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Towards more effective learning for sustainability: reconceptualising science education

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Introduction

In mid 2007, on the west coast of Australia, the World Conference on Science and Technology Education released its *Perth Declaration on Science and Technology Education* (see Appendix). A week after the conference, on the east coast of Australia, the Ford Motor Company announced that it would close its six-cylinder engine plant in Geelong in 2010, after 81 years of continuous operation (Gordon, 2007; Shanahan & Holroyd, 2007). Why am I linking these events in starting this paper?

The reasons for the closure of the Ford plant are several – they relate to environmental controls, technological advances, economic realities and social pressures, in particular:

- The six cylinder engine currently being produced at the plant had "been left behind by changes in fuel efficiency and emissions technology" (Gordon, 2007, p.1) and will not meet the emission control standards that come into force in three years time.
- Consumer demand for six cylinder cars has slumped in favour of smaller cars because of high petrol prices.

The fact that society – through both government controls and consumer demand – is exerting such influence on the motor vehicle industry is a reflection of how far we have come in society's levels of environmental awareness since Rachel Carson published *Silent Spring* in 1962 and Garrett Hardin (1968) wrote "The tragedy of the commons", galvanising a worldwide environmental movement.

It is thus disappointing to see environment and sustainable development being treated in such a relatively tokenistic way in the Perth Declaration. Although the Declaration ended with the pledge that "We, the participants, are committed to ensuring that students are scientifically and technologically literate and able to contribute to sustainable, responsible, global development in their respective nations", there was no acknowledgement that science education's lack of incorporation of environmental or sustainability education might be linked to the "global decline in the level of interest in science" (Australian Science Teachers Association [ASTA], 2007). About the closest acknowledgement of something that might hint at this deficiency is in the last key reason for the global decline noted by the Australian Science Teachers Association in its media release on the Declaration, that is, "Perceived lack of relevancy of modern science curricula resulting in student disengagement" (ASTA, 2007). In the Declaration itself this is phrased differently, as "a widespread lack of student interest in current school science and technology education and of its relevance to them" (World Conference on Science and Technology Education [WCSTE], 2007). What we do know from numerous surveys and research studies, is that students are interested in the environment, yet this is generally not reflected in science curricula in schools. I will return to this point later in this paper.

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None of the actions for governments around the world included in the Perth Declaration addressed the bringing together of science education and environmental or sustainability education beyond:

- Promoting "critical awareness of the contribution of science and technology to personal, social, economic and environmental wellbeing through building partnerships with national stakeholders and the media";
- Calling on UNESCO "to integrate its science and technology education endeavour as fundamental to achieving educational, environmental, cultural, social and sustainable development goals". (WCSTE, 2007)

The only curriculum action was "to initiate revisions of the curriculum for school science and technology that will increase student interest in and recognition of the roles of science and technology in society" (WCSTE, 2007).

I was not a participant at this conference so I can only ponder from a distance as to why the relationship between science and environmental education continues to be so estranged, particularly given that we are already in the fourth year of the United Nations Decade of Education for Sustainable Development and there is some scant acknowledgement of the Decade's existence in some of the wording of the Declaration. However, even the call on UNESCO seems to be ill-informed as the connection between Education for Sustainable Development (ESD) and Science and Technology Education (STE) is already being made there. According to the UNESCO Sustainable Development and STE website (2007a):

> 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 non formal education at the primary and secondary levels and collaborates with other divisions and Sectors of UNESCO operating at other levels of education.

If the Perth conference participants were not aware of this, it could be evidence that UNESCO's Decade implementation scheme is not reaching this audience, even though "The goal of the United Nations Decade of Education for Sustainable Development (2005-2014, DESD), for which UNESCO is the lead agency, is to integrate the principles, values, and practices of sustainable development into all aspects of education and learning" (UNESCO, 2007b).

In this paper I am arguing that, with the growth of Education for Sustainable Development in the past decade or so, the potential relationship between environmental education and science education has strengthened, with a growing recognition that an understanding of ecological sustainability is essential if we are to achieve sustainable development. When this potential relationship is combined with the global decline of the level of students' interest in science in schools there would seem to be an argument for reconceptualising science education for their mutual benefit. This needs to be beyond just "re-imagining science education" (Tytler, 2007) – it will require a major reconstruction. That the environment (and thereby environmental education) is the elephant in the science classroom needs to be acknowledged and taken advantage of.

Firstly, however, for those who are unfamiliar with the common ground between these two areas I will provide a short history that extends an earlier paper (Gough, 2002) to include more recent developments in education for sustainable development and science education.

Where have we come from?

The field that has become environmental education arose out of the growing awareness of the threat of environmental degradation in the 1960s. Increasingly throughout the decade scientists such as Carson and Hardin drew attention to the growing scientific and ecological problems of the environment and the need for greater public awareness of these problems, such as the increasing contamination of land, air and water, the growth in world population and the continuing depletion of natural resources. These problems were formally recognised in the 1972 United Nations Declaration on the Human Environment (in Greenall & Womersley, 1977, p.15):

> We see around us growing evidence of man-made harm in many regions of the earth; dangerous levels of pollution in water, air, earth and living things; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiencies in the man-made environment of human settlement.

The scientists' calls were for more information about the environment for the public, and for education. For example, Rachel Carson (1965, p.30) argued that "The public must decide whether it wishes to continue on the present road, and it can do so only when in full possession of the facts". Similarly, Paul and Anne Ehrlich (1972, p.357) criticised the "almost total failure" of countries throughout the world to prepare the general public to understand and make responsible decisions on environmental issues. At the 1972 United Nations Conference on the Human Environment the importance of education was asserted. In the prelude to recommendations for international action it stated (in Greenall & Womersley, 1977, p.16) that "Education and training on environmental problems are vital to the long-term success of environmental policies because they are the only means of mobilising an enlightened and responsible population, and of securing the manpower needed for practical action programmes".

In the wake of publicity and political actions attending these concerns, environmental education initially entered school curricula in the early 1970s through science education (Gough, 1997). Indeed, at that time there was a broad acceptance in society that threats to human wellbeing and the environment could be countered through further scientific research and the application of technology. Such a belief is exemplified in the Tbilisi Declaration (UNESCO, 1978, p.24), which states, "Education utilising the findings of science and technology should play a leading role in creating awareness and a better understanding of environmental problems". In the past decade, UNESCO has emphasised the link between environmental education and science education by changing the subtitle of its publication *Connect,* from "UNESCO-UNEP environmental education newsletter" (as it was from 1976-1996) to "UNESCO international science, technology & environmental education newsletter" (since 1997).

In its early formulations, the explicit aims of environmental education were often concerned with stimulating a sense of individual responsibility for the physical and aesthetic quality of the total environment based on a knowledge of general ecological principles, an understanding of the impact of human society on the biosphere, and an awareness of the problems inherent in the environmental change. The underlying belief seemed to be that "if you provide people with accurate information about a situation, their values, attitudes, and behaviour change for the better" (McInnis, 1975, p.54), and this belief was enacted in the curriculum development strategies used by environmental educators. For the most part, they simply translated scholarly scientific material into subject matter to be taught and learned, generally through science education, because the construction of school environmental knowledge in the science curriculum was seen to be a direct outcome of scientific production.

However, as a result of forums such as the UNESCO-UNEP Belgrade workshop (1975) and the Tbilisi conference (UNESCO, 1978), the goals and objectives for environmental education changed during the 1970s to emphasise more explicitly values and attitudes clarification, decision-making skills and an action component. The reports from these forums also recognised that the traditional formulations of the academic disciplines are individually inadequate for achieving the aims of environmental education, and instead proposed an interdisciplinary approach rather than a new or separate subject. For example, in one of the papers from the Belgrade workshop, Buzzati-Traverso (1977, p.13) argued that:

> The field under discussion is vast and multifaceted; it should be approached with a holistic attitude in that man [sic] and the innumerable components of his [sic] physical and cultural environment should be examined together in order to identify the complex and often hidden interactions which determine the pattern of human concerns.

These aspects of environmental education did not sit comfortably with conventional representations of science in science education as an objective, rational and value free search for "one true story" (Harding 1986, p.193), and some science educators began to question the relationship between science education and environmental education. For example, Hall (1977, p.76) claimed that "science teachers will do environmental education a grave disservice if they try to take it over". Others, including Greenall (1979) and Fensham and May (1979), argued for a closer relationship between environmental education and a reformed science education that they envisaged as being distinctly different from the version practiced in classrooms of the period.

Lucas (1980, p.1) adopted a different stance, expressing concern that "too many science educators seem to believe that their discipline is *the* vehicle for environmental education". He saw an "omnipotent disciplinary chauvinism" (1980, p.6) in assertions that science teachers could teach topics on society (beyond the social issues that arise from the application of science) – "will their worldviews as empirical experimenters seriously distort the nature of historical understanding and aesthetic judgement?" – and yet concluded that "science educators must not ignore the other forces acting to promote environmental wisdom, and must begin to look beyond the confines of their own and other educational literature for inspiration for research and practice" (1980, p.21). At that time, as now, many environmental educators were concerned with the political character of environmental problems and the implications of this for the type of education they were advocating. Their argument was that science and environmental education were incompatible and that environmental education could more appropriately be implemented in curriculum areas other than science, because the science curriculum of the time was inhospitable to engaging with social issues.

Concerns about the relationship between science education and environmental education continued into the 1990s. For example, Webster (1996, p.82) argues that:

> Science, like economics, has been reformed through the promotion of investigative science and the contextualisation of science. The contexts are often social, utilitarian concerns: health, science in everyday life, a nod to environment, and industry. Content still dominates, as does experimentation. As in economics, the hidden values and assumptions about the way the world works remain largely unexplored.

Ashley (2000, p.275) similarly discusses the limitations of current science education practices and argues that, "A scientific education for all that is more likely to result in [a more responsible attitude to science] therefore has to be a key objective for environmental education".

In the 21st century, from an environmental education perspective, discussions about the relationship between science education and environmental education have almost been subsumed by the shift in discourse from environmental education to education for sustainable development, where one pillar is environment – the others being society and economy (United Nations, 2002; UNESCO, 2004). However, the importance of understanding the scientific concepts that underpin sustainable development continues to be re-affirmed. For example, the "environment" pillar is described as "an awareness of the resources and fragility of the physical environment and the effects on it of human activity and decisions, with a commitment to factoring environmental concerns into social and economic policy development" (UNESCO, 2004, p.4).

From a science education perspective, environmental education continues to be the elephant in the room. In a recent review of science education in Australia, entitled *Re-imagining Science Education*, my colleague Russell Tytler (2007), whether intentional or not, neatly explicated the tensions in the relationship. In developing his argument for emphasising the 'working scientifically' or 'investigating' strands of Australian school science curricula he refers to the importance of citizens being able to engage with evidence in science in their personal lives and community issues – a central concern of environmental education:

> By engaging in investigations that involve a consideration of what constitutes reliable and valid evidence and how this evidence is used to establish knowledge, students will gain important skills in a variety of ways of reasoning, and develop a capacity to make judgments about evidence in scientific argument. There are many social issues that involve appeals to scientific evidence, such as the effects of waste disposal policies on the environment, of tourism on the Great Barrier Reef, or of personal lifestyle factors on cancer risk. An understanding of how such knowledge is generated and evaluated is therefore a powerful aim for science education (p.45).

A couple of pages later, he provides an example from his own research (Tytler, Duggan and Gott, 2001) which describes the complexity of socio-scientific issues that makes them difficult to engage with in the classroom or by the "lay public":

- It deals with data that is difficult to treat statistically and is subject to experimental cost and uncontrolled initial conditions.
- It involves complex models that themselves introduce uncertainties into the interpretation of data.
- The outcome is intended to be an action, rather than the production of generalisable knowledge, and, as such, is subject to a range of dimensions that are value-laden.
- The science is highly contextual and subject to variation over which the scientists had no control.
- It involves measuring trace elements at the limit of detection, with resulting uncertainty.
- It involves the generation and comparison of two numbers (pollution indices), representing two conditions which themselves involved the problematic weighting of data based on previous epidemiological research (pp. 48-49).

Fortunately, from an environmental education perspective, he concludes that, "If students are to be taught how evidence is developed and used in science in authentic settings, they need to grapple with features of scientific methods such as these. Ways need to be found to represent them in the curriculum" (p.49). Herein lies some hope for reconstructing science and environmental education for mutual benefit.

It should be noted that Tytler is not alone in recognizing the importance of engaging with the environment in science classes. For example, August 18-26, 2007 was National Science Week in Australia, and Melbourne's broadsheet newspaper, *The Age*, had a special Education Supplement to mark the event. The topics covered in the 16-page supplement were predominantly environment related. The cover was a King Emperor Penguin in Antarctica. "A year of scientific discovery" had subheadings of palaeontology, astronomy, genetics, animal behaviour and climate change. Other articles looked at "The last Huskies", "Researching Earth's frozen end" (2 pages), "Australia's great Antarctic explorers" (2 pages), "The wave watchers" (2 pages), food science and a colossal squid. There were only 5 pages where the environment did not dominate – one of these focused on the IMAX movie *Roving Mars*, another was about a (female) Melbourne student who is attending the European Space camp in Norway, another showed where scientific research facilities were in Melbourne, another was on "quirkology" and the last was on children's science books. Less than one-eighth of a page was devoted to the Australian Synchrotron.

At a more academic level, recent articles in the *Journal of Biological Education* have included topics such as "The future of science lies outdoors" (Slingsby, 2006) and "Students' interest in biology and their out-of-school experiences" (Uitto et al., 2006). Slingsby, in particular, makes some pertinent observations: "Outdoor Science at its best is interdisciplinary. We need to explore the contribution each traditional discipline has to offer to the whole if we are to ensure that Outdoor Science is truly balanced and truly credible" and "Fieldwork should be an essential part of any campaign to reverse the decline in young people wanting to study sciences beyond GCSE" (2006, p.52).

This brings me to an important reason for reconstructing science and environmental education - today's students have different priorities and interests from those of the past. Traditional science education is becoming a threatened species while students become more concerned about the environment within a context of a marginalised environmental education. A different relationship between the two educations could enhance their mutual survival.

Student interest in science education and environmental education

One reason for developing a different relationship between science education and environmental education arises from the need to respond to students' declining interest in science despite their high levels of environmental concern and desire to know more about the environment. As Coffey (2008) reports from his recent investigation into young Australians' level of understanding and excitement about careers with a sustainability focus: "High school students are very aware of environmental issues and concerns … They are hungry for credible, big picture, action oriented information/resources on long term environmental issues, especially on whether and how to respond" (p.3). However, he also found that "school is a significant potential site for awareness and activism, though underdeveloped" (p.4), and that, "Students want practical, hands-on experience, 'getting out' into the environment … [they] need to see how their own local, personal actions will contribute to the local picture" (p.5).

In Australia and elsewhere in the Western world there is widespread concern about decreasing student participation in upper secondary science courses. An even greater concern is that although there has been a national increase in participation in upper secondary school education in recent decades, there has not been a proportional increase in participation in science education at the same level (Dekkers & De Laeter, 1997). Indeed, Dekkers and De

Laeter (1997) report that although enrolments in senior secondary school level biology, chemistry and physics increased from 1976 to 1992 they declined quite dramatically (approximately 20%) between 1992 and 1995. In my home state of Victoria, after continuing to decline for a few years, enrolments in biology and chemistry have now increased to above 1995 levels (but not 1992), however physics enrolments continue to decline (see Table 1).

Table 1: Enrolments in relevant Victorian Certificate of Education (VCE) subjects in selected years

SUBJECT	1992#	1995#	1997#	2000#	2001*	2002*	2003*	2004*	2005*	2006*
Biology	15183	10918	10823	10546	10668	11123	11579	11499	11648	11465
Chemistry	10737	8503	9051	8090	8166	8348	8712	8770	9083	9125
Physics	10176	7234	8005	7534	7697	7632	7871	6970	6978	6812
Psychology	7831	9428	11352	12272	13418	14014	14781	14727	14439	14924
Science	668	253	127	59						
Environmental Studies	980	826	893	662						
Environmental Science					530	408	360	376	319	301
Outdoor Education	n/a	1531	1925	2148						
Outdoor & Environmental Studies					2263	2287	2492	2112	2390	2176

Unit 4 enrolment figures * Unit 3 enrolment figures

A number of explanations can be offered for students' declining interest in studying science subjects, many of which are beyond the scope of this paper. However, from recent research conducted in Victorian primary and secondary schools (Gough, 2007), it would seem that while students come to secondary school from primary school interested in studying science, the content of the science curriculum is a strong negative influence and students rapidly lose interest in pursuing further studies in science beyond the compulsory years (i.e. beyond Year 10 or over 15 year olds). Science education curriculum at lower secondary levels is in urgent need of change if we are to retain student interest in science studies in and beyond the compulsory years (Jenkins, 1992, 2007). Environmental education might be an appropriate emphasis for rekindling students' interest in the relevance of science, because young people are concerned about the state of the environment.

Other international research supports the view that science education needs to change and that students are concerned about the environment. On the first point, the findings from the Relevance of Science Education (ROSE) project (Sjøberg & Schreiner 2005), which surveyed 15 years olds across approximately 40 countries include:

- Students in most countries see more benefits than harmful effects in science, but in many industrialised countries the feelings are more ambivalent, in particular among girls;
- Students in most countries indicate sound scepticism to what scientists have to say (and girls have less trust than boys);
- Students in most countries indicate doubt that scientists are neutral and objective (and girls have more doubt than boys);

- Students in all countries strongly agree that science and technology are important for society;
- Students differ in their views about science and technology as problem solvers for the environment, and girls are much more sceptical than boys, but in the industrialised countries the level of confidence is less than the mean;
- In many industrialised countries science is less popular than other subjects, especially among girls;
- In many industrialised countries students do not think that science has opened their eyes to exciting jobs, especially girls;
- In industrialised countries few students aspire to becoming scientists, in particular girls.

Jenkins and Pell (2006) reported on some of the results from the ROSE project questionnaire with respect to the students' attitudes towards a series of environmental challenges. They found that their sample of students was clearly concerned about the environment, even though they were also "overwhelmingly optimistic about the future" (p.777). As with the findings of the total ROSE project noted above, Jenkins and Pell similarly found significant gender differences in the students' responses. However, they were also not greatly interested in learning about some of environmental topics presented in the questionnaire (see Table 2), which has implications for science curriculum content.

Table 2: Students' views on what I want to learn about (by gender)
Adapted from Jenkins and Pell (2006, p.775)

Topic	Boys' mean *(n = 517)*	Girls' mean *(n = 571)*
The ozone layer and how it might be affected by humans	**2.55**	2.30
The greenhouse effect and how it might be changed by humans	2.25	2.14
What can be done to ensure clean air and safe drinking water	2.37	**2.50**
How technology helps us handle waste, garbage and sewage	2.04	1.85
The possible radiation dangers of mobile phones and computers	**2.61**	**2.58**
How loud sound and noise may damage my hearing	2.32	2.27
How to protect endangered species of animals	**2.55**	**2.78**
How to improve harvest in gardens and farms	2.00	1.87

Note: 1 = not interested, 4 = very interested. Results ≥2.5 in bold.

In a similar vein to Tytler (2007), as discussed in the previous section, Jenkins and Pell (2006, p.777) conclude that:

> Given that many environmental problems (and their solutions) are science related, there is clearly a role for school science education in such an engagement. However, environmental education is not simply a matter for science educators. To the extent that such education requires the accommodation of the personal, social, and economic with the

> scientific as an integral whole, it constitutes a challenge to a conventional subject-based curriculum and pedagogy.

Other studies have documented students' interest in the environment and how science education programs that respond to students' lives and interests and seek to develop meaningful understandings (see for example, Gough & Sharpley, 2005; Gough, 2005).

Science has a very minor part in the Australian primary school curriculum. According to the most recent national research study (Goodrum, Hackling & Rennie, 2001, p.93), primary teachers estimated that the average time spent teaching science each week was 59 minutes. Primary school teachers often struggle to teach science because they lack confidence and competence in science content, and they have difficulty finding a place for science in what they perceive as an already overcrowded curriculum. In contrast with this observation, Gough and Sharpley (2005) provide several stories of primary school teachers' and students' experiences of implementing new science teaching and learning strategies that have also led to more environmental education occurring in the schools' curriculum.

Another success story for science in primary schools comes from the Australian Sustainable Schools initiative (Gough, 2005) – although this again was not necessarily the intended outcome. Sustainable Schools are the equivalent of Green Schools or Eco-schools in other parts of the world. Sustainable Schools take a whole school approach:

> Whole-school approaches are advocated as best supporting the implementation of Environmental Education in a way that reflects the goals, aims, and purposes of this area… Whole school approaches also appear to be most successful when they build on the existing culture, priorities, and values of schools and their communities (Bolstad et al., 2004, p.95).

Sustainable Schools integrate changes to the practical operations of the school, with sustainability issues in the curriculum, and help to build links to local communities. The four theme areas that are implemented are:

- "Waste" (waste and litter minimisation, green purchasing, recycling and composting);
- "Energy" (energy efficiency, renewable energy and reduction in greenhouse gas emissions);
- "Water" (water conservation, stormwater control and freshwater ecology); and
- "School Grounds / Biodiversity" (developing a whole school master plan which may include indigenous gardens that attract native butterflies and birds and special theme gardens and habitats).

Participating schools are able to choose all or some of the four optional themes. Each of these themes is science related and so the science content of the curriculum in Sustainable Schools – which are predominantly primary schools – is greatly increased as a result of an environmental education intervention.

Reconstructing science and environmental education

Despite all the research and literature related to making science education more relevant to society's needs for a scientifically literate citizenry (and the significance of environmental education for achieving this), as well as meeting students' interests, most science education practices continue much as they were before environmental education came into being. There are several explanations for this.

Firstly, the global trend in the past decade or so for standardised curriculum documents with specified content and reportable learning outcomes has meant that teachers no longer have the discretion to plan their own curriculum to the extent they once could. With the introduction of the standardized curriculum and its requirements to report to parents on the achievement of the specified learning outcomes teachers believe that they have lost the option of planning a local curriculum and have retreated to teaching science from textbooks that covered the science learning outcomes and little else.

Secondly, the content of the science curriculum specified in the new curriculum statements has been very much influenced by scientists and their priorities for university studies rather than by student interests or educational issues (such as recognition that schools "can only teach a sample of all the knowledge, skills and experiences related to science" (Malcolm, 1987, p.35)).

Thirdly, many science teachers see environmental education as yet another pressure for inclusion in an already overcrowded curriculum, and as an area in which they may have little interest (Lucas, 1980).

Fourthly, many science teachers are, in Lucas' (1980) terms, 'disciplinary chauvinists' who place a higher priority on teaching content from their own disciplinary specialisation rather than engage the interdisciplinary or cross-disciplinary demands of environmental science.

As a final and most significant point, the question remains as to whether science teachers understand environmental education as environmental educators understand it. Those who control the science curriculum appear to have only a very superficial understanding of environmental education and their representations of environmental education for science educators reinforce the view that science is a limited vehicle for environmental education within the curriculum.

By bringing science education and environmental education together in the school curriculum, science content is appropriate to a wider range of students and more culturally and socially relevant. The convergence is also important for environmental education, because it needs science education to underpin the achievement of its objectives and to provide it with a legitimate space in the curriculum to meet its goals, which are very unlikely to be achieved from the margins.

An examination of educational politics over recent years indicates that environmental education continues to be a priority for environment ministries but not education ministries whereas science education is a perennial priority in education ministries (Gough 1997; Department of Education, 2007a). Even where there is an environmental education policy from an education ministry (Department of Education, 1998) it is advisory rather than mandatory – although the discussion paper for the new Corporate Plan of the Victorian Department of Education (2007b, p.1) does locate itself within an Education for Sustainable Development agenda:

- Education has a fundamental role to play in bridging disparities in wealth and opportunity, and in building social cohesion. Young people must be literate, numerate, curious, articulate and passionate.
- Many of the critical challenges we face, for example environmental degradation, wealth concentration, religious extremism, climate change, assimilation of refugees, are global in nature.
- Education can play a major role in building the foundations of global citizenship in a global context and build innovative and creative capacity to ensure environmental sustainability.

Thus, from both a science education and an environmental education perspective it would seem politically astute to forge a new, mutually beneficial relationship between the two areas.

A science education that is mutually respectful of environmental education, accepts Lucas' (1980) challenge to look elsewhere for inspiration for research and practice. As a starting point, this different agenda for environmental science education will involve some integration of the sciences, will be problem orientated, will consider the scientific aspects of real systems (not abstracted ones), and will (finally) recognise the need for contributions from other disciplines (Fensham 1978; Lucas 1980), rather than remaining separate from them. However, developing a new relationship will also involve more than this – as the lack of success of past attempts to develop environmental education within the P-10 science curriculum and to create a popular senior secondary environmental science curriculum in Victoria, testify (Gough, 2002). A new environmental science education will need to take account of:

- Critiques of traditional science education from feminist, postcolonialist and anti-racist perspectives (see, for example, Brickhouse, 1994, Carter, 2003, Harding, 1993);
- Critiques of traditional science education from cultural and constructivist perspectives (see, for example, Aikenhead & Jegede, 1998 and Bencze, 2000, respectively);
- Declining interest of students in studying science at school (Dekkers & De Laeter, 1997; Sjøberg & Schreiner, 2005);
- Calls for increasing the scientific literacy of the general public (Hodson, 2002; Jenkins 1992);
- Discussions of the role of science in environmental discourse (Hajer, 1995); and
- Research that explores differences between the youth of today and previous generations (Gough, 1999).

It will also need to consider significant documents such as *Our Common Future* (World Commission on Environment and Development [WCED], 1987) and the implementation scheme for the United Nations Decade of Education for Sustainable Development (UNESCO, 2004), both of which envisage a positive role for science and technology and a relationship between scientific knowledge and environmental education for sustainable development.

For example, *Our Common Future* includes statements such as "our technology and science gives us at least the potential to look deeper into and better understand natural systems" (p.1), "the promotion of sustainable development will require an organized effort to develop and diffuse new technologies" (p.87) and "unless action is taken to accumulate biological knowledge, valuable information... will be lost forever" (p.88). Education is given the task of providing "comprehensive knowledge, encompassing and cutting across the social and natural sciences and the humanities, thus providing insights on the interaction between natural and human resources, between environment and development" (p.113).

Similarly, the Decade implementation scheme (UNESCO, 2004, p.16) states that

> The role of science and technology deserves highlighting as science provides people with ways to understand the world and their role in it. ESD needs to provide a scientific understanding of sustainability together with an understanding of the values, principles, and lifestyles that will lead to the transition to sustainable development. Science should be regarded broadly to include social sciences as well as natural sciences and traditional approaches to learning and understanding as well as formal science.

The science education that can have a relationship with environmental education (and sustainable development) is not necessarily that currently practiced, but a reconstructed form which incorporates a more mutualistic relationship.

Some science educators have recognised the possibilities of forging a different relationship between science and environmental education. For example, Jenkins voices the challenge that "perhaps most difficult of all, however, is constructing science courses which will help empower young people as future citizens in ways that existing science courses are widely seen as having failed to do so" (1992, p.243). He notes that "environmental education exposes with particular clarity the complex interactions among social, economic, personal and other value positions associated with almost any environmental issue" (1994, p.606). He believes that it is fundamental for students to be engaged with genuine practical reasoning in order to experience a science education for action, so there is a need for a local context or community of practice, to make the experiences genuine, and without this the activity is reduced to its technical dimension. The local context also provides the opportunity for generation of local knowledge informing and empowering action. Privileging local knowledge also helps to destabilise notions of the universal status of scientific knowledge.

In Jenkins' proposal there is a vital connection between science education and environmental education. Environmental education should have an *in* the environment component, an *about* the environment component and a *for* the environment component (Lucas 1979). Through Jenkins' science education for action there is the potential to realise all of these dimensions. Such a proposal might be threatening to those who practice traditional science education, but as the proportion of disinterested students in science classes increases and the total numbers of students studying science decline, the alarm bells should be triggered that change is needed in science education practices. Adopting an environmental education approach might be just what science education needs. However, the task is to convince those who control the school curriculum and those who teach science in classrooms that science education needs to change. Yet there are positive signs – such as those mentioned earlier in this paper with Slingsby's (2006) argument for "Outdoor Science" and Tytler's (2007) argument for science education in authentic settings.

Two approaches from the sustainable development literature might also help this convergence and reconstruction. One is "The Natural Step", developed by Swedish scientist Karl-Henrik Robert, and the other is the five capitals approach.

"The Natural Step" is a model for sustainable development which, through four system conditions (or concepts) derived from the laws of thermodynamics, encapsulates the dictates of science that are non-negotiable conditions for sustainable development. The purpose of the Natural Step is to develop and share a common framework comprised of easily understood, scientifically based principles that can serve as a compass to guide society towards a just and sustainable future. The four system conditions (EcoSTEPS, 2007) are:

1. In a sustainable society nature's functions and diversity are not systematically subject to increasing concentrations of substances extracted from the earth's crust.
2. In a sustainable society nature's functions and diversity are not systematically subject to increasing concentrations of substances produced by society.
3. In a sustainable society nature's functions and diversity are not systematically impoverished by physical displacement, over-harvesting, or other forms of ecosystem manipulation.
4. In a sustainable society resources are used fairly and efficiently in order to meet basic human needs globally.

The *five capitals approach* identifies essentially the same principles for a sustainable society but addresses sustainability from an economic rather than a bio-physical framework. An extension of the triple bottom line of financial, environmental and social accountability, the five capitals approach is based upon the five types of capital an organisation needs to function properly (Fien et al., 1999):

- *Natural capital:* the life support systems that provide air, water, materials and energy that support all life both bio-physically and socio-economically. Natural capital provides the renewable (timber, grain, fish and water) and non-renewable (fossil fuels) resources used to satisfy human wants and needs, as well as the physical processes, such as wind and climate regulation, we depend upon, as well as the sinks that absorb, neutralize or recycle wastes.
- *Human capital:* the systems and processes developed by a society for advancing the health, knowledge, skills and motivation of individuals, and which give them the personal resources with which to engage with the world.
- *Social capital:* the structures or institutions such as families, communities, businesses, trade unions, schools and voluntary organizations that enable individuals to maintain and develop their dignity and skills in partnership with others, thus, enhancing the vitality and resilience not only of individual human capital but also of a community.
- *Manufactured capital:* the tools, machines, buildings and other forms of infrastructure produced by humans, which enable us to more efficiently utilize natural capital in the extraction, production, distribution and consumption of goods and services.
- *Financial capital*: the system of exchange value established by society, that allows types of capital to be owned, compared and traded.

Maintaining a dynamic and balanced integration of the five forms of capital is essential for sustainable development, and science education can take a significant role in developing students' and community understandings of this.

Conclusion

For nearly three decades I have been working to promote environmental education in schools and to change the science education that is taught in schools. Rather than accepting that science education is something static and in its traditional form incompatible with – or at least a limited vehicle for – environmental education, I believe these two areas of the school curriculum can mutually benefit from a reconstructed science education. This new form of science education would be more appealing to senior secondary students, more consistent with calls for scientific literacy (or science for action) and would address the critiques of traditional science education by feminists, postcolonialists and others.

Environmental education has changed over the past three decades too. In its current association with Education for Sustainable Development through the United Nations Decade agenda, it is also linked to the Education for All Dakar Framework for Action and the Millennium Development Goals (UNESCO, 2004). This provides a great opportunity for reconstructing science education and linking it to the future. As the Introduction to the Decade implementation scheme states (UNESCO, 2004, p.7):

> There can be few more pressing and critical goals for the future of humankind than to ensure steady improvement in the quality of life for this and future generations, in a way that respects our common heritage – the planet we live on. As people we seek positive change for ourselves, our children and grandchildren; we must do it in ways that respect

> the right of all to do so. To do this we must learn constantly – about ourselves, our potential, our limitations, our relationships, our society, our environment, our world. Education for sustainable development is a life-wide and lifelong endeavour which challenges individuals, institutions and societies to view tomorrow as a day that belongs to all of us, or it will not belong to anyone.

The challenge for us as science educators is to reconstruct our curricula so that our students as citizens of the world understand and respect the planet we live on. This is a win-win situation for science education, environmental education and the planet. It is a very different science education from that envisaged in the Perth Declaration – but I believe it is one that will better address the needs of society and the interests of our students.

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Appendix

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**The Perth Declaration on
Science and Technology Education**

We, the participants at the 2007 World Conference on Science and Technology Education, held in Perth, Western Australia, 9 - 12 July 2007, and comprising more than 1000 science and technology educators from 50 nations worldwide; believing in the importance of science and technology for **sustainable, responsible, global** development, and in the need to bridge the gap between science and technology and the public.
Express concern at the lack of recognition of science education as a vehicle for meeting national educational goals, and social and economic needs;
Observe a widespread lack of student interest in current school science and technology education and of its relevance to them;
Note the shortage in many countries of specialist teachers of science and technology;
And consider that the rapid changes taking place in science and technology and their applications must be reflected in the planning, teaching and learning of science and technology.

Resolved to recommend to Governments:

- To promote critical awareness of the contribution of science and technology to personal, social, economic and environmental wellbeing through building partnerships with national stakeholders and the media;
- To initiate revisions of the curriculum for school science and technology that will increase student interest in and recognition of the roles of science and technology in society;
- To promote from the primary years onwards the career opportunities that stem from the study of science and technology;
- To recruit graduates into science and technology teaching and to value, support and retain them with appropriate rewards;
- To resource and promote continuous, effective professional development for science and technology teachers in order to meet changing student needs and societal aspirations;
- To recognise and support the significant role of teacher associations in building a quality professional learning community for science and technology;
- To resource the development of relevant and effective assessment processes so that learners achieve essential life skills, meet academic and vocational standards and personal aspirations;
- To engage in greater international cooperation to ensure the provision of well-trained science and technology teachers to meet current and future challenges;

- To call on UNESCO to integrate its science and technology education endeavour as fundamental to achieving educational, environmental, cultural, social and sustainable development goals.

We, the participants, are committed to ensuring that students are scientifically and technologically literate and able to contribute to sustainable, responsible, global development in their respective nations.