Indeed Slaughter (2016) characterises flatland as the "metaproblem" of our day, part of a defective Western worldview that provides only a thin, instrumental view of the world, which, though successful in the short term, cannot be maintained in the long term without serious social and environmental problems. Further, Slaughter believes that current dominant global political and economic powers are not interested in working towards a truly sustainable future that takes account of social, economic, and environmental concerns. Rather, he sees that significant areas of human experience have been marginalised or overlooked by Western institutions, and modern technologies do little or nothing to assist people in solving the perennial problems of human existence. For Slaughter then, STEM in its current form cannot alone be the vehicle to a flourishing future.

STEM and Education

Since the "Sputnik shock" of 1957 when the United States was caught napping by the launch of the Sputnik satellite by the Soviets, education in the STEM disciplines has been seen as critical for global competitiveness and especially military prowess (Powell, 2007). Orientation to STEM soon followed in the education sectors of the United Kingdom and Australia amongst others, though the term itself was not used till 2001 by the US National Science Foundation (who originally called it "SMET") (Marick Group, 2016). The chemistry curriculum of the 1960s in most nations was heavy with industrial processes, mathematics was the mathematics of engineering and science—algebra, trigonometry and calculus—rather than of accounting, statistics and economics. Once the structure of DNA was understood, genetics, the precursor to biotechnology, became a major focus in biology education. Agriculture education promoted the use of pesticides rather than sustainable agriculture.

Alan Finkel himself affirmed the relationship between STEM and STEM education in his comments following his appointment: "My personal experience across research, business and STEM education will guide my ability to formulate relevant advice … We exist in a competitive international environment and to compete effectively, business needs science, science needs business, Australia needs both" (Quoted in Lee & Hannam, 2015, para.4).

The current promotion of STEM has direct implications for education and educational policy. Although STEM itself is not yet represented as an entity in the Australian school curriculum (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2015), there is a *STEM Report* on the ACARA website exhorting it to be included, and for teachers to engage in professional learning in STEM (https://www.australiancurriculum.edu.au/resources/stem/stem-report/). Reports from Australia and other countries bemoan the fact that not enough teachers and students have a strong background in STEM, meaning that there are limits in numbers and quality of school and university graduates in STEM fields, which places serious constraints on Australia's capacity for innovation and economic growth (Hackling, Murcia, West & Anderson, 2014). Hackling et al. further note that,

> *[e]ducation in science, technology, engineering and mathematics (STEM) is a powerful and productive driving force for economic growth. A strong STEM education system provides the essential underpinning of an innovative and scientifically literate culture that develops the capabilities for individuals to function effectively within a science and technology based society, provides an ever-widening range of career opportunities and, builds the productive capacity required to drive a prosperous economy and enhanced well-being in an increasingly competitive world. (p.1)*

Prinsley and Johnston (2015) agree, arguing in their opening to the *Report to the Office of the Chief Scientist - Transforming STEM teaching in Australian primary schools: everybody's business* that,

> *[a] strong economy in the twenty-first century prospers through science, technology, engineering and mathematics (STEM). Across the world, nations are competing for the high-growth firms and highly capable workers of the future; and securing the pipelines in their education systems today. They know that children entering the education system in 2016 will be joining a very different workforce in 2030. They see the rising premium on skills in STEM. In these nations, STEM education counts. (p. 1)*

Similarly, in the United States, under former President George W. Bush, reports from the early 2000s pointed to what was termed "the dire need" for US students to increase their proficiency in STEM disciplines. In 2005, a report from the United States National Academies of Science, Engineering and Medicine, alarmingly titled *Rise Above the Gathering Storm*, noted that US student proficiency in STEM was falling behind other countries, and argued that if the United States wanted to continue to be a global leader, the future workforce would need to be better prepared in STEM disciplines (Marick Group, 2016). In 2009, President Obama announced the *Educate to Innovate* initiative, whose goal was to move US students to the top in STEM achievement over the next 10 years. Key initiatives included increasing federal investment in STEM and preparing 100,000 new STEM teachers by 2021. A White House press release in 2016 stated that the United States had passed the halfway mark in achieving the goal of preparing the new STEM teachers (Marick Group).

President Trump appears to be continuing these initiatives, signing a Presidential Memorandum expanding access to high-quality STEM education to K-12 students. The administration states that the initiative is designed is to give Americans the opportunity to obtain the necessary education and tools to provide them, particularly the young, with the skills they need to be competitive in the employment market (The White House, 2017).

In all these initiatives, the purpose of STEM education is clear—to prepare students for a hypermodern techno-optimist, competitive future. We argue that, rather than the gateway to a rosy future, STEM is in many ways contributing to an increasingly unsustainable business-as-usual future. In particular, we question the rhetoric around STEM and employment and STEM and environmental sustainability.

STEM and Employment

In the rapidly changing globalised world of hypermodernity, humans are increasingly cast as atomised individuals within the discourse of the global free market economy. Here, we are supposed to find dignity in economic freedom, while free markets are the path to individual and social virtue, and collectively, to increased standards of living for all. Bauman (2000) refers to this current historical period as "liquid modernity," where rapid globalisation has conferred new ways of being that present individuals with challenges never before encountered. STEM sits comfortably within liquid modernity; its highly paid successful actors are those who are able to move and work wherever they can access appropriate digital platforms, the so-called "global nomads" (Pickering, 2009). As James (2016) points out, "we all have to be global nomads these days or we're failures. If we want to stay in our communities and work for the good there, we are often not able to" (p. 32). STEM is heralded as the solution to concerns about looming unemployment in the digital revolution, as long as the workforce is suitably trained. Australian government documents such as *Mathematics, Engineering and Science in the National Interest* (2012) note that, "[t]here is a global perception that a workforce with a substantial proportion educated in Mathematics, Engineering and Science … is essential to future prosperity" (p.6).

The Chief Scientist, Alan Finkel, is particularly optimistic that STEM is the answer to future employment, dismissing disquiet about problems of permanent structural unemployment through automation, believing it will never eventuate. Finkel argues that worries about technological revolutions causing permanent loss of jobs have been around for some 250 years, and this revolution will be no different. For Finkel, the digital revolution, often referred to as the 4th Industrial Revolution (e.g., Hamann, 2017), like those that have preceded it, will open up a range of new and never before imagined jobs (Dean, 2016).

Notwithstanding the confidence expressed by Finkel and much of the global government and business community, the neoliberal edifice is looking ever more shaky, and cracks and critiques are beginning to appear. Increasingly buffeted by the shockwaves of globalisation, global insecurities and anthropogenic climate change, the negative impacts on employment are already running deep (Hamilton, 2017; Piketty, 2014). Intentionally or not, neoliberal policies and frameworks have ignored the reality of the forms of work available in different local communities and which for many, will now never exist no matter how work-ready people may be. Policies targeted at young people are ever more paralleling those imposed on "developing" countries by focusing on increasing educational retention and attainment, and now focusing on STEM, with the false promise that this will bring young people professional work (Pickering, 2009). The situation for those in developing countries may be even more dire as automation threatens to replace skills-based jobs (Hamann, 2017; Lee, 2017).

Within the global economic sphere, there are already increasing inequalities, wealth disparities (Piketty 2013; Stiglitz, 2013), and Gini coefficients (OECD, 2017) between and within countries. Jobs continue to move from developed to developing economies and from there, towards increased automation, while wealth becomes concentrated into fewer hands. For the millions already left behind—the working class, the young and the elderly, women, those in the global South and the large numbers of refugees—the STEM Utopia is already out of reach (Smith, Fraser, & Corbett, 2017). In fact, from the 1970s onwards, the gap between productivity and wages growth has continued to widen whereas as Smith (2017) reminds us, once "these were supposed to be inseparable" (Figure 1).

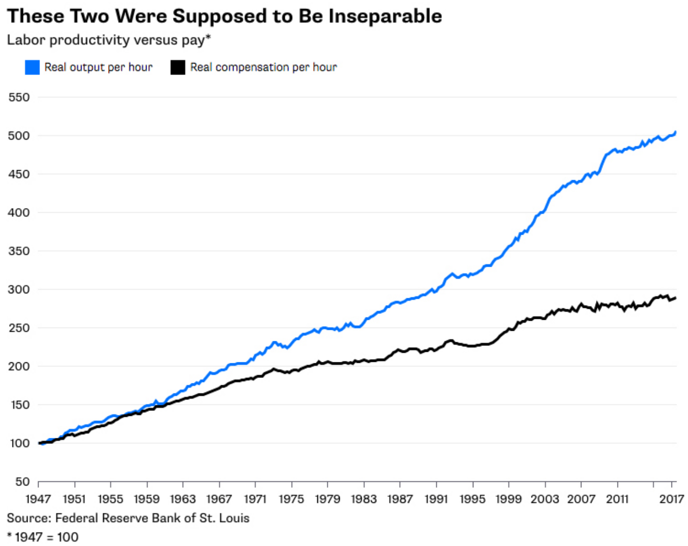

Figure 1. Labour productivity versus pay in the United States, 1947-2017 (Smith, 2017). Source: https://www.bloomberg.com/view/articles/2017-12-04/workers-get-nothing-when-they-produce-more-wrong

In spite of Finkel's optimism, unlike previous revolutions such as those enabled by the printing press and industrialisation, this one may well not only result in fewer jobs, but also severely curtail current employment levels. Although improvements in machine learning, artificial intelligence

(AI), big data, and robot automation have already resulted in significant advances in medicine, science, commerce, and human understanding, it is becoming obvious that there will be significant consequences for employment (Marr, 2016). As Marr points out, we are poised to create jobless growth and be presented with the paradox of an exponentially growing number of products, manufactured more and more efficiently, alongside rising unemployment and underemployment, falling real wages, and stagnant living standards. Drum (2017) agrees, suggesting that in the near future there will be very few jobs that will not be able to be carried out by increasingly smart robots using AI. Hence the digital revolution will be quite unlike those that preceded it.

Thus we find a disturbing contradiction between the promise of STEM and the notion of employment for all. In this digitised, globalised world, how is investment in STEM able to close the gap and provide enough work for all with the concomitant rise of increasingly intelligent robots poised to take over many jobs? And where will those STEM workers whose expertise is still required, come from? It is now likely that any jobs that do emerge from the pursuit of a techno-optimist future will be filled by workers mainly from China and India. The OECD estimates that by 2030, China and India could account for more than 60% of STEM graduates, compared with only 8% in Europe and 4% in the United States. In 2013, some 40% of Chinese graduates completed their studies in a STEM discipline, more than twice the share of US graduates, meaning the graduates who are the foundation of a STEM-based future are increasingly disproportionately likely to come from China and India, and indeed are already doing so (Schleicher, 2016). See also Figure 2.

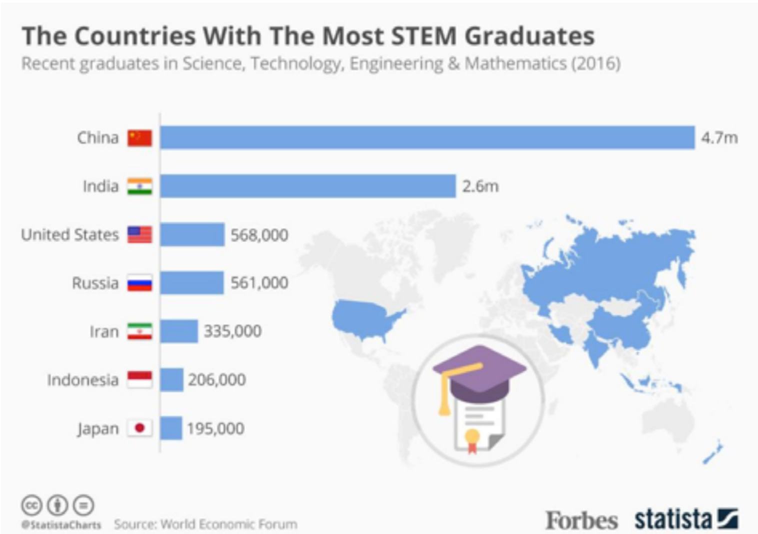

Figure 2. The countries with the most STEM graduates, 2016. Source: https://blogs-images.forbes.com/niall-mccarthy/files/2017/02/20170202_STEM.jpg

Currently, China is rapidly building capacity to become the world leader in hi-tech fields such as AI, robotics, and quantum computing. This capacity building includes new universities and other technical institutions, as well as luring expertise from the United States and Europe (Lucas & Feng, 2017). Global mass unemployment has to be a probable future scenario unless radical structural adjustments are made, and has serious implications for human flourishing. Economic and social sustainability is not possible unless humans continue to have meaningful livelihoods and adequate services in a world where robots may carry out much of the work. Solutions that focus on looming high levels of unemployment lie in the direction of concepts such as Jobs Guarantee (Mitchell & Fazi, 2017), Universal Basic Services (Moore, 2017), the intriguingly titled "Automated Luxury Communism" (Marr, 2016), as well as various manifestations of a Universal Basic Income.

STEM and Environmental Sustainability

A further contrary, less rosy stance to the optimism of STEM argues that we now live in a time of such mass existential identity crises that humanity is no longer capable of fully understanding its place in the biosphere (Stein, 2016). Technological solutions alone are not enough to ensure a sustainable footing into the future. This identity crisis has coincided with the onset of the Anthropocene, the new geological epoch in Earth's history where "natural forces and human forces became intertwined, so that the fate of one determines the fate of the other" (Zalasiewicz, Williams, Steffen, & Crutzen, 2010, p.2231). Looming catastrophic climatic and environmental degradation now pose an existential threat to the future of humanity and the more-than-human world (Abram, 1996), as Earth enters the Anthropocene (Intergovernmental Panel on Climate Change [IPCC], 2014).

Stein (2016) further argues that we are not prepared for, nor do we even understand, the responsibility imposed by the Anthropocene, where urgent, critical questions must be asked about the relationship between the human and the natural world. For Fenwick and Edwards (2010) and Malafouris (2013), our salvation lies in nothing less than the decentering of the sovereign human subject: in other words, a shift from anthropocentrism toward a more inclusive ecocentrism where the more-than-human-world that is our ultimate life support system, is taken account of and nurtured rather than destroyed.

In its present conceptualisation, STEM is unable to frame such questions, let alone provide answers that will see humanity and the more-than-human-world thrive. Arising from its unexamined neoliberal worldview and the internationalisation of economies that accompany globalisation, STEM proponents assume economic growth as a given, in spite of the growing recognition of its ecological impacts on the world's ecosystems. Increasingly from the second half of the 20th century it has become very clear that continued growth, driven by development of the technologies and powered by fossil fuels, is unsustainable on a planet with finite material resources (Thiele, 2013).

Changes to Earth systems that characterise the Anthropocene include marked acceleration in rates of soil erosion and sedimentation (Nearing, Yun, Baoyuan, & Yu, 2017), large-scale chemical perturbations to the carbon, nitrogen, and phosphorus cycles (Galloway & Schlesinger, 2014), significant change to global climate and sea level (IPCC, 2014), and unprecedented levels of alien species invasions[1] across Earth leading to biodiversity decline across the planet (Regan et al., 2016). Many of these changes are geologically long-lasting and irreversible in the short term. Figure 3 indicates that a number of the biophysical boundaries that need to be maintained for sustainable planetary futures have already been breached.

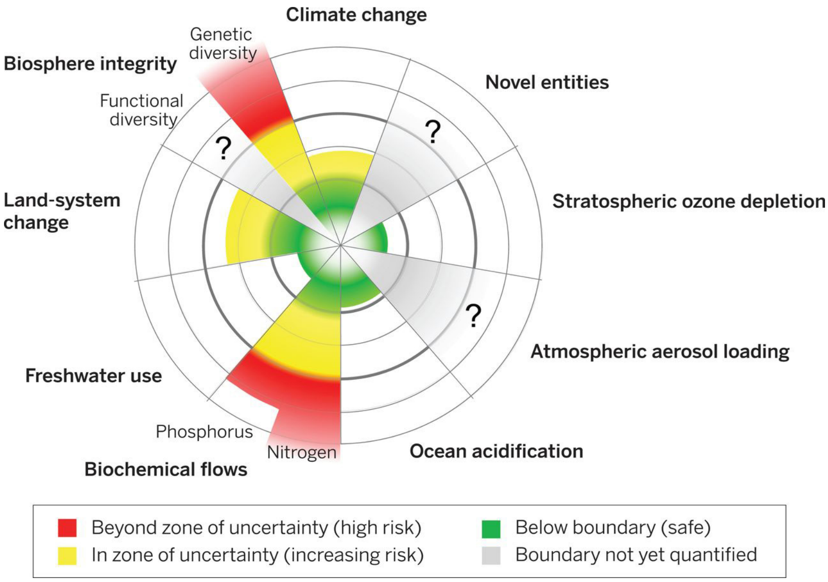

Figure 3. Biophysical planetary boundaries. Source: Stockholm Environment Institute (2015).

The boundaries (in red) that have certainly been breached are biochemical overflows into the environment through agriculture, and dangerously low levels of generic diversity (and hence resilience), especially in food crops. Others, such as changes in land systems and climate change, are an increasing risk but there may still be a chance for reversal if appropriate steps are taken (Stockholm Environment Institute, 2015).

At the same time, then, as we try to fathom new ways of promoting a flourishing future across all spheres of sustainability—social, economic and environmental—we are forced to question the very notion of growth itself. Although some level of growth is still needed if basic needs for the global South are to be met, in the global North a rethinking of the economy towards concepts such as zero-growth, decoupling, de-growth, steady state, and ecological macro-economics is necessary to stem the tide of continued ecological catastrophe (Jackson, 2009; Washington & Twomey, 2016). This means a shift from extraction and manufacturing technologies tied to economic competitiveness to those geared to reducing our ecological and carbon footprints and increasing biodiversity and human and ecosystem health. Such economic systems are incompatible with current framings of STEM, hence are rarely mentioned or even understood within much of the STEM community. Even worse, they are often disparaged.

McMillan (2017) outlines ten drivers that she considers are damaging the living world while economic growth continues to be a key priority of nations (Thiele, 2013). STEM is directly implicated in half of these and indirectly in others (Table 1).

Table 1. *Contribution of STEM to Drivers of Damage to the Living World (McMillan, 2017, p.9)*

Driver	STEM is directly implicated
Dominant neoliberal world view of free markers, individualism and technological progress	Yes
Disconnecting from and undervaluing nature	
The endless pursuit of economic growth through unrestrained free markets and associated advertising	Yes
Corporate marketing and overconsumption	Yes
Limited accounting measures that externalise environmental damage e.g., GDP	
Media that reflect and support dominant power structures	Yes
Discounting risks not seen as immediate, rejection of myths that seem overwhelming; psychological desire to conform	
Population growth	
Technological advancement that amplifies human impact on nature	Yes
Institutions and corporations that ignore environmental degradation	
Limited access to environmental justice within the legal system	

Where STEM does directly address sustainability concerns, generally solutions consistent with its techno-optimist discourse are actively promoted, such as renewable energy generation, storage as a response to climate change, and SMART technologies for agriculture using machine intelligence. For example, the concept of "Ecomodernism" advanced by the Breakthrough Institute (Asafu-Adjaye et al., 2015) signifies a major attempt to apply neoliberal values to environmental futures. Ecomodernism claims that "a good Anthropocene demands that humans use their growing social, economic, and technological powers to make life better for people, stabilise the climate, and protect the natural world" (p.7).

These approaches are echoed in school education, where emphasis on scientific and technological solutions are now education's main way of addressing sustainability (Davis, 2012). For example, the *STELR* project (Science and Technology Education Leveraging Relevance) designed by the Australian Academy of Technological Sciences and Engineering (ATSE), a STEM-supportive organisation (ATSE, 2010, 2016) taps into the high level of concern that the majority of students have about climate change but bases its modules only around technical solutions such as renewable energy. However, as Gasparatos, Doll, Esteban, Abubakari, and Olang (2017) note, renewables alone are not the answer without reducing footprints, meaning taking radical decisions about reducing consumption. Further, negative impacts on biodiversity need to be considered when developing renewable energy policies. In many ways, this position has not moved much from Orr's (1999) description of education where,

> *The Western education system, which has replaced indigenous forms of education throughout the world, prepares students almost exclusively for an urban existence and dependence on fossil fuels and global trade. Children are taught from an early age how best to compete with each other rather than how best to work towards and live in a sustainable society. (p. 166)*

The only difference now is that we admit renewable energy in place of fossil fuels.

Critiques of these approaches abound. Hamilton (2015) for example, has been particularly scathing of the partial solutions of the Breakthrough Institute's Ecomodernist agenda. He also believes that technological solutions alone cannot rescue what seems our headlong race into a dystopian probable future. Clearly, technological advancements are important and necessary but they alone they cannot provide sustainable solutions to the looming employment and environmental crises.

In a disturbing twist, Robinson (2017) cautions that AI tools have the potential to interfere with the human ability, which is perhaps even a need, to transfer nature expertise between people. He refers to the philosopher Daniel C. Dennett (2017) who argues that the real danger of AI is the potential of overestimating the comprehension of these tools and ceding authority to them far beyond their competence. For example, Robinson notes that state-of-the-art in computer vision is rapidly approaching that of human perception in the identification of birds. He fears that there is an unexamined notion of what human perception is, as if machine intelligence can parallel the emergence of the unique complexity of mind, emotion, previous knowledge, and sheer joy that each human observer brings to bear when identifying birds. As Robinson puts it, "It's easy to forget that each record in all that training data represents … a special act of observation, a sudden spark of curiosity, a unique moment of seeing that belongs to the individual" (para 20). The flatland parallel is easy to identify.

STEM and Education for Sustainability (EfS)

Given the ecological crisis humanity and the more-than-human world finds itself in, one might imagine that education would play a critical and leading role in what Thomas Berry (1999) has called the *Great Work*—the transformation of society towards a sustainable future. It seems, however, that in education, many students continue to experience a profound, but largely unconscious dissonance between what they hear about the state of the planet and their lived experience of education—there is a crisis of praxis. The underlying message transmitted through much of education, not just STEM, remains one of "do well, get a good job, and consume," and, in spite of the United Nation's *Decade of Education for Sustainable Development (UN DESD) 2005-2014* (United Nations, 2002), education that explicitly addresses the ecological crisis continues to play a minor role (Smith, 2007).

Although its advocates would argue that STEM education does address sustainability, as noted earlier, we contend that it does so predominantly from a neoliberal, technical growthist, flatland perspective that is not sufficient to move us towards a flourishing future.

A deeper, more integral educational project is Education for Sustainability (EfS) that formed part of the (then) Australian Government's response to the *UN DESD* (United Nations, 2002)[2]. Titled *Living Sustainably: The Australian Government's National Action Plan for Education for Sustainability* (NAP EfS) (Department of the Environment, Water, Heritage, and the Arts, 2009), the NAP EfS is not based in hypermodernity and does not mention economic growth nor the role of markets. Rather, it sees technology as something that is important but needs to be used in the service of the wider ecological understanding that the continued flourishing of life cannot be achieved by technological and other modernist frameworks solutions alone. As the *UN DESD* (United Nations, 2002) put it,

> *[s]ustainable development cannot be achieved by technological solutions, political regulation or financial instruments alone. We need to change the way we think and act. This requires quality education and learning for sustainable development at all levels and in all social contexts. Education for Sustainable Development is about enabling us to con-*

> *structively and creatively address present and future global challenges and create more sustainable and resilient societies. (para. 1)*

The principles of EfS are:

1. Transformation and change: developing the skills, capacity, and motivation to plan and manage change towards sustainability. EfS is designed to be socially transformative not socially reproductive (Wade, 2008).
2. Education for all and lifelong learning: for people of all ages and backgrounds, at all stages of life, all possible learning spaces, formal and informal, in schools, workplaces, homes, and communities.
3. Systems (and network) thinking: understanding the bigger picture, the connections between environmental, economic, social, and political systems to create solutions that go beyond just addressing the isolated symptoms of a larger problem.
4. Envisioning a better future: developing and harnessing the energy to build towards a shared vision for a sustainable future. As Lowe (2012) puts it, the only common future is a sustainable future.
5. Critical thinking and reflection: reflecting on challenge, personal perceptions and experiences, assumptions and accepted ways of interpreting, and engaging with the world in thinking about sustainability, i.e., the important role of "interiors"—mental models, values, culture, and worldviews (see Riedy, 2016).
6. Participation: providing and using skills to allow participation, engaging groups and individuals in sustainability action.
7. Partnerships for change: seeking and building partnerships to build networks and relationships, and improve communication between different sectors of society towards a sustainable future. (Department of the Environment, Water, Heritage, and the Arts, 2009, p. 9)

EfS became a focus in schools after the launch of the NAP EfS, with the *Australian Schools Sustainability Initiative (AuSSI*) (2011) being an initiative of note. Although AuSSI remains active in some jurisdictions, in others, e.g., Tasmania, it is no longer supported. In the *Australian Curriculum* (ACARA, 2017), Sustainability is one of three Cross-Curriculum Priorities. The website contains the following description.

> *Sustainability addresses the ongoing capacity of Earth to maintain all life.Sustainable patterns of living meet the needs of the present without compromising the ability of future generations to meet their needs. Actions to improve sustainability are individual and collective endeavours shared across local and global communities. They necessitate a renewed and balanced approach to the way humans interact with each other and the environment.*
>
> *Education for sustainability develops the knowledge, skills, values and world views necessary for people to act in ways that contribute to more sustainable patterns of living. It enables individuals and communities to reflect on ways of interpreting and engaging with the world. Sustainability education is futures-oriented, focusing on protecting environments and creating a more ecologically and socially just world through informed action. Actions that support more sustainable patterns of living require consideration of environmental, social, cultural and economic systems and their interdependence. (https://www.australiancurriculum.edu.au/f-10-curriculum/cross-curriculum-priorities/sustainability/)*

Further, the priority was developed around the key concepts of Systems, World views and Futures, implying that the original writers indeed had a Futures perspective. So although the notion of a cross curriculum priority appears significant, the contribution of each of the nine curriculum areas is summarised, and the term "sustainability" appears 197 times in the curriculum content (ACARA, 2015), in reality, no one subject body has responsibility for sustainability curriculum and the depth to which it is addressed. Thus, its inclusion largely depends on the expertise and interest of individual schools and teachers, and currently there is no way to determine whether and how sustainability is being taught across Australia (Garg, 2017).

It is also noteworthy that as neoliberalism tightens its grip in Australia, in recent years more critical notions of environmental stewardship have also taken a back seat in education (Thorne & Whitehouse, 2017). The NAP EfS document itself is now only to be found in the archived material on the Department of the Environment and Energy's Sustainability Education website (<www.environment.gov.au/sustainability/education>) (Smith & Watson, 2016).

At the same time within education, however, there are some signs that both STEM and sustainability proponents are coming to appreciate the need to promote each other at both school and university level across all the STEM disciplines; see for example, Hopkinson and James (2010), Pitt (2009), Pecen, Humston, and Yildiz (2012), and Farmer, Tank, and Moore (2015). STEM provides opportunities to re-interpret experiences in order to attract more attention and given its current high profile, more funding for research in schools. Some of the best examples are related to science and arise from the *Primary Connections* publications of the Australian Academy of Sciences <primaryconnections.org.au>.

Currently, the authors are working with primary school students to develop STEM projects. One example is seed dispersal. Students can learn about the biology of seeds and their dispersal, then design and test different dispersal mechanisms, using a statistical package to display and discuss their results. They can also consider possible futures for seeds and learn, for example, about the importance of the Svarlbard Global Seed Vault. With older students, a more critical approach is possible where there is discussion of the impact of industrial agriculture and biotechnology on crop biodiversity, sustainability, and seed futures. A previous study, conducted by Watson and English (2015) with Year 5 students explored environmentally friendly habits of Year 5 students in Australia, based on a survey from the Australian Bureau of Statistics *CensusAtSchool* website. Students set criteria and analysed data, providing evidence for their decisions about students' behaviours.

The Futures aspect of the Sustainability priority addresses EfS Principle 4, which can and should play a key role in STEM education. The tools and concepts of Futures Education (e.g., Gidley, Bateman, & Smith, 2004; Hicks, 2017; Slaughter, 2016), which derive from Futures Studies (Slaughter, 2005) help students to think actively about the future explicitly as something that is created, contested, and open, rather than something that merely happens to them. Futures Education enables students to explore and think critically and creatively about probable and preferable futures (Hicks, 2017). In his work on climate futures for example, Hicks identifies four dimensions that need to be addressed. They are,

> Climate ~ *Learning to live with climate change:* The role education must play in preparing learners for the transition from a high to low-carbon society;
>
> Sustainability ~ *Thinking and acting sustainably:* Why education should help learners distinguish between sustainable/unsustainable ways of doing things;
>
> Futures ~ *Preparing for the future:* How to help young people think more critically and creatively about probable and preferable futures; and
>
> Ideology ~ *Exploring values and beliefs:* How both education and society are influenced by competing ideologies about how the world works best. (Hicks, 2017, para.3)

For Hicks (2017), it is clear that both Futures and ideology need to be addressed explicitly, something that we have argued that STEM does not do. Within the STEM disciplines in the Australian curriculum, concepts from Futures Education can be addressed within Design and Technology. The Year 9 and 10 band description states that: "Students specifically focus on preferred futures, taking into account ethics; legal issues; social values; economic, environmental and social sustainability factors and using strategies such as life cycle thinking" (ACARA, 2015, p.2312). The Design and Technology Knowledge and Understanding strand asks students to,

> *Critically analyse factors, including social, ethical and sustainability considerations, that impact on designed solutions for global preferred futures and the complex design and production processes involved. (p.2313)*

An example given is,

> *recognising the impact of past designed solutions and possible decisions when creating preferred futures, for example the design of public transport systems that use renewable energy and the design of rural communities to reduce fire risk. (p.2313)*

There is considerable potential here to examine technologies from a critical futures perspective, and hence the Design and Technology curriculum may offer the best hope for taking the cross curriculum priority of Sustainability seriously. Again, however, the extent to which this is successful depends on the interest and expertise of teachers. In Australia, professional learning for teachers in Futures Education is patchy, and nowhere is it core in pre-service teacher programs, though there have been calls for its inclusion (e.g., Gidley, Bateman, & Smith, 2004; Paige & Lloyd, 2016; Smith, 2007).

In Conclusion: Rethinking STEM from Flatland to a Viable Future

In this article we have argued that the disciplines of STEM are promoted as providing significant answers to the existential questions of the 21st century, particularly in the fields of employment and sustainability, with concomitant implications for education. However we have also argued that the hypermodern techno-optimist worldview from which STEM emerges, especially in its neoliberal form, is deeply conflicted and presents unexamined barriers to constructive pathways to a viable future. At the same time, we recognise that STEM can and should provide critically important skills and insights into alternative ways forward for economic, social, and environmental sustainability, as well as education, as we navigate the difficult waters of the Anthropocene. Rather than providing the means to continue to lay waste to Earth's ecosystems and resources, STEM needs to be harnessed in the service of the flourishing of humanity and the more-than-human world. This will only be possible if STEM and STEM education is explicitly broadened to include critical and futures dimensions.

Correspondence

Dr Caroline Smith
University of Tasmania
Cradle Coast Campus
Burnie
Tasmania 7320
Australia
caroline.smith1@utas.edu.au

Endnotes

1. This is somewhat ironic given that the biggest invading species is Homo sapiens!
2. It should be noted that both EfS and ESD are terms in use to describe these concepts. Further, the notion of sustainable development itself has been critiqued as a neoliberal project. Sterling (2001) prefers the term 'Sustainable Education'. Here, we are treating then all as consistent with a flourishing future.

References

Abram, D. (1997). *The spell of the sensuous: Perception and language in a more-than-human world*. New York: Random House.

Allen, M. (2006). *Broadband technologies, techno-optimism and the "hopeful" citizen*. In J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas, (Eds.), *International handbook of virtual learning environments* (pp. 1525-1547). Dordrecht, Netherlands: Springer Netherlands. doi: 10.1007/978-1-4020-3803-7_61

Asafu-Adjaye, J., Blomqvist, S., Brand, S., Brook, B., Defries, R., Ellis, E., Foreman, C., Keith, D., Lewis, M., Lynas, M., Nordhaus, T., Pielke , R. Jnr., Pritzker, R., Roy, J., Sagoff, M., Shellenberger, M., Stone, R., & Teague, P. (2015). *An Ecomodernist Manifesto*. Oaklands, CA: Breakthrough Institute. Retrieved from http://www.ecomodernism.org/manifesto-english/

Australian Academy of Technological Sciences and Engineering. (2010). *Renewable Energy: The ATSE STELR Stage One Project 2010*. Melbourne: Author.

Australian Academy of Technological Sciences and Engineering. (2016). *About STELR*. Melbourne: Author. Retrieved from http://www.stelr.org.au/aboutstelr

Australian Curriculum, Assessment and Reporting Authority. (2015). *Australian Curriculum, Version 8.1,* 15 December 2015. Sydney, NSW: ACARA.

Australian Curriculum, Assessment and Reporting Authority. (2017). *Cross-curriculum priorities: Sustainability*. Sydney, NSW: ACARA. Retrieved from: https://www.australiancurriculum.edu.au/f-10-curriculum/cross-curriculum-priorities/sustainability/

Australian Government. (2017). *National Innovation and Science Agenda (NISA)*. Retrieved from https://www.innovation.gov.au/page/agenda

Australian Government Department of the Environment, Water, Heritage and the Arts. (2009). *Living sustainably: The Australian government's National Action Plan for Education for Sustainability*. Canberra: Commonwealth of Australia. Retrieved from http://www.environment.gov.au/system/files/resources/13887ab8-7e03-4b3e-82bb-139b2205a0af/files/national-action-plan.pdf

Bauman, Z. (1993). *Postmodern ethics* (Vol. 195). Oxford: Blackwell.

Bauman, Z. (1995). *Life in fragments: Essays in postmodern morality*. New York: Wiley.

Bauman, Z. (2000). *Liquid modernity* (Vol. 9). Cambridge, UK: Polity Press.

Berry, T. (1990) *The dream of the earth*. San Francisco: Sierra Club.

Berry, T. (1999). *The great work: Our way to the future*. New York: Bell Tower.

Burton, S. (2017). Leadership articles: Beyond the flatlands. *The Forbes Group*. Retrieved from http://www.forbesgroup.com/inner2.iml?mdl=articles.mdl&ArticleID=44&ArticleCat=2

Carter, L. (2016). Neoliberalism and STEM Education. *Journal for Activist Science & Technology Education*, *7*(1), 31-41.

Carter, L. (2017). Neoliberalism and STEM education: Some Australian policy discourse. *Canadian Journal of Science, Mathematics and Technology Education, 17*(4), 247-257. https://doi.org/10.1080/14926156.2017.1380868

Davis, J. (2012). ESD starts where STEM stops: Integrating the social sciences into STEM. In K.-T. Lee (Ed.), *2nd International STEM in Education Conference*, *Beijing, China* (pp. 177-183). Retrieved from http://eprints.qut.edu.au/67370/

Dean, T. (2016). Australia's new chief scientist speaks on techno-optimism. *The Conversation*. Retrieved from https://theconversation.com/australias-new-chief-scientist-speaks-on-techno-optimism-renewable-energy-and-encouraging-stem-54231

Dennett, D. C. (2017). *From bacteria to Bach and back: The evolution of minds*. New York: W. W. Norton Company.

Department of Sustainability, Environment, Water, Population and Communities. (2011). *Australian Sustainable Schools initiative (AuSSI)*. Canberra: Australian Government. Retrieved from http://olr.npi.gov.au/education/aussi/index.html

Drum, K. (2017). You will lose your job to a robot and sooner than you think. *Mother Jones*. Retrieved from http://www.motherjones.com/politics/2017/10/you-will-lose-your-job-to-a-robot-and-sooner-than-you-think/

Farmer, S. A., Tank, K. M., & Moore, T. J. (2015). Using STEM to reinforce measurement skills. *Teaching Children Mathematics*, *22*(3), 196-199.

Fenwick, T., Edwards, R., & Sawchuk, P. (2011). *Emerging approaches to educational research: Tracing the socio-material*. New York: Routledge.

Galloway J. N., & Schlesinger, W. H. (2014). *Biogeochemical cycles*. Washington, DC: National Climate Assessment. US Global Change Research Program. Retrieved from https://nca2014.globalchange.gov/report/sectors/biogeochemical-cycles

Garg, K. (2017). Teaching sustainability in Australian schools: Who's missing out? *SBS News*. Retrieved from https://www.sbs.com.au/news/teaching-sustainability-in-australian-schools-whos-missing-out

Gasparatos, A., Doll, C. N. H., Esteban, M., Abubakari, A., & Olang, T. A. (2017). Renewable energy and biodiversity: Implications for transitioning to a green economy. *Renewable and Sustainable Energy Reviews, 70*, 161-184.

Gidley, J., Bateman, D., & Smith, C. (2004). Futures in education: Principles, practice and potential. *Australian Foresight Institute Monograph Series*. Melbourne: Swinburne University of Technology.

Goldberg, M. (2017). No wonder millennials hate capitalism. *The New York Times*. Retrieved from https://www.nytimes.com/2017/12/04/opinion/millennials-hate-capitalism.html

Hackling, M., Murcia, K., West, J., & Anderson, K. (2014). *Optimising STEM education in WA schools. Part 1: Summary report*. Joondalup, WA: Edith Cowan Institute for Education Research.

Hamilton, C. (2015, April 21). *The technofix is in: A critique of "An Ecomodernist Manifesto."* [Latest news] *Earth Island Journal*. Retrieved from http://clivehamilton.com/the-technofix-is-in-a-critique-of-an-ecomodernist-manifesto/

Hamilton, C. (2017). *Defiant earth: The fate of humans in the Anthropocene*. Sydney: Allen and Unwin.

Hamann, R. (2017). Developing countries need to wake up to the risks of new technologies. *The Conversation*. Retrieved from https://theconversation.com/developing-countries-need-to-wake-up-to-the-risks-of-new-technologies-87213?utm_medium=email&utm_campaign=Latest%20from%20The%20Conversation%20for%20January%205%202018%20-%2091617764&utm_content=Latest%20from%20The%20Conversation%20for%20January%205%202018%20-%2091617764+CID_3f27eeef02b03055fb1afd116a8eef8c&utm_source=campaign_monitor_africa&utm_term=Developing%20countries%20need%20to%20wake%20up%20to%20the%20risks%20of%20new%20technologies

Hicks, D. W. (2017). *Teaching for a better world: Learning for sustainability*. Retrieved from http://www.teaching4abetterworld.co.uk/

Hopkinson, P., & James, P. (2010). Practical pedagogy for embedding ESD in Science, Technology, Engineering and Mathematics curricula. *International Journal of Sustainability in Higher Education*, *11*(4), 365-379.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate change 2014: Synthesis report*. Contribution of working groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R. K. Pachauri & L. A. Meyer (eds.)]. Geneva: Author. Retrieved from http://www.ipcc.ch/report/ar5/syr

Jackson, T. (2009). *Prosperity without growth: Economics for a finite planet*. London: Earthscan.

James, A. (2016). This might change everything: Finding shared meaning beyond consumerism. *Earthsong, 3*(2), 24-25.

Lee, J., & Hannam, P. (2015). Alan Finkel appointed Australia's next Chief Scientist. *Sydney Morning Herald*. Retrieved from http://www.smh.com.au/federal-politics/political-news/alan-finkel-appointed-next-australias-next-chief-scientist-20151026-gkitd7.html

Lee, L. (2017). Managing automation: Developing countries could suffer – up to 80% will lose jobs through robotics. *Al Jazeera*. Retrieved from http://www.aljazeera.com/news/2017/12/managing-automation-developing-countries-suffer-171225113739871.html

Lowe, I. (2012). The only common future is a sustainable future. *Advocate: Newsletter of the National Tertiary Education Union*, *19*(1), 39. Retrieved from http://search.informit.com.au/documentSummary;dn=429814990217909;res=IELBUS

Lucas, L., & Feng, E. (2017). China's push to become a tech superpower triggers alarms abroad. *Financial Times*. Retrieved from https://www.ft.com/content/1d815944-f1da-11e6-8758-6876151821a6

Malafouris, L. (2013). *How things shape the mind: A theory of material engagement*. Cambridge, MA: The MIT Press.

Mandel, E. (1975). *Late Capitalism*. London: Humanities Press.

Marick Group. (2016). *A look at the history of STEM (and why we love it)*. Retrieved from http://marickgroup.com/news/2016/a-look-at-the-history-of-stem-and-why-we-love-it

Marr, B. (2016). Are we headed for 'automated luxury communism'? *Forbes*. Retrieved from https://www.forbes.com/sites/bernardmarr/2016/06/30/are-we-headed-for-automated-luxury-communism/#5525715637e3

McKeown, J. (2017). *A corpus-based investigation of techno-optimism and propositional certainty in the National Intelligence Council's 'Future Global Trends Reports" (2010–2035)*. Retrieved from http://journals.sagepub.com/ doi/pdf/10.1177/1750481317735625

McMillan, S. (2017). What's driving our planet's destruction. *Habitat, 45*(2), 6-9.

Milbrath, L. (1989). *Envisioning a sustainable society*. New York: SUNY Press.

Mitchell, W., & Fazi, T. (2017). *Reclaiming the state*. London: Pluto Books.

Monbiot, G. (2017). *Out of the wreckage – a new politics for an age of crisis*. The Gaia Foundation. Retrieved from https://www.youtube.com/watch?v=uE63Y7srr_Y

Moore, H. (2017). Forget a basic income – here's how Universal Basic Services could fund housing and transport for all. *Prospect Magazine*. Retrieved from https://www.prospectmagazine.co.uk/politics/forget-a-basic-income-heres-how-universal-basic-services-could-fund-housing-and-transport-for-all

Nearing, M.A., Yun, X., Baoyuan, L., & Yu, Y. (2017). Natural and anthropogenic rates of soil erosion. *International Soil and Water Conservation Research*, *5*(2), 77-84.

OECD. (2017). *Income Distribution Database (IDD): GINI, poverty, income, methods and concepts*. Paris: OECD. Retrieved from http://www.oecd.org/social/income-distribution-database.htm

Office of the Chief Scientist. (2012). *Mathematics, engineering & science in the national interest*. Canberra: Commonwealth of Australia. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/Office-of-the-Chief-Scientist-MES-Report-8-May-2012.pdf

Office of the Chief Scientist. (2013). *Science, technology, engineering and mathematics in the national interest: A strategic approach*. Canberra: Australian Government. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/STEMstrategy290713FINALweb.pdf

Orr, D. (1999). Education for globalization. *The Ecologist, 29*(3), 166-169.

Paige, K., & Lloyd, D. (2016). Use of future scenarios as a pedagogical approach for science teacher education. *Research in Science Education, 46*(2), 263-285.

Pecen, R., Humston, J. L., & Yildiz, F. (2012). Promoting STEM to young students by renewable energy applications. *Journal of STEM Education*, *13*(3), 62-72.

Pickering, M. (2009). *Neoliberal nomads: Sustainable development and enclosure on the Tibetan plateau*. Victoria, Canada, BC: Centre for Asia-Pacific Initiatives, Victoria University.

Piketty, T. (2013). *Capital in the twenty-first century*. Cambridge, MA: Harvard University Press.

Pitt, J. (2009). Blurring the boundaries – STEM education and education for sustainable Development. *Design and Technology Education: An International Journal, 14*(1). Retrieved from http://ojs.lboro.ac.uk/ojs/index.php/DATE/article/view/201

Powell, A. (2007). How Sputnik changed U.S. education. *Harvard Gazette*. Retrieved from https://news.harvard.edu/gazette/story/2007/10/how-sputnik-changed-u-s-education/

Prime Minister of Australia. (2015). *Dr Alan Finkel AO appointed as Australia's next Chief Scientist*. (Media release). Retrieved from https://www.pm.gov.au/media/2015-10-27/dr-alan-finkel-ao-appointed- australias-next-chief-scientist

Prinsley, R., & Johnston, E. (2015). *Transforming STEM teaching in Australian primary schools: everybody's business*. Canberra: Office of the Chief Scientist. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/Transforming-STEM-teaching_FINAL.pdf

Regan, E., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., Gonzalez, P., Grosholz, E. D., Ibañez, I., Miller, L. P., Sorte, C. J. B., & Tatem, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. *Nature Communications*, 7, Article number 12485. Retrieved from http://dx.doi.org/10.1038/ncomms12485

Riedy, C. (2016). Interior transformation on the pathway to a viable future. *Journal of Futures Studies, 20*(3), 35-54.

Robinson, A. (2017). AI is learning from our encounters with nature - and that's a concern. *The Conversation*. https://theconversation.com/ai-is-learning-from-our-encounters-with-nature-and-thats-a-concern-88484?utm_medium=email&utm_campaign=Latest%20from%20The%20Conversation%20for%20December%2029%202017%20-%2091387742&utm_content=Latest%20from%20The%20Conversation%20for%20December%2029%202017%20-%2091387742+CID_87386445a8a8328fe2ecfffa9efdaa72&utm_source=campaign_monitor&utm_term=AI%20is%20learning%20from%20our%20encounters%20with%20nature%20-%20and%20thats%20a%20concern

Schleicher, A. (2016). China opens a new university every week. *BBC*. Retrieved from http://www.bbc.com/news/business-35776555

Shafer, W. E. (2006). Social paradigms and attitudes toward environmental accountability. *Journal of Business Ethics, 65,* 121-147. doi:10.1007/s10551-005-4606-2

Slaughter, R. A. (2005). *Knowledge base of futures studies: Series introduction*. Retrieved from https://foresightinternational.com.au/wp-content/uploads/2015/04/KBFS_Series_Introduction.pdf

Slaughter, R. A. (2016). *Futures education rationale. What is Futures and Futures Education?* Melbourne: The Futures Foundation. Retrieved from http://futuresfoundation.org.au/futures-education-rationale/

Smith, C. (2007). Education and society: The case for ecoliteracy. *Education and Society, 25*(1), 25-37.

Smith, C., Fraser, S. P., & Corbett, M. (2017). Liquid modernity, emplacement and education for the Anthropocene: Challenges for rural education in Tasmania. *Australian and International Journal of Rural Education, 27*(3), 196-212.

Smith, C., & Watson, J. (2016). STEM and Education for Sustainability (EFS): Finding common ground for a flourishing future. In M. Baguley (Ed.), *Proceedings of the Annual Conference of Australian Association for Educational Research*. Melbourne: AARE. Retrieved from http://www.aare.edu.au/data/2016_Conference/Full_papers/547_Caroline_Smith.pdf

Smith, N. (2017). Workers get nothing when they produce more? Wrong. *Bloomberg View*. Retrieved from https://www.bloomberg.com/view/articles/2017-12-04/workers-get-nothing-when-they-produce-more-wrong.

Stein, Z. (2016). *Education in the Anthropocene: Re-imagining schools in the midst of planetary transformation*. Retrieved from http://www.zakstein.org/education-in-the-anthropocene-re-imagining-schools-in-the-midst-of-planetary-transformation/

Sterling, S. (2001). *Sustainable education: Revisioning learning and Change*. Schumacher Briefing Series. Cambridge, UK: Green Books.

Stiglitz, J. (2013). The Price of inequality. *New Perspectives Quarterly*, *30*, 52-53. doi:10.1111/npqu.11358

Stockholm Environment Institute. (2015). *Biophysical planetary boundaries*. Retrieved from https://www.sei-international.org/planetary-boundaries

The White House. (2017). *President Trump signs memorandum for STEM education funding*. Retrieved from https://www.whitehouse.gov/articles/president-trump-signs-memorandum-stem-education-funding/

Thiele, L. P. (2013). *Sustainability*. Cambridge, UK: Polity Press.

Thorne, M., & Whitehouse, H. (2017). Environmental stewardship in the Anthropocene (Part One): What have we learned from recent research in North Queensland schools adjacent to the wet tropics? *Social Education*, *35*(1), 17-27.

United Nations (2002). *UN Decade for Education for Sustainable Development (UN DESD)*. Ahmedabad, India: Author. Retrieved from http://www.desd.org/

Wade, R. (2008). *Education for sustainability: Challenges and opportunities*. In J. Coriddi (Ed.), *Policy & practice: A development education review* (pp. 30-48). Dublin: Centre for Global Education.

Washington, H., & Twomey, P. (Eds.). (2016). *A future beyond growth: Towards a steady state economy*. London: EarthScan from Routledge.

Watson, J. M., & English, L. D. (2015). Introducing the practice of statistics: Are we environmentally friendly? *Mathematics Education Research Journal*, *27*, 585-613. doi:10.1007/s13394-015-0153-z

Wilber, K. (1996). *A brief history of everything*. Boston & London: Shambhala.

Zalasiewicz, J., Williams, M., Steffen, W., & Crutzen, P. (2010). The new world of the Anthropocene. *Environmental Science and Technology, 44*(7), 2228-2231.