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CHAPTER TEN

Values in Science, Environmental Education and Teacher Education

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Introduction

The aim of this chapter is to establish values as a key component of science and environmental education, consistent with the troika framework, and to explore the implications of this for teacher education. In the chapter, we review research that has increasingly placed values at the centre of the process of learning science, and central also in framing students’ responses to school science. We then present findings from three projects that explore the relationship of values to teaching and learning science: first, an exploration of the pedagogies of effective teachers of science; second, an environmental education project in which students explore science and sustainability ideas in the context of a community exchange program in Mexico and Alaska; and, third, a teacher education initiative focused on place-based education. In the chapter, we argue that learning science and engaging with the environment entails pedagogies that link conceptual learning, values and community.

Value dimensions of conceptual learning and teaching in science

Science in school and often in popular perception has been cast as objective and values neutral, concerned with the disinterested pursuit of defensible knowledge. Pedagogies, and school texts that support them, have traditionally seen the establishment of canonical science concepts as the key agenda of school science, with methods focusing on careful explanation, modelling and illustration through practical work. Values have always, however, been an acknowledged aspect of any teaching and learning about science. Curiosity and interest in natural phenomena have been assumed as both drivers and outcomes of an education in science, as have objectivity and rationality been seen as the methods by which science is established, and learned, and also the outcomes of an education in science. These are, we should note, values internal to the pursuit of science knowledge. They do not speak to the operation of science as it interacts with the personal and social domains.

With regard to the values associated with learning science, Piaget’s notions of children’s discovery of fundamental ontological categories through exploration and
activity place considerable value on exploratory behaviours and stances, such as curiosity and independence. The process curricula of the 1970s and 1980s promoted similar values concerning exploratory stances. Since the 1980s, science learning theory has been dominated by research into students' conceptions and conceptual change (e.g., Driver, Guesne & Tiberghien, 1985; Duit, 2002). Early views of the nature of conceptual change (e.g., Posner, Strike, Hewson & Gerzog, 1982) tended to emphasise the process of learning as a rational activity undertaken by individual students. Since then, the conceptual change literature has expanded to accommodate a wider view. Strike and Posner (1992) move beyond the strictly conceptual in arguing for the importance of a students' conceptual ecology in framing the change process, a term that encompasses students' broader beliefs and dispositions. Other writers have emphasised the importance of affective factors in the process. Pintrich, Marx and Boyle (1993) described a range of classroom contextual, motivational and cognitive factors that impact on conceptual change. Sinatra (2005) describes a rich research literature in the affective dimensions of science learning that followed this early work, showing that attitudes and values emerge as critical determinants of learning.

Bloom (1992) showed how children's thinking is extremely fluid and progresses through a rich mix of conceptual, emotional, ethical and aesthetic commitments. Tytler and Peterson (2001, 2004) have shown how students' interpretation of a science learning task is coloured by social and personal emotional factors and is highly individual and identity related. Wickman (2006), drawing on the work of Dewey (1996), argues that the traditional opposition between aesthetic and values positions on the one hand, and conceptual work on the other, is a false dichotomy and that each is constitutive of the other in scientists' work. Aesthetic judgments should not be seen as dispositions but rather as an element of the culturally determined, learned discursive practices of science: “To Dewey, it was clear that the scientist, like all humans, does not rely exclusively on cognition, but also on values and aesthetic meanings during work” (Wickman, 2006, p. 17). Jakobson and Wickman (2008) show how primary school students use aesthetic judgments to decide what to include or exclude in the science class, what their place is and whether they belong. They argue the relevance of this for understanding identity formation and “the transformation of the values of the whole person” (p. 64).

Tytler and Darby (2009) call for research into the personal dimensions of teaching, such as the role of teachers' passions, interests and commitments in shaping their interactions with students and with the subject matter. In an account of an exemplary teacher of science, Tytler, Cripps Clark and Darby (2009) couch her practice in terms of a relational pedagogy (see Darby, 2005):
The relationship dimension to Suzanne’s pedagogy not only underpinned her approach to the classroom, but it provided the fine threads that draw the various dimensions together: her views about mathematics and science teaching, her approach to the quality classroom and what children need to learn, and her expectations of how children approach their own thinking. One could not help but be impressed by this classroom environment that fostered the notion of children taking risks in their learning and valued children’s voices as part of real conversations. (p. 24)

Darby (2008) broaches the relationship of classroom practice, including teachers’ beliefs, values and commitments in relation to teaching and learning and the nature of school science, with a framework of aesthetic understanding. To have an aesthetic understanding of what it means to teach a subject is an indication of: 1) where a teacher’s passions lie with respect to teaching the subject and the discipline; 2) to what extent a teacher has a coherent and intuitive sense of what is required to teach the subject and bring it to life for students; and, 3) how the teacher is transformed by what they know as they develop an identity in relation to the subject.

Hipkins (2006), in an investigation of approaches to teaching by science teachers who had spent a year on scholarship undertaking research, found that these teachers tended to replace more formal accounts of the way science knowledge is generated with more impassioned accounts based on the practices and objects of their own scientific inquiries. Teachers’ narratives revealed both passion for their personal learning and an ethical concern for their students’ learning to care for both the natural world and science as a means of its investigation.

**Values, identity and the science curriculum**

There are three major areas of concern with regard to student engagement with science that are currently being interpreted, using identity as an explanatory construct. First, there is the long standing concern with gender differences in attitudes to and participation in science; second, there is ongoing concern with the response to science of Indigenous populations; and, third, there is concern about negative responses to and engagement in school science by students in post-industrial compared to developing countries (see Sjøberg & Schreiner, 2005). Aikenhead (2006) argues that to learn science meaningfully is ‘identity work’, in that coming to appreciate science involves students coming to see themselves as science-friendly. Aikenhead and Ogawa (2007, p. 540) argue that the way science tends to be presented in schools, free from values and without context, marginalises some students, especially Indigenous students, on the basis of their ‘cultural self-identities’.
Identity construction and interests are two important factors influencing youth’s educational choices (Schreiner & Sjøberg, 2007). Therefore, school science should be attentive to students’ values and concerns, and should respond to questions about why an education in science matters, integrating scientific values with other ethical and social values, and working together with teachers, students and parents. Science can help to identify unforeseen consequences or causal relationships where ethical values or principles are relevant (Allchin, 1988). According to Allchin, values intersect with science in three primary ways: 1) there are epistemic values which guide scientific research itself; 2) the scientific enterprise is always embedded in some particular culture and so values enter science through its individual practitioners, whether consciously or not; and, 3) values emerge from science, both as a product and process, and may be redistributed more broadly in the culture or society.

On the second point, that of gender, there has been a long history of findings concerning the negative attitudes of girls to science, particularly the physical sciences, compared to boys (Gardner, 1975; Tytler, Osborne, Williams, Tytler & Crisps Clark, 2008). In a study of responses to school science, Haste (2004) identified five distinct, highly gender specific student types. She found that girls related more strongly to ‘green’ values associated with science (socially responsible and people oriented aspects), rather than the ‘space and hardware’ aspects differentially preferred by boys. In a more recent study, Haste, Muldon, Hogan & Brosman (2008) identified, using a factor analysis, four features that discriminated students in their response to science, two of which related to ethical considerations and ‘science in my life’. For girls, consideration of ethical factors was a positive contributing factor in their response to science whereas, for boys, it was negative. Similarly, the perception of relevance in their lives was more positive for girls than for boys. The implication of these findings is that any attempt to present a de-contextualised and value-free notion of science will reduce the engagement of girls, but not necessarily boys. This is supported by the findings of Johnson (2007) that minority women’s interest in science is “inextricably united to their altruism” (p. 819). Johnson argues for a science curriculum that emphasises its rich history of service to humanity.

Schreiner and Sjøberg (2007), using similar analyses of a survey of students’ responses to science, explained the decreasing commitment to school science of students in the more developed economies in terms of the identities of youth in late modern societies. They see these as connected with late modern values, such as self realisation, creativity and innovation, working with people and helping others. Traditional science teaching does not accord with these values. Thus, there is increasing agreement that school science should deal much more explicitly with the context and values underpinning science and the interactions of science with society, if we
are to engage the attention of youth in the more developed economies, and particularly girls.

These arguments accord with increasingly vocal strands of thinking about scientific literacy as the key aim for science education. Interest in argumentation as classroom focus, representative of the epistemic foundations of science, has expanded to include values positions on socio-scientific issues (Zeidler & Sadler, 2008a, 2008b). Hodson (2003) argues that science education should include the dimension of engaging in social-political action, as well as science knowledge and its applications, and knowledge of the epistemic basis of science. He suggests that scientific literacy can contribute to a more socially compassionate and environmentally responsible democracy: "science can provide knowledge to develop effective solutions to its global and local problems and can foster the intelligent respect for nature that inform decisions" (p. 653). Hodson's suggestion to broaden the scope of school science by including environmental education and extending scientific literacy to encompass political literacy, prioritise the affective and make greater use of community based learning opportunities, is consistent with the thrust of the case studies that form the core of this chapter, and aligns with the structure of the troika framework.

What are the implications of these developments for the pedagogies employed in science classrooms or in teacher education? Three cases, drawn from the authors' research, will be used to illustrate the role of values and quality teaching practices in learning and teaching science, from different perspectives: first, from the perspective of current classroom practice; second, from the perspective of innovative practice in environmental education; and, third, from the perspective of teacher education.

**Case 1: The values and beliefs of effective teachers of science**

The first case explores the extent to which, for effective teachers of science, their practice can be said to represent values education enacted through quality teaching practices. The teacher case descriptions that form the basis of this case were originally written as part of the process of developing and refining a framework for describing effective teaching and learning in science for the School Innovation in Science research project in Victoria (Tytler, 2009). To sharpen the framework, the beliefs and practices of selected effective primary and secondary teachers were examined. Each teacher was identified as an effective practitioner by science teacher educators or government teaching and curriculum advisors who had worked with them. 'Effective' is thus based on judgments of the education community.

The teaching and learning framework (the SIS Components: Tytler, 2003; Tytler, Waldrip & Griffiths, 2004) was based on interviews with 13 primary and 6 secondary
school teachers. The current analysis is based on 10 primary and 5 secondary teachers whose case descriptions were sufficiently detailed to admit such an analysis. Each teacher was interviewed by a project team member. The interviews were face to face and involved a broad discussion stimulated by questions which focused on building up a picture of what happened in their science classrooms, what they saw as their core purposes, their attitudes and beliefs concerning science teaching and learning, and influences on their practice. The intention was to focus on quality teaching and learning issues and not values as such. However, it became clear that each case description is imbued with the teachers' own value positions and the ways in which these values permeated the lesson content and activities and therefore the set provides useful data concerning the ways that effective teachers of science incorporate the teaching of values both in and through their science lessons.

For the purposes of this chapter, two case descriptions were chosen from the set, and cut to focus mainly on passages that represent these teachers' value positions and quality teaching practices. The original case descriptions were roughly twice as long, with the extra material referring mainly to specific practices. In each case, the values that seem to flow from these teachers' descriptions and their quality teaching practices were itemised (presented at right in the following descriptions). One primary and one secondary teacher case description is given in Table 10.1 on the next page as representative of the full set.
<table>
<thead>
<tr>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sarah, a primary teacher</strong></td>
<td>Respect for individuals.</td>
</tr>
<tr>
<td>Sarah's science program is strongly conceptually based. She groups children flexibly to support concept development. With younger children she tends to begin with concrete experiences that arouse curiosity and are designed to challenge understandings, and this is followed by a process of deconstruction whereby understandings are discussed and further activities grow out of children's specific interests, questions and suggestions.</td>
<td></td>
</tr>
<tr>
<td>Sarah herself came to science late, and appreciates it for the sense it makes of daily phenomena and the satisfaction of being able to explain what's happening.</td>
<td></td>
</tr>
<tr>
<td>Sarah believes that curiosity and questioning are deeply embedded in science, and part of the reason science is central in her program is its capacity to promote questioning, and the opportunity it provides for children to engage with and enjoy that sense of owning ideas. Doing science in this exploratory yet focused way allows the teacher to engage with children in ways not possible with other curriculum areas. In order to support children's deepening knowledge the teacher needs to be able to draw from a deep and close understanding of the individual child. Science demands that the teacher engage with children and develop a feel for the classroom energy needed to sustain learning.</td>
<td></td>
</tr>
<tr>
<td>Thus, for Sarah, the fundamental issues of engagement with ideas and evidence flow from a deep concern with the development of meaningful understandings, and the encouragement of a fundamentally questioning position towards the world.</td>
<td>Student responsibility, autonomy.</td>
</tr>
<tr>
<td></td>
<td>Quality teaching Curiosity, questioning orientation.</td>
</tr>
<tr>
<td></td>
<td>Interest Enjoyment of learning and knowing.</td>
</tr>
<tr>
<td></td>
<td>Valuing understanding the world.</td>
</tr>
<tr>
<td></td>
<td>Commitment to deeper understandings.</td>
</tr>
</tbody>
</table>
Cleo, a secondary teacher

Cleo uses a variety of learning technologies in her teaching, and has promoted open ended investigative work in the school. She is interested in contemporary science and social issues, and in new technologies.

Cleo’s view of an effective learning environment involves ‘lots of interaction'; students talking about science, doing things in groups, and learning in an interactive, problem solving way based on practical activity. She is committed to a view of science that is contemporary, relevant to students, and linked to social and personal ethical issues. She favours theme based approaches to science because ‘kids see connections’ with their lives, and with personal issues. The technological and ethical ramifications of gene technologies were illustrative for her of her excitement in this sort of approach to science. Cleo uses a media file, and continually encourages discussion of current events and their link with science. She is less concerned with coverage of formal content, and enjoys ‘going off tack’ to follow interesting discussions.

There seem to be three themes driving Cleo’s view of science teaching and learning:

Enjoyment of lively interaction and rapport with students, and a concern that the science they discuss is relevant in a deeper sense than just knowledge;

A belief in student responsibility and autonomy in searching for new knowledge and carrying out their own investigations; and

Interest in and enthusiasm for contemporary science and associated technologies, which includes gene technologies, and their social implications; and learning technologies.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Cleo, a secondary teacher</strong></td>
<td>Values</td>
</tr>
<tr>
<td>Cleo uses a variety of learning technologies in her teaching, and has promoted open ended investigative work in the school. She is interested in contemporary science and social issues, and in new technologies.</td>
<td>Autonomy and responsibility.</td>
</tr>
<tr>
<td>Cleo’s view of an effective learning environment involves ‘lots of interaction'; students talking about science, doing things in groups, and learning in an interactive, problem solving way based on practical activity. She is committed to a view of science that is contemporary, relevant to students, and linked to social and personal ethical issues. She favours theme based approaches to science because ‘kids see connections’ with their lives, and with personal issues. The technological and ethical ramifications of gene technologies were illustrative for her of her excitement in this sort of approach to science. Cleo uses a media file, and continually encourages discussion of current events and their link with science. She is less concerned with coverage of formal content, and enjoys ‘going off tack’ to follow interesting discussions.</td>
<td>Open mindedness, respect for ideas.</td>
</tr>
<tr>
<td>There seem to be three themes driving Cleo’s view of science teaching and learning:</td>
<td>Commitment to considering social and ethical issues.</td>
</tr>
<tr>
<td>Enjoyment of lively interaction and rapport with students, and a concern that the science they discuss is relevant in a deeper sense than just knowledge;</td>
<td>Respect for others’ ideas.</td>
</tr>
<tr>
<td>A belief in student responsibility and autonomy in searching for new knowledge and carrying out their own investigations; and</td>
<td>Quality teaching</td>
</tr>
<tr>
<td>Interest in and enthusiasm for contemporary science and associated technologies, which includes gene technologies, and their social implications; and learning technologies.</td>
<td>Exploration.</td>
</tr>
</tbody>
</table>

Relevance of science to our lives. Enjoyment of ideas and learning. Commitment to deeper understandings.

*Table 10.1: Teacher case descriptions*
These teachers have a number of features in common, evident in the case studies. These represent values underpinning science, and learning science, as follows:

- There is a sense of enthusiasm for science;
- Engagement with ideas and evidence is the major focus, and great importance is placed on conceptual understanding;
- They emphasise flexibility and responsiveness to students' ideas and learning needs;
- All these teachers emphasise science being socially and personally contextual, emphasising exploration and concerned with theory and evidence. For secondary teachers there is considerable emphasis on the type of science being represented, and a formal focus on science investigations;
- There is a strong sense of catering for individual students, and promoting responsibility both for learning and towards others; and,
- There is a strong sense of community in learning, especially with the primary teachers. For primary teachers this is often linked with the wider community, especially through environmental projects. Two of the secondary teachers emphasised the social and ethical issues surrounding science.

**Analysis: Teachers' values and practices**

These teachers are in general representing a coherent and strongly projected values position that is anchored in notions of how children learn, what children should learn, and what their attitude to learning and knowing should be. To describe in more detail the practices and values represented by these teachers' case descriptions, the practices and values identified for each were collected and arranged into categories that seemed to emphasise different aspects of students' preferred orientation to science implied by the case descriptions. The numbers in the last two columns represent the number of instances of the practice or value, per teacher, for each of the primary and secondary group. In some cases, the number exceeds 1.0 because different aspects of the practice or value were sometimes found in the one case description. How values were embedded and expressed in the pedagogy was mainly through reference to the way the classroom activities were structured. The identified values and practices coming out of this analysis are shown in Table 10.2.
<table>
<thead>
<tr>
<th>Orientation to ways of interacting with the world</th>
<th>Values &amp; practices</th>
<th>Primary instances</th>
<th>Secondary instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest—a positive orientation, or movement towards engagement with phenomena</td>
<td>0.9</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Curiosity, questioning orientation</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Exploration—the valuing of an exploratory stance, of engaging with evidence</td>
<td>1.0</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Open mindedness</td>
<td>0.6</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Objectivity, respect for evidence</td>
<td>0.2</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Orientation to knowledge and ideas</td>
<td>Valuing of ideas, respect for ideas, enjoyment of learning and knowing</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Commitment to challenge and deeper understandings</td>
<td>0.8</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Orientation to judgments about the worthwhileness of science ideas</td>
<td>Valuing science for its personal and social relevance</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Personal stance with regard to self in relation to the world</td>
<td>Autonomy, responsibility for own learning, for actions and ideas, independence</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Orientation to others at a personal level</td>
<td>Cooperation, respect for others</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Valuing the shared nature of learning, others’ ideas</td>
<td>0.5</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Orientation to community and society</td>
<td>Responsibility to community, adopting an ethical stance on science and society</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 10.2: Quality teaching practices and values represented in teacher cases
Thus, these effective teachers of science operate with a coherent and comprehensive values system that permeates their pedagogies in such a way as to ensure that students are engaged in quality learning experiences which both require and reinforce the demonstration of values, such as respect, responsibility, cooperation and inclusiveness. This first case affirms the double helix of quality teaching and values education.

While the third aspect of the troika, service learning, does not show up very strongly in this analysis, in the larger SIS project, this component was taken up by many schools that initiated a range of school-community linked projects (Tytler & Nakos, 2003). Many of these focused on environmental regeneration projects. From this time, there has been a good deal of interest in linking schools with community organisations so that students can extend their learning of values and science through authentic and collaborative projects designed to benefit the broader community. The case which follows provides an example of service learning as applied in environmental education.

**Case 2: Service learning in environmental education**

Environmental education, in contrast to science education, has for many years acknowledged the value positions that are central to environmental action. This happens because environmental education promotes active participation by giving students opportunities to plan and implement actions to address real environmental problems in their communities. Confronting ethical environmental issues represents a kind of service learning in which students not only apply their knowledge to solve ‘real-world’ problems, but through establishing connections with community members, conducting observations and reflecting on their own scientific learning process, students are also clarifying and contextualizing their values as well as their attitudes towards the environment. Ethics is a process of making choices that enable better ways of seeing and doing things (Jickling Lotz-Sisitka, O’Donoghue & Ogbuigwe, 2006). Being able to reflect on how environmental knowledge can be applied to solve community problems has rendered environmental education with a leading role in the search for new paradigms in science education. It has emphasised the relevance of incorporating a holistic approach when dealing with environmental issues, as environmental issues are tightly linked with cultural values as well as political issues within a North/South dimension (Barraza, Duque-Aristizábal & Rebolledo, 2003).

According to UNESCO (2000), new paradigms in science education are focused on moving towards a sustainable society, meaning redefining the educational practices and developing new methods in order to establish better relationships among individuals, groups and society. For example, in the book "Caring for the Earth: A
Strategy for a Sustainable Living” (IUCN/UNEP/WWF, 1991), the proposed principles for a sustainable society are as follows:

[To] respect and care for the community of life, improve the quality of human life, conserve the Earth’s vitality and diversity, minimise the depletion of non-renewable resources, keep within the Earth’s carrying capacity, change personal attitudes and practices, enable communities to care for their own environments, provide a national framework for integrating development and conservation, and forge a global alliance. (p. 3)

These principles strongly deal with the development of values and ethical issues such as democracy, equity, justice, action and participation, among others. In order to achieve the principles for a sustainable society, it is fundamental to build a pedagogy based on values education as a teaching and learning curriculum organisation. This means to redefine the school environment in terms of the relationships. According to Jickling (2005), many of the world’s social and environmental problems are not resolved because ethics questions are not asked. He suggests that we should start asking philosophical questions such as: “What is a ‘good’ way to live?” and “What are ‘good’ relations between people and society?” We should then connect philosophical questions with ontological and methodological questions in relation to the teaching and learning processes that we need to develop in a school setting.

Education for the twenty first century should be based on critical and social theories of the environment and development in order to link the prospects for sustainability to new forms of economy, social welfare, governance and education (Barraza et.al, 2003).

Weston (1992) argues that our challenge is not to systematize environmental values, but rather to create the ‘space’ for environmental values to evolve. Following Weston, what would happen if we were concerned that individuals and groups could actually begin to create, or co-evolve, new values through everyday practices? What kind of experiments could we enable? By ‘space’, he is speaking about the social, psychological and phenomenological preconditions that are needed to enable this evolutionary process. He is also referring to the conceptual, experiential and physical freedom to move and think. Therefore, the pedagogies that we need to build in order to create and favour the ‘space’ for environmental values to evolve require an integrated curriculum, supported by a constructive, transformative and participatory approach. According to McClaren and Hammond (2005), the nature of contemporary knowledge and knowledge construction demands increasing collaboration and communication among once isolated disciplines. Curriculum integration can reduce
curriculum fragmentation, promoting a better appreciation of the way that different forms of knowledge work and contribute to collaborative knowledge construction stimulating a critical and reflexive perspective in their learners.

Environmental education is an ideal arena for the development and practice of critical thinking and an opportunity for students to connect their scientific learning and reflect on how they can actively participate in the solution of environmental problems. Environmental education is about helping individuals to develop the knowledge, skills, values and attitudes for a better understanding, appreciation and a sense of caring for the environment. One of the most important aspects of teaching, especially in science education, is that one would want one’s students to relate the concepts that are learned to real world experiences. In the following section, we present an example that illustrates how Mexican high school students from two forestry communities were able to engage and enrich their environmental learning and gain environmental values through their participation in an international environmental education exchange program.

**The project**

After three years of an ongoing research project on environmental knowledge, attitudes and perceptions involving adolescents aged 15 to 18 years in two Mexican forestry communities’ two key findings took our attention:

1. In local conditions, the interest of youths does not include a basic understanding of climate changes as factors of global processes; and,
2. Youngsters ignore important aspects of their own history, as well as the environmental and scientific knowledge of elder members in their communities (Bodenhorn, Barraza & Ruiz-Mallen, 2009).

We then organised a comparative project in different ecosystems but within similar social contexts: two Mexican communities and one Eskimo community on the coast north of Alaska. These three communities share the following characteristics:

- Indigenous communities;
- Communal organization;
- Each community has the responsibility and the right to develop a natural resources management plan; and,
- Similar political position.

The goals of the project were to provide potential young scientists with a unique learning opportunity to think beyond their local knowledge in a more informed way;
to introduce them to a variety of scientific approaches to environmental research, to provide them with practical training in qualitative and quantitative research methods, and to establish international links between young members of Indigenous communities with responsibilities for maintaining environmentally sound development strategies. In addition, we aimed to foster a greater sense of appreciation in the young participants for the special qualities of their own communities (Bodenhorn, 2007). The program integrated twelve young people for a month in a range of scientific research and cultural activities currently being conducted on the North Slope of Alaska (Barrow) and in the mega bio-diverse regions of the Sierra Norte of Oaxaca and the Pátzcuaro region of Michoacán, Mexico. The project was thus holistic, encouraging understanding that emerges at the conjunction of scientific research, experiential observation, language, and cultural processes of various sorts.

The learning and understanding of scientific processes was fundamental to the process of providing the students with the experience of being in the Arctic, and having them experience for themselves the dramatic evidence of climate change processes that are found in the Arctic. The unique offering of this interchange was that the combination of work in the basic ecological systems of the Arctic and the mega bio-diverse systems in the Mexican communities provided the students with the opportunity to learn firsthand how global processes can manifest themselves differently depending on context (Bodenhorn, 2007). We followed a constructivist approach and developed multiple pedagogical strategies (discussion groups, field trips, data collection, observations, school based classes, group and individual presentations, writing essays, among others). During eight weeks (four in the Arctic and four in Mexico), students displayed the following learning: they exercised their critical thinking when discussing environmental issues; they collaborated in research studies on climate change; they carried out field trips and participated in data collection and monitoring for research studies on Tundra ecosystem and archaeological excavations; they participated in forest management activities and studies on biodiversity in the forest regions of Oaxaca and Michoacan in Mexico; they received lessons on how to apply scientific methods and participated in discussions on environmental changes; they carried out discussions and exercises in themes such as history, traditional knowledge and the richness and diversity of natural resources in their communities; and, furthermore they learned about the Indigenous culture, history, environment and language of the Ixtlecos, San Juaneros and Inupiaq communities. This program not only encouraged students to improve their skills in the organisation and presentation of complex material, but it also encouraged students to think ecologically, that is, to recognise the inter-connections between factors that include physical, social, economic and political processes.
Learning science is about participating in scientific community practices (Campbell & Tytler, 2007). This project, together with the school community of three different regions, provided authentic science practices to students, allowing them to build an understanding of scientific processes by connecting, linking, reasoning and establishing comparisons between their environmental management practices and their cultural activities in their communities. Reasoning is a complex mental activity that depends on the scientific knowledge that students possess and the effective learning strategies used by teachers (Campbell & Tytler, 2007). Following Weston’s (1992) ideas, what we did with this experience was to create the ‘space’ for environmental values to evolve through multiple learning strategies. In this process, students were able to understand environmental concepts more effectively and they actively participated, together with their community, in the development of various environmental projects by experiencing individual and collective values. Forming values is a matter of finding cognitive, affective and behavioural connections when learning about life as a biological and social system. As a result of participation in the science program the students’ values were applied and refined through the learning processes of inquiry and critical thinking. Students shared and expressed their ideas by working together. They learned to listen to each other, to respect their different opinions, to be tolerant and patient among themselves, to cooperate and to be equitable when distributing tasks. Furthermore, they learned to be responsible when attending classes, to look after each other, to understand different management environmental practices in relation to their context, and to establish links and connections between their cultural values and environmental practices.

We discussed with students their exposure to new challenges and their commitment to generating new learning possibilities after their exchange experience. These were some of their ideas:

I have applied my learning in multiple ways (...) with my friends and my family I have talked a lot on how important it is to listen to the elderly because they are wise and have a lot to teach us. In school, I am more interested and I participated more in my biology class; the learning that I had from working in the Arctic in topics like bio complexity has helped me a lot with my scientific understanding and generally with my learning. (Atzin).

Participating in this project has changed entirely my perspective about things and the world, I see life different. (Rodo).

This international environmental education exchange program represents an example of service learning because it has helped students not only to make cognitive
links between their scientific knowledge and their real life experience but also to establish affective and behavioural links in order to value their environment, their culture and traditions, and so become better citizens.

The conjunction of collaborative, interdisciplinary work and multiple pedagogical strategies applied in this specific educational practice has shown the potential of implementing service learning in science education. We believe that service learning creates opportunities for students to work together towards a goal defined as a common good. Such educational approaches contribute significantly to effective science learning in schools as well as extending student understanding of their role as competent and powerful agents in responding to issues of local and global importance.

**Science teacher education**

Thus far, we have developed an argument that conceptual learning in science is deeply entwined with values education and quality teaching. This has been explored from the perspective of the teachers in Case 1. Case 2 has argued for the importance of values education and service learning as evidenced in the example provided from environmental education. What is still to be argued concerns the implications of these perspectives for science teacher education. It was argued earlier that a teacher's aesthetic understanding, which is deeply related to values, can be linked to a commitment to students' learning in a subject, or to a relationship with the transformative nature of the subject knowledge itself. From a teacher education perspective, the commitment of teachers to student learning is a fundamental aim but, in reality, is not necessarily addressed at a deep level. The Deakin University primary science education unit has for two decades been taught in local schools through a partnership arrangement in which pre-service teachers workshop science activities and ideas for 90 minutes before teaching science to small groups of children. The rationale for this was based on a realisation that science was rarely addressed in the normal practicum rounds. A stronger point to be made however is that small group teaching of this sort carries with it a moral imperative, granted that pre-service teachers are placed in an intimate setting with children as learners of science. They inevitably engage seriously with conversations focused on science ideas arising from objects and activities and children's personal narratives. This experience thus takes them out of a management mode and into more morally defensible ways of interacting with children's ideas and beliefs. This intimacy we believe is the reason that this approach is so strongly supported by pre-service teachers (Hubber 2005) and has been adopted by other institutions.

The other dimension of aesthetic understanding relates to a realisation about the transformative nature of science knowledge. Case 3 involves a teacher education unit
built around 'place-based education' that exemplifies the links between pedagogy, values and community, or service learning.

Case 3: Place-based teacher education

Students can identify causes of climate change, identify hundreds of celebrities but cannot name butterflies, birds or Indigenous plants in their local area (Louv, 2005; Schumacher, 1973; Sobel, 1996). Louv (2005) describes this as 'nature-deficit disorder' and Eckersley (2002) as 'student disengagement'. Both researchers say this leads to a lack of connectivity to place and a sense of belonging for many students in the over-developed world. Place-based education can be seen as being central to people developing emotional attachments to meaningful places (Semken & Freeman, 2008). It can also be seen as holding creative tension between fostering a depth of experience and place and developing critical ecological and social awareness through experiential-based learning (Cameron, 2004; Woodhouse & Knapp, 2000). Place-based education is pedagogy that science educators are exploring in order to connect students to their community and local place. It is pedagogy that could be used to address the diminishing numbers of students selecting science-based courses in Australian secondary schools and universities. This section of the chapter describes one case study where fourth year undergraduate students undertake a place-based experience as part of their final year science education course.

Context

The case study is based in a primary/middle school undergraduate teacher education program. The students graduate as generalist teachers for Years 3-7 but also have two areas of specialisation which they are able to teach in middle school within a secondary setting (Years 8-9). Two strands of the program involve science education. The first strand is a sequence of four compulsory curriculum courses over the four years. These courses integrate science and mathematics which provides an opportunity for students to participate in science-based learning experiences in each of their four years. All courses are characterised by an interactive pedagogy, a focus on developing pre-service teachers' science and mathematical conceptual understanding and thinking and working scientifically and mathematically, and a focus on integrated curriculum with a leaning towards educating for ecological sustainability and planning for learning.

The second strand is the general study sequence where students select two different learning areas to complete four courses. In science, the courses have an ecological sustainability focus and are entitled, Science, Humans and Environments, Atmosphere and Climate and Astronomy and The Universe (Lloyd, & Wallace, 2004; Paige,
Values in Science, Environmental Education and Teacher Education

Lloyd, & Chartres, 2006, 2008). Students who have taken four science courses and have elected an optional course in their fourth year which links to the science learning area specialisation constitute the group on which this case study is based.

This structure has several benefits. The student cohort traditionally does not have a strong science and mathematics background. By participating in a series of compulsory science and mathematics curriculum courses and optional science courses, graduates from this program have maximised their chances of being confident and competent to teach science. As a result, they are well placed to gain employment either as a generalist teacher with an expertise in science or as a middle school teacher of science.

Science and mathematics professional pathway group

This final course is an elective and is issues-based. Whilst students who enrol in this course find it one of the most useful in their degree (course evaluation comments include: "This subject allowed me to strengthen my understandings of these two learning areas. This has been one of the best courses that I have done."), the numbers that participate are very low; numbers between 8 and 12 are typical. The course consists of three components. These include: a) researching a topic to present to colleagues. Topics that are covered include Educating for sustainability, Futures thinking, Trans-disciplinary planning and middle schooling philosophy; b) a focus on planning and programming where students plan a trans-disciplinary unit of work and a year’s science program for a nominated level of schooling; and, c) undertaking a place-based experience and constructing a digital narrative. It is the third component which is the basis of this case study where students spend between two days and one month connecting with people and places within an ecologically sustainable context in a voluntary capacity.

What is Place-based Learning?

Theoretical Framework

There is significant research (Hawken, Lovins & Hunter, 1999; Lowe, 2006, 2009 Meadows, Randers & Meadows, 2004; Plotkin, 2008; Raskin et al., 2002; Sobel, 2008; Suzuki, 2006) that argues that we have to change the way we live, as the planet can no longer sustain our Western way of life. Schumacher (1973, p. 662) has said that we have to reject our current values of bigger, faster and more powerful, higher production and wealth generation in favour of the organic, the non-violent, the elegant and the beautiful.

There is also a growing education literature that suggests it is the responsibility of education to be part of the solution to global issues (Jucker, 2002; Roth & Desautels,
Gruenewald (2003) and Gruenewald and Smith (2008) argue that re-developing a sense of place has become a most revolutionary idea, because currently science education is about standardising the educational experience of students from diverse cultural and geographical backgrounds so they can compete in the global economy, thereby reducing the importance of a student's place in a primary experiential and educational context.

The key value of place-based education lies in the way that it serves to strengthen students' connections to others and to the place in which they live and values education supports this conjecture through its emphasis on promoting individual agency and accountability with respect to fostering interpersonal relationships within a community and preserving and maintaining the 'health' of the natural environment. The value of a sense of belonging and connection to place for deep learning in the primary/middle years of schooling has been documented (Daniels & Tait, 2005; Suzuki, 2006). It serves individuals and communities, helping individuals to experience what they value and hold for others, and allowing communities to benefit from the commitment and contributions of their members. Place-based education provides opportunities beyond classroom walls. It is intergenerational, multidisciplinary and experiential; it uses knowledge and skills in real life situations, is authentically connected to student life-worlds and builds a sense of ecological relationship (Edwards, 2003; Smith, 2002a).

By spending time in an urban ecological setting and working in a voluntary capacity, pre-service education students connect to a place and identify how this has benefits for them as beginning teachers of science. Place-based education encourages ethical action and social responsibility through dealing with community issues. As Smith (2002b) states: "Place-based education does not come pre-packaged. Its curriculum and activities arise from the individual qualities of specific communities and the creative impulses of particular teachers and students" (p. 31).

Making connections with the places that people inhabit is an important component of wellbeing and a dimension of a trans-disciplinary approach to teaching and learning. As Suzuki says:

The current generation of children are some of the most disconnected from nature ever in our history ... they have heard of climate change and endangered species but can't name a few native species from their home..... when direct experience with nature is limited, so is our emotional connection to the places that ultimately sustain us. (Suzuki, McConnell & Mason, 2008, p. 45)
The place-based experience

Early in the study period, students are exposed to the ideas associated with place-based learning. From this point, students begin investigating places and organisations with an urban ecological focus, exploring opportunities for voluntary work. The students experience a range of challenges in finding a location to which they would like to be connected and in which they have the time available to participate in a meaningful way. Settings have included Marine Discovery Centre, Global Education Centre, Trees for Life, Urban Ecology Centre, Botanic Gardens for World Environment Day, Astronomical Society, Friends of National Park and Waterwatch. It is the students’ responsibility to make contact and to organise visits. They negotiate with the particular organisation’s representative to participate in a range of activities, contribute to the organisation, as well as ask a range of questions that would assist them as beginning teachers to connect with the organisation. The students develop their ability to work as professionals in communities, being mentored by community group members who take an activist role towards sustaining and improving environmental and social parameters. Predominantly, this is a self-directed study with each student documenting their progress through reflective journals, email trails and digital photographs.

The students have undertaken a range of tasks during the place-based experiences including:

- Running workstations about fish identification, with an emphasis on characteristics and similarities/differences between species, at the Marine Discovery Centre;
- Identifying and eradicating non-indigenous plants from national parks;
- Attending professional development on water monitoring and undertaking to monitor water quality in a creek near their home for a year;
- Working at the Gould League to organise teacher resource material and setting up a system to distribute key resources to pre-service teachers; and,
- Work-shadowing astronomers and assisting at night viewings.

In the last three years, for their final assessment, the science pathway students were required to construct a digital narrative and present a summary of their place-based experience to the seminar group. The students were asked to take photographs, inquire about the organisation and construct a report of key findings to share with peers, all of whom would be exiting teachers in the following semester. The first task was to select up to ten key photographs and to organise the sequence to best communicate to future beginning teachers how the place-based setting might be a helpful part of their educational network. Adding appropriate music and text through the use of photo story or i-movie, they constructed a three minute narrative.
The learning from the place

The learning for pre-service teachers had several foci, including practical ways to develop science knowledge in an environmental context, modelling latest trends in ecological education pedagogy and the importance of connecting to place. The science knowledge that they learned included: astronomical ideas and concepts; identification of native plants or weeds by their botanical name; role of weeds in ecosystems; and, background information on weather and forecasting. For beginning teachers, there was also the emphasis on a range of pedagogical practices, such as using place as the basis for curriculum planning, developing links with local environmental care groups, observing teachers in non-traditional settings, integrating subject areas, developing educational fact sheets about introduced and threatening weeds, debating with students whether weeds should be removed and using new equipment (e.g., the Zeiss Projector).

Three cohorts of students, now early career teachers, who had been involved in the voluntary service learning and could be located, were asked to complete an email questionnaire. In terms of connections to place, the following ideas and actions were reported. Ideas included:

- Realisation of the human connectedness to space in a time in which people are increasingly isolating themselves from their natural surroundings;
- Reinforcing we are part of the natural environment no matter how embedded we are in the technosphere;
- The importance of giving back to the community through volunteer work; and,
- Seeing the work that other people and businesses do to help schools involved in environmental protection.

Actions included:
- Helping with the reintroduction of possums into the region;
- Helping research and develop a junior primary resource kit and book about globalisation; and,
- Setting up a piece of land for school groups to regenerate to a native state.

The digital narrative as an assessment item exemplifies Groundwater-Smith, Mitchell and Mockler’s (2007) principle of aligning curriculum, pedagogy and assessment. In particular, the course provided opportunities for students to develop science knowledge through contextual learning, to develop the capacity to work independently and to develop expertise with new technological software. Sharing their story with others in their learning community resulted in a very powerful learning
experience. As they constructed their story, they demonstrated the extent to which they have internalised the knowledge and then revealed the depth and transfer of their conceptual understanding.

In summary, the benefits for students are four fold. First, students added to their knowledge of ecological science. Second, they developed a sense of belonging with a community and connecting to a new place. Third, students explored and used new technology software (photo-story) as an authentic assessment strategy, and, finally, they could see the possibility of accessing local resources and organisations as a beginning teacher.

As part of the course evaluation, students were invited to reflect on their place-based experience and to identify possible benefits as beginning teachers of science. One student’s reflection follows:

As I am passionate about science and sustainability, I contacted Trees for Life. I would hardly call myself a green-thumb but decided on a challenge and signed up with a section of Trees for Life called Bush for Life, a group who relies heavily on volunteers to protect and maintain native bushland. I attended a one day training session which completely changed my mindset about tackling weeds.

The benefits for me as a pre-service teacher are numerous. I have started to create my own collection of plant samples; I have gained some techniques on how to destroy invading weeds and now that I have been allocated my own piece of bushland to care for, right in the heart of suburbia, I have an outdoor classroom at my fingertips with an endless supply of resources and inspiration for some place-based learning. (pre-service teacher)

Connecting fourth year undergraduate students with place has enabled them to engage in relevant community-based science. The course provided an authentic place-based education experience because it was both experiential and multidisciplinary. In one way, the place-based experience addressed the negative factors that exist in many tertiary and secondary science classrooms. Personal relationships were developed with a range of community members on an ongoing basis. These often extended beyond the requirements of the course as students connected to the group and became enthusiastic participants. The experience was activity-based and there was flexibility and an opportunity for negotiation for students regarding where they went, when they went and with whom. The place-based experience also incorporated a collaborative community approach to generating new knowledge that crossed discipline areas which is reflective of contemporary science research. They worked
alongside groups of retirees to identify and remove non-Indigenous plants from a national park and water experts to collect data about the health of local rivers. The sharing of knowledge between generations and experts in the field were features of the experience. Students have accessed the outdoors and community on an ongoing basis and participated in explorations that have led to them developing deeper ecological awareness (Semken & Feeman, 2008).

Conclusion

In this chapter, we have argued, on the basis of the research literature, that: a) values and beliefs are continuous with conceptual learning in science and cannot be thought of as separate, prior conditions for learning; b) the focus of science education needs to change to incorporate personally meaningful contexts and values if it is to represent the practice of science and if it is to capture the aspirations of young people; and, c) pedagogies, including quality teaching practices and service learning, must be promoted to perform this integration.

How values education has begun to be used to frame pedagogies aimed at rich science learning was described in three cases. First, a study of effective teachers of science showed clearly how the combined effects of values education and quality teaching resulted in optimal learning conditions for science students. The second case dealt with students engaged in a service learning environmental project that crossed international communities. The argument was made that environmental education has always paid explicit attention to moral agency, distinct from traditional science education. The case showed how environmental education employs pedagogies that entwine science knowledge with affective and ethical responses to the environment. The third case took these perspectives into teacher education. The argument was made that science teacher education needs to develop in pre-service teachers a moral commitment to the learning of science, and this dimension was represented by a brief description of a school based science teacher education unit, involving pre-service teachers interacting with small groups of children around science activities. A second value dimension involves a realisation of the transformative nature of science knowledge. This was also the focus of the third case, which demonstrated how teacher education can be enriched when it intertwines experiential, community-based science with a pedagogy that incorporates values and collaborative processes.

Pre-service teachers learn science in a context that pays serious attention to local contexts and purposes and the moral agenda that science education can serve. We can see in these cases the integration of pedagogy, values and community. Hence, the troika theme, and its implications for holistic student wellbeing, works well to frame productive directions for science education and teacher education.