

Article

All STEM-Ed up: Gaps and Silences around Ecological Education in Australia

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Abstract: Similar to much of the world, the Australian Government has a vision for society to be engaged in and enriched by science which has, as its prime focus, building skills and capabilities in Science, Technology, Engineering and Mathematics (STEM). Simultaneously, the Government's policies and projects, including in education, ignore intergovernmental environmental initiatives, such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). This article critically analyses the Australian Government's STEM and climate change education policies and programs, including Citizen Science activities, through an ecological education lens and finds many, and growing, gaps and silences in these areas. It compares the Australian situation with STEM and ecological education-related developments in several other countries. In the context of significant global changes such as the COVID-19 pandemic, this article argues that it is time for the Australian education agenda to take the Government's international responsibilities seriously, include meaningful engagement with climate change and biodiversity related topics through ecological education in the school curriculum, and discusses what a reimagined school science curriculum could look like.

Keywords: ecological education; environmental education; STEM; sustainable development goals; climate change; goals for schooling; Australian curriculum; citizen science grants



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1. Introduction

The close relationship between science and technology and responses to global environmental changes has been highlighted since at least the 1972 United Nations Conference on the Human Environment. In the Stockholm Declaration from this conference, Principle 18 states, "Science and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind [sic]" [1] (p. 3). Likewise, environmental education statements from around this time consistently envisage science and technology as providing the solutions to environmental problems. For example, Recommendation 1.9 in the Tbilisi Declaration (from the 1977 Intergovernmental Conference on Environmental Education), recommends that, "[environmental education] should be addressed to . . . scientists and technicians whose specialized research and work will lay the foundations of knowledge on which education, training and efficient management of the environment should be based" [2] (p. 26).

At this time the environmental movement and the need for environmental education were the focus of attention for many scientists, such as Rachel Carson [3], Paul and Anne Ehrlich [4,5], Garrett Hardin [6]. Indeed, in Australia, the first conference on "Education and the Environmental Crisis" was convened by the Australian Academy of Science in April 1970 [7]. As I have discussed previously [8,9], at this time and for several years afterwards, there was a close relationship between environmental education and science education, with science education being a frequent vehicle for environmental education, albeit a limited one for some [10], but the relationship could also be of mutual benefit as students' interest in studying science declined but their interest in the environment increased [8,9].

Fast forward around fifty years and the close relationship between science education and environmental education has disappeared, yet an understanding of ecological sustainability is essential if society is to achieve sustainable development. This disassociation between the two areas is apparent in the work of UNESCO, as well as Australia and elsewhere. In 2007 the connection between Education for Sustainable Development (ESD) and Science and Technology Education (STE) was being strongly made on the UNESCO Sustainable Development and STE website [11]:

“STE is thus a major vector in the search for sustainable development. Consequently, the Section for Science and Technology Education maintains sustainable human development as its ultimate objective while promoting an integrated approach to STE focusing on concrete socio-cultural issues related to the environment, health, consumption, etc. Its [sic] operates in formal and nonformal education at the primary and secondary levels and collaborates with other divisions and Sectors of UNESCO operating at other levels of education” [9]. (p. 33).

However, in 2021, the current UNESCO Science Education home page mentions Science, Technology, Engineering and Mathematics Education but not sustainable development or ecological education [12], and the Science, Technology, Engineering and Mathematics Education home page and related links is totally focused on “Girls’ and women’s education in science, technology, engineering and mathematics (STEM)” [13]. A relationship between sustainable development and science and technology on the Sustainable Development Goals (SDGs) for Natural Sciences web page, is still acknowledged but remains isolated from education: “The new 2030 Agenda for Sustainable Development represents a significant step forward in the recognition of the contribution of Science, Technology and Innovation (STI) to sustainable development” [14].

The SDGs also prioritize the human condition over that of the environment: with the first goal being to eradicate poverty as an indispensable requirement for sustainable development [15]. Indeed, many of these goals are very human-centered, with the focus of the first five being human issues: eradicating poverty, removing hunger, human health and well-being, education for all, and achieving gender equality. It is not until goals 9, 11, 12, 14, and 15 that the SDGs recognize concerns about the state of the environment and reducing human impact on it through reducing resource consumption and protecting and conserving life in the water and on land. This focus differs from that adopted in the previously mentioned Stockholm Declaration [1], which foregrounded concerns about environmental protection. It is closer to an ecological education approach recognizes that reducing the impact of human activities on the environment requires changes in the fundamental cultural beliefs and practices that contribute to the degradation of the natural environment.

This article discusses the gaps and silences around ecological education within the current Science, Technology, Engineering and Mathematics (STEM) emphasis in Australian Government policies and Science curriculum documents. These gaps and silences are despite various intergovernmental environmental initiatives to which Australia is a signatory (such as the United Nations Sustainable Development Goals [15] and the Paris Agreement [16], which included education for sustainable development (ESD) and climate change education as action areas in their associated work programs). The article also discusses how the situation in Australia is not very different from developments in other Western countries, and what a reimagined school science curriculum that attends to global changes could look like. Firstly, though, Australia’s STEM education agenda, environment and climate change policies and the Australian Curriculum are discussed to provide a context for this analysis.

2. Australia’s STEM Education Agenda

In the 21st century, policy makers in countries around the world have become preoccupied with STEM [17,18], and this has influenced their educational agendas. Internationally, various governments’ STEM agendas have several aspects in common [18]:

- Enacting an economic policy agenda with a focus on lifting the general quality of the supply of human capital as STEM qualifications prepare graduate for a wide range of occupations both professionally and vocationally;
- Enlarging the high-end STEM skilled workforce to engage in research and development, industry innovation and effective responses to technological change;
- Lifting the overall scientific literacy of the population (when the trend is tending to decline);
- Attracting more students to study STEM at senior secondary and university levels.

The Australian Government is investing in STEM education as part of its neoliberal future productivity agenda: “The Australian Government regards high-quality science, technology, engineering and mathematics (STEM) education as critically important for our current and future productivity, as well as for informed personal decision making and effective community, national and global citizenship” [19].

National concerns about STEM education have persisted for around a decade, with a focused effort from a number of sources to promote a strategic approach to STEM “in the national interest” [20,21] for government and industry action, but with a strong emphasis on the teaching of STEM subjects in schools and the preparation of STEM teachers for schools to address the five most significant challenges facing society [21] (p. 5):

- Living in a changing environment;
- Promoting population health and wellbeing;
- Managing our food and water assets;
- Securing Australia’s place in a changing world;
- Lifting productivity and economic growth.

This Office of the Chief Scientist position paper [21] argues that, “addressing these challenges requires the development of a high-quality STEM enterprise and its strategic deployment” (p. 5). Thus, there were calls for “more STEM education to create smarter futures, economic competitiveness and growth as well as a more scientifically literate society” [18] (p. 446). These calls were accompanied by a plethora of national and state programs to promote STEM education, including teacher education. At the national level these included five projects which were part of the Enhancing the Training of Mathematics and Science Teachers Programme from 2013–2017 [22], which was one of a range of initiatives funded under the Australian Government’s \$54 million Investing in Science and Maths for a Smarter Future strategy [23].

Australia is not alone in pursuing this direction in STEM policy, as Ian Chubb, then Australia’s Chief Scientist, made clear when he launched the STEM position paper [21]. In the launch speech [24] and the position paper, as well as in the *STEM: Country Comparisons* [17] (the consultants’ reports for this provided useful comparative data for the Chief Scientists’ documents), much is made of comparing the current status of STEM policies and practices in other countries to create a deficit position for Australia, if not now, then in the near future. For example, both the Office of the Chief Scientist’s position paper [21] and his speech [24] quote the Rocard et al. (2007) report for the European Commission [25] to support their argument for Australia to have a national STEM strategy: “Around the world there is a sense of urgency—a need to improve a nation’s capacity and a commitment not to take the future for granted or to presume that past practice will be good enough: *because Europe’s future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change*” [21] (p. 8) [italics in original].

The Chief Scientist documents also refer in a positive way to the European Commission’s plans and strategies that attend to “their STEM enterprise—all of it, education, research and innovation” [24], as well as Canada’s 2007 strategy and the follow-up report STEM policy and science education [26] and the US strategic plan [27].

Currently there are a number of National Innovation and Science Agenda (NISA) schools and early years initiatives are being funded as part of the *National STEM School Education Strategy 2016–2026* [28] in the belief that “a renewed national focus on STEM in

school education is critical to ensuring that all young Australians are equipped with the necessary STEM skills and knowledge that they will need to succeed” (p. 3). According to this Strategy, STEM education is a national priority that is closely linked to Australia’s productivity and economic well-being; it is also seen as central to a well-rounded education that will contribute to a diverse and capable STEM workforce pipeline.

In addition, as part of the Inspiring Australia–Science Engagement Programme [29] there are Citizen Science Grants: “to engage the public in science by offering opportunities to participate, as citizen scientists, in scientific research projects that have a national impact and include the collection or transformation of data in Australia . . . The intended outcome of the grant opportunity is increased community participation in scientific research projects where participants learn new skills, form new networks, receive acknowledgement for their participation, and receive updates on their participation in specific research projects”.

What is significant when comparing the research reports and statements from the Office of the Chief Scientist and the Australian Government departments is the confusion as to what is included in STEM. As noted previously, according to the Chief Scientist’s 2013 position paper [21], many of the most significant challenges facing society today that need to be included in the school curriculum are environment related (as well as overlapping with the United Nations Sustainable Development Goals [15]). Similarly, the recent STEM workforce report from the Office of the Chief Scientist [30] looks at Engineering, Information Technology, Natural and Physical Sciences, and Agriculture and Environmental Science as fields of STEM qualification. In contrast, the National STEM Education Strategy [28] refers to science in general with mathematics and technology, as does the government support for STEM website [19] which also very strongly emphasizes mathematics and digital technologies. Indeed, a new digital technologies curriculum, launched in 2018, is seen as providing “a framework for challenging and engaging STEM activities” [31]. However, neither the Strategy nor the STEM website refer to the Sustainable Development Goals nor natural and environmental sciences as content areas. The Australian STEM curriculum is discussed in Section 4 below.

3. Australia’s Environmental and Climate Change Policies

The greatest threat to the environment and sustainability and their associated education in Australia at present is the Australian Government. For example, Australia’s key piece of national wildlife protection law, the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), was enacted in 2000. However, the current government is attempting to change this law to hand greater responsibility for development assessments to the states, which would increase risk and uncertainty over proposals and lead to more environmental destruction, not protection [32]. This is happening at a time when the recent regional assessment report on biodiversity and ecosystem services for the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [33] commented, “Exotic vertebrate predators have been largely responsible for native mammal extinctions in countries such as Australia, where predation by foxes and cats have led to the highest rate of mammal extinction (>10 per cent) of any continent globally” (p. 22). The current government is giving a good impression of not caring about environmental protection; Australia’s wildlife faces an extinction crisis, but the Government is proposing amendments to the national environment law which contain nothing designed to improve environmental protection or save national treasures like the koala whose survival was majorly threatened by the 2020 Black Summer bushfires [34] which have been linked to climate change [35]. At the same time the government is denying environmental groups and others access to vital information about its action and operations which are having significant impact on the environment and “which is limiting all Australians’ access to information as well as their ability to hold our governments to account on a range of urgent social, economic and environmental issues” [36] (p. 1).

Despite the obviously increasing impact of climate change in Australia [37,38], the Australian Government continues to resist international pressure to set emission targets

for 2050, in accordance with the Paris Agreement on Climate Change [39], and at the recent (11 January 2021) One Planet Summit, organized by France, the United Nations and the World Bank, Australia was not one of the more than 50 countries (including Canada, the European Commission, Japan, United Arab Emirates and the United Kingdom) [40], that committed to protecting 30% of the planet, including land and sea, over the next decade to halt species extinction and address climate change issues [41].

In addition, although a signatory to the United Nations 2030 Agenda for Sustainable Development [42] (the Sustainable Development Goals (SDGs)), from the government's official reporting on progress towards the SDGs [43,44] it is apparent that they are not being taken seriously with respect to environmental protection, climate change or associated education programs. That the current Australian government is ignoring its obligations as signatory to the Sustainable Development Goals and the Paris Agreement has significant implications for how environmental and ecological education is being supported in the Australian Curriculum.

4. STEM, Sustainability and Ecological Education in the Australian Curriculum

The term 'ecological education' as "an emphasis on the inescapable embeddedness of human beings in natural settings and the responsibilities that arise from this relationship" [45] (p. 139) has not yet made it onto the Australian education agenda, although, as discussed below, there are Australian researchers who have written and are writing in this space, generally referring to environmental education as encompassing these aspects rather than using the term ecological education [46]. However, as discussed in Section 5, environmental education is also subject to many interpretations, not all of which are consistent with this view of ecological education. This section discusses the current curriculum situation and uses ecological, environmental and sustainability education as equivalents unless otherwise noted.

4.1. National Education Declarations

Since 1989 the ministerial council of national, state and territory ministers of education in Australia have agreed on national goals for schooling each decade, or thereabouts, and these goals have framed the direction for curriculum and assessment. Each of these documents saw science and environmental sustainability in different ways. The first of these sets of goals, the *Hobart Declaration on Schooling* [47], included that students should develop "an understanding of the role of science and technology in society, together with scientific and technological skills" and "an understanding of, and concern for, balanced development and the global environment". This latter goal stimulated a range of environmental education activities by departments of education around Australia [46].

The successor document, *The Adelaide Declaration on National Goals for Schooling in the Twenty-First Century* [48], included the goal that students should "have an understanding of, and concern for, stewardship of the natural environment, and the knowledge and skills to contribute to ecologically sustainable development" and agreed on eight key learning areas for the curriculum, including "science" and "studies of society and environment".

In 2008 the *Melbourne Declaration on Educational Goals for Young Australians* [49] replaced the *Adelaide Declaration*. This document included a commitment to develop a national curriculum which would include Science (biology, chemistry and physics) and noted that "a focus on environmental sustainability will be integrated across the curriculum" (p. 14). Significantly, this document expanded on the environmental content of the *Adelaide Declaration* and recognized the unprecedented challenges posed by climate change: "Complex environmental, social and economic pressures such as climate change that extend beyond national borders pose unprecedented challenges, requiring countries to work together in new ways. To meet these challenges, Australians must be able to engage with scientific concepts and principles, and approach problem-solving in new and creative ways" (p. 5). While students' digital literacy was seen as essential for the future, STEM was not mentioned.

The most recent declaration is the 2019 *Alice Springs (Mparntwe) Education Declaration* [50]. Here, the education system is seen as preparing “young people to thrive in a time of rapid social and technological change, and complex environmental, social and economic challenges” (p. 2). That the reference to climate change has been deleted from this statement, which is otherwise similar in wording to the *Melbourne Declaration* quoted above, is telling in terms of the Australian Government’s position on climate change. Nevertheless, there is also a goal that students should be active and informed members of the community who “have empathy for the circumstances of others and work for the common good, in particular sustaining and improving natural and social environments” (p. 8), however, consideration of sustainability in the curriculum is reduced to encouraging students to “engage with complex ethical issues and concepts such as sustainability” (p. 15), not as a part of the mandated curriculum as previously. Consistent with the Education Council’s *National STEM school education strategy, 2016–2026* [28], in this Declaration, the STEM learning areas are seen as “a key national focus for school education in Australia and are critical to equip students to engage productively in a world of rapidly changing technology” (p. 15), but gone is the association of science with problem solving around complex environmental, social and economic pressures.

These successive declarations are important because they set the tone and directions for education initiatives, such as pursuing a national curriculum or national testing regimes as part of the goal of Australia having world class curriculum and assessment (a phrase that recurs over several declarations), prioritizing that students should sustain and improve natural environments, or pursuing a STEM agenda.

4.2. Australian Curriculum

Work on the Australian Curriculum, in eight learning areas including science and mathematics, with sustainability as a cross curriculum priority, commenced in 2009 and the Foundation-Year 10 curriculum was endorsed by Australia’s education ministers in September 2015. “The curriculum provides teachers, parents, students and the community with a clear understanding of what students should learn regardless of where they live or what school they attend. The national curriculum was introduced to improve the quality, equity and transparency of Australia’s education system” [51]. Most States and Territories follow the Australian Curriculum however, New South Wales, Victoria and Western Australia do have their own local curriculum documents which do, at times, differ from the Australian Curriculum, but generally not to any great extent.

Parallel with the release of the Education Council’s *National STEM school education strategy, 2016–2026* [28], the Australian Curriculum, Assessment and Reporting Authority (ACARA) initiated the STEM Connections project [52] “to explore potential connections between STEM disciplines in the Australian Curriculum by implementing an integrated, project-based approach to the teaching of STEM” (p. 5). Specifically, the aims of this project were to:

- Help students recognise the importance of knowledge, understanding and skills across STEM subjects;
- Improve the confidence of students in STEM and their capacity to transfer knowledge, understanding and skill across STEM subjects and contexts;
- Identify explicit connections for students between classroom learning in STEM and future work and learning opportunities;
- Develop strategies that encourage girls to remain engaged in STEM subjects
- Establish guidelines for developing school–industry STEM initiatives;
- Enable dialogue about the collaborative development of an integrated STEM program of study or subject (p. 5).

Subsequently, resources were developed to support the teaching of STEM in the Australian Curriculum [53]. There are no equivalent resources to support the teaching of sustainability as a cross curriculum priority, but the STEM resources did include a portfolio on “Sustainability” [54] which seems to have little to do with sustainability: “Students use effective project planning techniques for a designed solution. They outline a research

plan, design criteria and success criteria. Students explain the need for a designed solution, using photographic evidence and survey results. They demonstrate research into a range of options and provide a number of preliminary sketches before deciding on the solution. They are able to justify their designed solution. Students prepare an implementation plan. They make effective use of technologies". The work sample provided was "Experimental investigation: Light intensity" but it is not made clear as to how this activity relates to sustainability. There is also a STEM resource portfolio on "Environment" [55]. Here, the work sample is "Design project: The top playground": an exercise where students collaborate in small groups to investigate the effect of overpopulation on the school's playground (including consideration of preventing soil degradation and sustaining grass), which is a little better.

In addition, it fails to engage with biological, earth and environmental sciences, thus providing students with a distorted understanding of science. If these sciences are engaged at all it is almost incidental, for example as a vehicle for an engineering or design project.

Understandings of education for sustainability are currently elaborated in the Australian Curriculum as a cross curriculum priority [56]. According to the Sustainability overview statement:

"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." (para. 6)

Although this statement about Sustainability is consistent with holistic approaches to environmental education and sustainability, the actual content of the subject areas does not enact the statement's intent, nor the Organising Ideas for Sustainability [56]—particularly those associated with "world views" and "futures" (see Table 1)—and there is no guidance for teachers in implementing these organizing ideas.

These organising ideas are particularly interesting for their valuing of the environment for its own sake, rather than just as a resource for exploitation. Indeed, in many ways they come close to being concerned with what characterizes ecological education: "developing a citizenry capable of making wise decisions about the impact of human activities on the environment, examining and altering fundamental cultural beliefs and practices that are contributing to the degradation of the planet's natural systems" [45] (p. 139). However, there is a mismatch between the Sustainability cross curriculum priority statement, the organising ideas, and the Science curriculum content statements discussed below. Additionally, significantly, there is no specific guidance to teachers for implementing the Sustainability organizing ideas.

There is a specific symbol () to indicate particular content where the Sustainability cross curriculum priority is appropriate in each curriculum statements. However, this symbol rarely occurs across the eleven years of schooling covered by the curriculum statements, including only ten times in the Science curriculum content statements (see Table 2).

Table 1. Sustainability Organising Ideas in the Australian Curriculum. (From <https://www.australiancurriculum.edu.au/f-10-curriculum/cross-curriculum-priorities/sustainability/> (accessed on 15 March 2021)).

Systems
OI.1 The biosphere is a dynamic system providing conditions that sustain life on Earth OI.2 All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival OI.3 Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems
World Views
OI.4 World views that recognise the dependence of living things on healthy ecosystems, and value diversity and social justice are essential for achieving sustainability OI.5 World views are formed by experiences at personal, local, national and global levels, and are linked to individual and community actions for sustainability
Futures
OI.6 The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future OI.7 Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments OI.8 Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgments based on projected future economic, social and environmental impacts OI.9 Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments

The Science content associated with sustainability is mainly focused on the environment and basic ecological concepts. Notably absent from the above content statements are specific and urgent ecological issues facing Australia and the planet, such as the climate crisis and loss of biodiversity, even though the Preamble to the *Melbourne Declaration* [49] intimates that science understanding is important in meeting complex challenges such as climate change. However, as noted previously, mention of climate change has been deleted from the successor *Alice Springs (Mparntwe) Education Declaration* [50]. While the content statements are what must be taught at the year level, there are suggestions for teaching the content, called elaborations, but these are optional.

There are 55 elaborations in the Science curriculum which are associated with the leaf symbol [57], but climate change only appears in 5 elaborations at Year 10 level, and biodiversity only appears in 3 elaborations at Year 10 level. Given that Science has often become a curriculum elective by Year 10 (for a variety of reasons including student disengagement and disenchantment with their science education and a shortage of qualified science teachers [18]) it is possible that few students will ever study these key understandings.

In addition, although sustainability is included as a cross-curriculum priority in the Australian Curriculum, its placement within the curriculum is haphazard, and generally develops a shallow understanding of sustainability, if it is taught to students at all [58,59]. Indeed, a 2014 review of the Australian Curriculum by Donnelly and Wiltshire [60] recommended that “ACARA reconceptualize the cross-curriculum priorities and instead embed teaching and learning about . . . sustainability explicitly, and only where educationally relevant, in the mandatory content of the curriculum” (p. 247). This recommendation was not acted upon, but in June 2020 the education ministers announced another review of the Australian Curriculum with the terms of reference to:

- Revisit and improve if necessary, the organising frameworks for the cross-curriculum priorities with reference to current research;
- Declutter the content of the Australian Curriculum by improving the relationship of the cross-curriculum priorities to learning area content, removing any repetition of content between the cross curriculum priorities and the learning areas and replacing

the current ‘icon tagging’ for cross curriculum priorities on the Australian Curriculum website with a more user-orientated approach [61].

At the time of writing this review is not yet completed, but it does not auger well for sustainability, nor ecological education in the light of the championing of STEM and the downgrading of references to ecological concerns in the *Alice Springs Declaration*.

Table 2. Content statements associated with sustainability in the Australian Curriculum Science. (From <https://www.australiancurriculum.edu.au/f-10-curriculum/science/> (accessed on 15 March 2021)).

Year Level	Content Statement (with Link to Elaboration)
Year 1	People use science in their daily lives, including when caring for their environment and living things (ACSHE022)
Year 2	People use science in their daily lives, including when caring for their environment and living things (ACSHE035)
Year 5	Living things have structural features and adaptations that help them to survive in their environment (ACSSU043)
Year 6	The growth and survival of living things are affected by physical conditions of their environment (ACSSU094)
Year 7	Interactions between organisms, including the effects of human activities can be represented by food chains and food webs (ACSSU112)
Year 8	Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150)
Year 8	People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE136)
Year 9	Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176)
Year 9	Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (ACSSU179)
Year 10	Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)

5. An Agenda Failing on Multiple Levels

5.1. Australia

In addition to the Australian Curriculum’s sustainability cross curriculum priority failing to be developed according to its own positioning statement and organising ideas, all science and STEM education initiatives and activities are occurring in a social and political vacuum [62], rather than teaching about their sociopolitical or ecological aspects. Rather, the STEM education being offered is an elite science education that “rarely expose students to systematic analyses of the social origins, traditions, meanings, practices, institutions, technologies, uses, and consequences of the natural sciences that ensure the fully historical character of the results of scientific research” [63] (p. 1). Neither does it “enable anyone to grasp how nature-as-an-object-of-knowledge is always cultural: ‘In science, just as in art and life, only that which is true to culture is true to nature’” [63] (p. 1), yet understanding how nature and resolving environmental and ecological problems is always cultural are core to a good science, environmental and/or ecological education.

The Education Council’s *National STEM school education strategy, 2016–2026* [28] outlines five areas for action in STEM education around Australia:

- Increasing student STEM ability, engagement, participation and aspiration;
- Increasing teacher capacity and STEM teaching quality;
- Supporting STEM education opportunities within school systems;
- Facilitating effective partnerships with tertiary education providers, business and industry;
- Building a strong evidence base (p. 6).

We are now halfway through the time frame for this strategy, and the report card is not good.

Regarding student ability, etc., student engagement and performance in STEM have been declining, partly because the “STEM curriculum is unbalanced and fragmented, leading to less interest among students”, and Australia does not have the supply of qualified teachers to improve learning [64]. Australia participates in both the Trends in International Mathematics and Science Study (TIMSS), a project of the International Association for the Evaluation of Educational Achievement (IEA), and the OECD’s Programme for International Student Assessment (PISA). In the report on Australian results from TIMSS testing in 2015, Thomson et al. [65] report that overall Australian Year 8 student achievement has declined slightly since 1995, and that Australia is falling down the rankings, with 17 countries being ahead of Australia in Year 4 science and 14 countries being ahead in Year 8 Science. PISA measures 15-year-olds’ ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges. The last round of testing was in 2018 and the results were not good from Australia: Between 2006 and 2018, Australia’s mean performance decreased on average by 24 points [66].

In addition, “ingrained gaps in socio-economic and gender attainment are not shifting” [64], as reflected in the Australia’s 2020 STEM workforce analysis by the Office of the Chief Scientist that found women account for only 21% of those who completed post-secondary STEM education and only 16% of the STEM-qualified (VET and university) workforce. Additionally, the future does not look great for girls changing their minds and choosing STEM subjects. A 2018 report from the longitudinal study of Australian children noted that boys outnumbered girls two to one in Advanced Mathematics, three to one in Physics and Engineering and almost five to one in Design Technology, whereas girls were more likely to select Biology, Creative Arts, Health, Psychology, Legal Studies, and Society and Culture than boys [67]. In addition, full-time female workers earn less on average if working in engineering, science and IT fields [68]. It is therefore not surprising that the Australian Government appointed its first Women in STEM Ambassador in 2018 [69], and the Australian Academy of Science released its *Women in STEM Decadal Plan* [70] in 2019 in an attempt to get more females engaged with STEM.

Additionally, significantly, STEM education is failing Indigenous students. According to Indigenous educator Elizabeth McKinley, “Indigenous students do not perceive STEM subjects as being welcoming” despite “PISA data shows that Indigenous students have an interest in science that is equal to that of their non-Indigenous peers” [71] (p. 64).

The lack of appropriately qualified teachers is a critical issue for both STEM and sustainability education. For example, Michael Timms et al. [72] comment on the need for Departments of Education to do more work on increasing teacher capacity and teaching quality in STEM, John Buchanan [73] found that sustainability was only sporadically included in teacher education programs, and Jane Edwards [58] found a rhetoric-reality gap between environmental education statements and teachers’ practices. In the state of Victoria, the government has been funding science/STEM/mathematics education initiatives for 20 years through interventions such as the *Science in Schools Strategy* which was launched in 2000 [74]. These interventions included a major school-based research project (School Innovation in Science), extended professional development programs, curriculum resources for primary teachers, and funded graduate certificate programs for primary teachers and secondary physics teachers (to meet specialist teacher guideline requirements). Subsequent interventions include the *School innovation in teaching: science, mathematics and technology* program [75] which, building on the Science in Schools Strategy, had as its primary objective to foster, in both primary and secondary schools, a culture of innovation and creativity in the teaching of science, mathematics and technology to:

- Improve the teaching and learning of science, mathematics and technology;
- Increase the level of student scientific, mathematical and technological literacy;
- Encourage more students to study post compulsory science, mathematics and technology (p. 23).

Despite these earlier efforts, in 2016 the Department of Education and Training released a vision statement, *STEM in the Education State* [76], because “Victoria is falling

behind the world's top performers in STEM participation and achievement, and too many people still lack the skills required by a technology and knowledge-based economy" (p. 1). More recently, the Department of Education and Training has embarked on a new program, the Secondary Mathematics and Science Initiative (SMSI), to retrain the current workforce of out-of-field teachers of mathematics and science [77]. This initiative recognizes that high quality, well-trained mathematics and science teachers are needed to meet these targets, and the government is making a significant financial investment. However, the vision of science in these recent initiatives is a scientific literacy that that does not include the environment—the science focus is on chemistry and physics.

5.2. Other Countries

Australia is not the only country that is not bringing STEM and ecological education together in their school curriculum, and having problems finding appropriately qualified teachers. For example, in 2020 the New Zealand Ministry of Education introduced Education for Sustainability (EfS) as a significant theme throughout their curriculum [78]. Their conception of EfS is environmentally and ecologically focused: "Education for sustainability includes learning about:

- the environment—water, land, ecosystems, energy, waste, urban living, transportation
- the interactions between the natural environment and human activities, and the consequences of these
- the choices and actions we can take to prevent, reduce, or change harmful activities to the environment." [78]

At the same time, the Ministry of Education is also promoting STEM/STEAM: "STEM/STEAM learning applies meaningful maths, science, and technology content to solve real-world problems through hands-on learning activities and creative design" [79], but there is no cross referencing between these two important curriculum areas, even though environmental problems are real world problems and STEM related expertise is part of preventing, reducing or changing activities that harm the environment and there is a silence around sustainability in the STEM/STEAM learning resources. New Zealand also has a crisis finding qualified STEM teachers [80].

According to Kevin Coyle, the United States Next Generation Science Standards (NGSS) "focus more on the place of STEM education in the context of the Earth and its resources and thus emphasize learning science in a broad context" [81] (p. 397), which he sees as a positive for sustainability, although sustainability is only mentioned three times in the standards, all at the upper secondary school levels (Grades 9–12) [82]. In addition, developments in the US are not uniform. Only 20 states have adopted NGSS [83]; there is no national STEM or sustainability education curriculum and the status of both areas varies hugely from state to state. Urmila Marak argues that the status of STEM education in the US is in crisis: there is a shortage of qualified teachers in schools, there are gender and socio-economic barriers to students studying STEM areas, and there are declining results in PISA in maths and science: students are disengaging with STEM studies despite a shortage of a STEM workforce, and there is limited interest from students in becoming science literate [84].

Rachael Tawbush and colleagues recently compared how K-12 STEM education was conceptualized in India, Italy and Singapore [85]. They found that STEM was a fragmented concept in India with gendered assumptions around who is capable of learning STEM concepts, and a shortage of qualified teachers and appropriate resources. They found that STEM was a splintered concept in Italy, with gendered assumptions that can exclude girls from studying STEM subjects, declining student interest in learning STEM content. These barriers to STEM were not apparent in Singapore where STEM education is more technology and computer driven. In all instances the "science" component was chemistry and physics concept based, with no mentions of ecological education concepts. However, it does not need to be like this.

6. Responding to Global Challenges

According to many scientists, the planet is now in a new geological era, the Anthropocene, because humans are now exerting so much influence over planetary processes [86]. As a result, some scientists and philosophers, such as Bruno Latour [87], argue that the Anthropocene is an era of negotiation in which humans must engage in a different kind of relationship with the rest of the members of our planet and acknowledge the need to leave behind ideas of human privilege. This is not the place for an in depth discussion of the Anthropocene, but the planetary circumstances are a global challenge.

The global challenge of the COVID-19 pandemic prompted the United Nations to reflect on each of the SDGs [15] with a COVID-19 response. In addition, they developed A UN framework for the immediate socio-economic response to COVID-19 [88]. This document is significant as it seems to be a pivot point, foregrounding the importance of the environment, consistent with an ecological education viewpoint: “The current COVID-19 pandemic is a reminder of the intimate relationship among humans, animals and the environment” (p. 4).

The framework recognizes that the current health crisis is a signal of an unsustainable economic model—with unsustainable patterns of consumption and production and that “The performance and resilience of our socio-economic systems depend on the state of the natural environment and ecosystems. A mutually beneficial symbiotic relation between humans and their surrounding ecosystems is inter alia the answer to more resilient economies and societies” (p. 4). Technological innovation and transfer are still seen as important at a macroeconomic level, but increased prominence is given to the interconnectedness of all life on the planet. “Rather than being put aside as aspirational in a time of crisis, the SDGs and the Paris Agreement offer a framework for a fair and sustainable transition, as they recognize the interconnected nature of all life on this planet. Beyond the socio-economic frame of the current response, the role the environment and natural capital will play in the path to recovery is a policy choice that warrants further elaboration, as do good governance, gender equality and empowerment, and the protection and promotion of human rights for all” (p. 39).

This foregrounding by the UN of the importance of the environment, through recommending that environmental considerations should be taken on board across all sectors of response and recovery effort rather than simply seeking technological solutions, provides an ideal opportunity to bring STEM and ecological education together.

7. New Alliances for Ecological and STEM Education

I have been arguing for nearly twenty years that science and environmental education should be in a mutualism relationship [8,9]. This situation has not changed, and in the light of the SDGs, climate change and species extinctions, together with continuing decline of student interest in pursuing STEM studies and careers, the need to bring together ecological and STEM education has become more urgent. This mutualism needs to be more than paying lip service to the interrelationship through design activities [54], as these activities do not take into account the partnership that there needs to be between human and nonhuman worlds. As Carolyn Merchant [89] argues, “By merging anthropocentric with ecocentric ethics—the ethic that includes all of nature within it—we can develop an integrated, interactive ethic based on partnership between the human and the nonhuman worlds . . . *A partnership ethic holds that the greatest good for the human and nonhuman communities is in their mutual living interdependence*” (p. 162) [italics in original]. Further discussion of the dissipation of the binary between human and nonhuman/posthuman/more-than-human in environmental education is beyond the scope of this article but it is discussed elsewhere (see, for example my writing with Hilary Whitehouse [90,91]). However, it is important to note that there is scope for developing this within the Sustainability Cross-Curriculum Priority that promotes a “renewed and balanced approach to the way humans interact with each other and the environment” [56] (n.p.).

Some educators are exploring bringing together engineering and sustainability education [92], arguing that engineering education must change in order to more fully integrate sustainability because, at present, “most engineering programs do not explicitly prepare students to engineer within the bounds of sustainability” (p. 1). Additionally, at a university level, Mychajliw et al. discuss how their students applied their STEM coursework towards contextualizing the novel problems that accompany global change, thus preparing them for the adaptive learning necessary in the Anthropocene [93].

At a school level, Gupta et al. [94] describe a high school study where a holistic science learning experience saw students gaining new understandings of complex natural phenomenon, developing systems thinking, and expressing excitement about science in the present and for their future pursuits. Additionally, relevant is the study by Velázquez and Rivas [95] which investigated incorporating ESD into STEM education through learning objectives as well as the key competences established in Sustainable Development Goal 11 (Sustainable Cities and Communities) and found that students developed “high levels of sustainable awareness of the importance of the environmental, social, and economic dimensions that underline the principle of sustainability” (p. 16). In a similar vein, the STEM Learning organization in the United Kingdom have produced a range of STEM related curriculum materials to promote student engagement with and understanding of the SDGs and their targets [96]. Susan Blackley and Rachel Sheffield [97] argue that STEM education could be re-imagined by addressing the E as a more cogent and inclusive approach to addressing environmental issues, “ecothinking”, and that such “an integrated and authentic STEM education could not only provide a space to investigate environmental issues but also offer a frame to image and implement solutions or resolutions” (p. 1). Others are taking a broader perspective to argue for new alliances between STEM and sustainability education. Justin Dillon and Bill Scott, for example, argue for a “shift from seeing ‘environment’ as a focus for the consideration of science concepts to seeing a STEM education as one which, properly, seeks to help students understand environmental issues in the context of their lives, and their lives in the context of environmental issues” [98] (p. 1112). Connie Russell and Justin Dillon similarly argue that “STEM education needs to change to reflect students’ needs and to produce not just the required numbers of scientists and engineers but also a scientifically literate society [99] (p. 1). However, there is a tension in that STEM education is more socially productive, designed to supply human capital, whereas ecological/environmental/sustainability education is explicitly critical, activist, and socially transformative of people and of human thinking [100].

Bringing ecological and STEM education together is essential if society is to be scientifically literate and able to respond to the global challenges: “Without an adequate STEM and environmental education, tomorrow’s citizens will be unable to appreciate their relationship with the environment and, as a result, might not make choices that will lead to a sustainable future” [99] (p. 3).

8. Science Literacy towards Global Citizenship in a Reimagined Science Education

De Coito et al. [101] pose thought-provoking questions that educators and researchers of STEM must grapple with as they ponder the tenets of STEM education and the role of scientifically literate citizenry, that also need to take into account ecological education: “What is the purpose of STEM education? Are we educating our children with the intention that they gain wisdom, knowledge, and become active democratic citizens? Do we see education as a means to prepare a workforce that is equipped to innovate and compete globally?...will STEM embrace ‘Science for All’ or will it further perpetuate science as elitist?” (p. 109).

As discussed previously, evidence to date would seem to indicate that, perhaps even if not the intention, STEM education in Australia is elitist, focused on producing human capital and it is not producing active democratic citizens. However, the bringing together of STEM with ecological education could encourage the development of such citizens. Science and technology will provide some solutions to our environmental crises, but soci-

ety will need an ecologically educated population prepared to change the way they live and work in order to reduce human impact on the planet. This will require a reimagined education, as Malone and Truong [102] suggest. The question is not whether education has role to play in ecologically sustainable futures, rather, they ask, “can we reimagine new ways of doing education and not repeat the same old practices? Are there new practices of education and educational research that can be performed that address these precarious times?” (p. 8). Education in the future needs to be socially reconstructive and transformative to create a scientifically literate global citizenship. The UN framework for responding to the pandemic [88] and discussions around the Anthropocene [86] highlight that business-as-usual that pursues social reproduction in a neoliberal and neoconservative agenda will not work in the future as society and our environment have been drastically altered. Both STEM and ecological education have a place in this reimagined education. For example, Lim sees STEM as an integral part of global citizenship: “Regardless of our location, we face a common destiny (at least in the midterm or long term); where the unfolding of an event in one part of the world affects lives in other parts. In such a new world order, education for global citizenship is essential in preparing our children and young people to be agents of change rather than just passive observers of world events; and at the same time, to live together in an increasingly diverse and complex society and to reflect on and interpret fast-changing information” [103] (pp. 1073–1074). Participatory approaches are important because people need to be learning to work together and live with climate change and the other environmental crises, as well as working across cultures and genders in addressing environmental issues.

This reimagined education will also need to be interdisciplinarity, transdisciplinarity and/or cross disciplinarity; to adopt community- and/or participatory-based approaches in the natural sciences; and to encourage alternative modes of thought, including human interrelationships with the rest of the planet [104]. This would be consistent with the recent UNESCO ESD roadmap [105] which states, under “Pedagogy and learning environment: Employ interactive, project based, learner-centred pedagogy. Transform all aspects of learning environment through a whole institution approach to ESD to enable learners to live what they learn and learn what they live”. This is much more than a narrow STEM approach.

The reimagined curriculum needs to be more holistic. As Tawbush et al. [85] found, a STEM curriculum can be very fragmented, even when that is not the intention. An ecological curriculum is also intended to be interdisciplinary, as indicated by the Australian Curriculum’s Organising Ideas for Sustainability [56], and these would be a good placed to start in planning a reimagined education, combined with the different pedagogies discussed above. The challenge will be to confront the tension between the objective nature of science education and the social aspects of ecological education.

One way these aspects have been brought together for some is through citizen science projects: 15 of the 18 recent Australian Government Citizen Science grants went to projects that had an ecological/human focus [106]. In an investigation of participants in biodiversity citizen science projects across Europe, Australia and New Zealand Maria Peter and colleagues found self-reported increases in knowledge, self-efficacy, interest and motivation “to be more pronounced when regarding the environment rather than science” [107] (p. 1). We need more such projects incorporated into the reimagined science education.

9. Conclusions

While the Australian people are concerned about climate change and losses to biodiversity, the Australian Government is neglecting its responsibilities in these areas and ensuring that students in schools are not studying topics that will help them become active informed democratic citizens able to participate in discussions about these issues. Instead, the push is very much for a STEM agenda that is not meeting the needs of employers and graduates, nor the interests of students. As has been discussed in this article, Australia is not alone in keeping its STEM and ecological education curricula in silos, but it is time for a change.

Through discussions around the Anthropocene and international responses to COVID-19 and other global challenges it is clear that we need to be working towards a scientifically literate global citizenry if people are to make informed choices towards a sustainable future. STEM education has a role in this, as does ecological education. A reimagined science education should be socially reconstructive and transformative. The content needs to be interdisciplinary, crossdisciplinary and/or transdisciplinary, and the pedagogy needs to be interactive, project based, learner-centred and participatory. We are moving beyond a time for choice. As the United Nations COVID-19 response framework states, “Securing the global environmental commons requires living within planetary boundaries, conserving and sustainably managing globally shared resources and ecosystems, as well as their shared vulnerabilities and risks to promote human wellbeing” [86] (p. 4).

Discussion in this article focuses on Australia and STEM and ecological education in a limited number of countries. Comparisons with other countries will add to the conversation, as will future investigations into the development of reimagined curricula that bring together STEM and ecological education.

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