Education for Sustainability: What Does This Mean for Tertiary Chemistry?

Janet Davies

School of Curriculum and Pedagogy, Massey University, Palmerston North (e-mail: *j.r.davies@massey.ac.nz*)

Education for sustainability is a responsibility for chemistry and every other discipline. The scale and urgency of the problems of unsustainability require critical examination of practice - research, teaching, and service. Population growth, increasing demand for commodities, waste accumulation and, most pressingly, climate change apply crippling pressure to the planet. The reports on the state of the planet, most significantly those of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment,[1] give us from 10 to 15 years to check the acceleration in temperature rise. Human action is squarely in the frame. The reports look to education to enable better understanding and to encourage changes to the way we live.

Despite intensive media coverage when the first three Fourth Assessment Reports were released, one year on *The Dominion Post*[2] has a double page spread lauding the search for oil in ever more inaccessible sites and welcoming the prospect of millions more barrels to support NZ's economic growth. Fritjof Capra[3] points us away from the mechanistic thinking that spawned this industrial approach and towards systems thinking derived from ecology. The systems he describes are interrelated self-organizing systems, living, non-living, and technological. From this systemic perspective, economic and technological decision-making cannot be seen in isolation from the social and biophysical systems in which they are embedded. Some argue for technological solutions to improve *eco-efficiency*,[4] including a *service and flow economy* built on lease rather than purchase of goods. This already exists within some industries, *e.g.* photocopying, where manufacturer responsibility for recycling of parts and materials occurs in a biomimetic approach[5] to components as technical nutrients.

Others argue that deeper change is needed. The UK *Forum for the Future* maintains that it is global capitalism rather than capitalism *per se* that is the problem and supports an international perspective aimed at human dignity and social justice, promoting national integrity and self-sufficiency. The *five capitals* model of sustainable development[6] draws particularly on real cost accounting research.[7] The model conceptualizes a sustainable society as one that maintains or restores capital assets, including the stocks and flows of natural, manufactured, human and social capital, as well as the financial capital by which the forms of substantive capital are measured and traded. That the values driving consumerism are beginning to be questioned is evident in recent media attention to research on the sources of *happiness*.[8]

The UN has required member states to develop and implement a comprehensive National Sustainable Development Strategy by 2005. So far the NZ government has approved only a *Programme of Action* focusing on selected aspects.[9] Late last year the Prime Minister[10] introduced two new energy strategies and stated that government intended to work towards *a carbon neutral New Zealand*, claiming leadership in the field. It is difficult to see how the strategies will achieve sustainability, when renewable sources are only preferable and biofuels are promoted despite all the known consequences for living, human and social systems. Clearly there is a key role for chemists in this debate.

Sustainability Literacy

The UN has declared 2005–2014 a *Decade for Education for Sustainable Development* (UNDESD), which promotes a key role for tertiary education. In late 2007, the Commission for UNESCO signed a partnership agreement with Sustainable Aotearoa NZ (SANZ) giving SANZ the mandate to coordinate UNDESD activities for NZ.

As the goal for education for sustainable development, and education for sustainability, there is wide support for sustainability literacy at the tertiary level. However, there is a range of views in regard to its meaning, *e.g.* Murray[11] describes the acquisition of defined skills relevant to the built environment. Such an approach has been criticized as indoctrination and inappropriate to university study. Acquisition of a broader set of facts-based and process-based skills is described by Dale and Newman.[12] A definition arising from the Forum for the Future's Higher Education Partnership identifies a sustainability literate person as one who understands the need for change to a sustainable way of doing things, has sufficient knowledge and skills to act appropriately, and rewards others' behaviour that favours sustainable development.[13] These definitions, however, derive from a cognitive deficit view of literacy, where essential knowledge and skills are defined by *experts* without recognition of the contexts and perspectives of the individuals concerned.

A contemporary view of literacy as social practice recognizes that literacy is embedded in culture.[14] James Gee has articulated such literacy as evident in the *way of being* or *Discourse* of the relevant social group entailing communication via language, illustrations and icons, and includes appropriate behaviours, attitudes and values consistent with those of the group;[15] fluency in the Discourse allows members to communicate effectively. This cultural view suggests a range of sustainability literacies; professional (including those of the graduate chemist), citizenship, and everyday literacies. Individuals acquire a number of Discourses, not all consistent with each other, and these evolve as aspects of a given Discourse are challenged.

Parallel and conflicting Discourses of sustainability and sustainable development have developed despite common meanings for the terms when they were introduced in the

1980s. Both terms referred to a society that met its own needs without affecting the chances of future generations. Contradictions developed between the Discourses largely through narrow understandings of *development* as economic development. Currently, however, broader understandings of development and common recognition of the biophysical limits of the planet have resulted in these Discourses increasingly overlapping. No distinction is made between the terms in the present discussion.

Recognition of Sustainability in Chemistry Courses at NZ Universities

An investigation of the sustainability content of undergraduate and postgraduate courses (or papers) in chemistry for chemistry qualifications offered at NZ universities in 2008 was carried out through a survey of the web listings of six of NZ's eight universities; neither AUT nor Lincoln offered qualifications in chemistry. Despite the limitations, which include the quality of the website and the policy decision in respect of the detail of course content provided, the survey identified those courses the university wished to advertise to enrolling students as addressing sustainability. The results are given in Table 1.

Only taught courses are included and only courses for which content is identified, either through the course title and/or the course description. Where special topic courses offer choice from specific modules they are included. Courses with the same content offered under different course numbers are identified just once. Courses are not distinguished by credit value. Indication that a course addressed sustainability was taken to be evident where topics referred to included sustainability or sustainable development, *green chemistry*, ecosystems, the environment, human or social issues, hazards, pollution or toxicology.

Nearly all universities offered specialist courses in environmental chemistry, mostly at postgraduate level and commonly in association with analytical chemistry. Otago linked the environment with physical chemistry at most levels. Only two universities, however, came close to infusing consideration of a more comprehensive whole systems approach to sustainability across the range of undergraduate chemistry courses. Auckland and Waikato each offered several courses at first year that either indicated specialisation through the course title or included consideration of issues in the course description; Waikato University carried this consideration through into the second year. Waikato and Otago offered sustainability-related courses that included interdisciplinary approaches.

While the introductory web pages of the chemistry departments tended to claim a central role for chemistry in understanding the world, the survey suggests this understanding was unlikely to recognise a world degraded by human action. Where there was recognition, courses tended to indicate investigation of changes to cycles and systems of the natural environment. Few courses investigated interrelationships between environmental and human, social or economic systems. Green chemistry, focussing on safety in chemical design and processing, was identified at Auckland and Massey The notion of sustainability was used at Auckland University, but it was unclear.

A survey of students enrolling in universities and colleges in the UK[16] found nearly two thirds would like to learn more about sustainable development in their coursework and 42% believed that such learning would help them get the job they wanted. Although 25,000 students responded to this on-line survey, the respondents represented only 7% of the sample contacted. However, only 30% of respondents identified themselves as environmentalists. Students were aware of the challenges facing the planet and believed there were radical lifestyle changes ahead.

Strategies for Education for Sustainability in the Tertiary Sector

The tertiary sector identified through NZ's Tertiary Education Strategy includes all the professional development carried out in the workforce, all learning and teaching undertaken through tertiary education organizations (universities, polytechnics, wananga, and private training organizations) and education in the community.[17] Five broad strategies are described for developing education for sustainability through chemistry.

Developing Understanding

Understanding how the planet works is dependent on understanding of cycles and systems of the natural world, and thus on science. The ongoing unpopularity of science[18] and perceived difficulty of chemistry, however, provides a significant challenge for extending fundamental understanding.

Table 1. Web-based university information on sustainability in chemistry courses

University	No. of taught chemistry courses with sustainability in title or content (cont) *vs* all taught														
	100-level			**200-level**			**300-level**			**Postgraduate**			**All levels**		
	Title	Cont.	All	Title	Cont.	All	Title	Cont.	All	Title	Cont.	All	Title	Cont.	All
Auckland	0	3	4	0	1	5	0	1	8	1	1	9	1	6	26
Waikato	2	1	4	1	4	9	1	0	5	1	0	5	5	5	23
Massey	0	0	3	0	0	5	0	1	5	1	0	4	1	1	17
Victoria	0	0	3	0	1	7	0	0	5	0	0	5	0	1	20
Canterbury	0	0	5	1	1	9	1	0	9	1	0	12	3	1	35
Otago	0	1	3	1	0	4	1	0	5	3	2	6	5	3	18
All	2	5	22	3	7	39	3	2	37	7	3	41	15	17	139

Tertiary education research over the last 30 years has identified the link between understanding and a deep, rather than surface, approach to learning, and learning for meaning, rather than reproduction. Learners successful in developing understanding relate new ideas to knowledge and experience, examine argument, and construct symbolic objects of understanding that represent the coherence of their ideas.[19] Despite understanding being a primary goal of the discipline, undergraduate science students are likely to adopt a surface approach to learning as they perceive the curriculum to be overloaded and to have little freedom of choice in regard to content or method.[20] Students' concern for the state of the planet provides an opportunity to develop learning tasks that will encourage their active and sustained engagement.

Critical Reflection on Practice

The distinctive Discourses of social groups, discussed above, are evident in the different *epistemic cultures* of practising scientists (Knorr-Cetina[21] identified the questions, theories and methods of high energy physics and molecular biology that lead to contrasting aims and practices) and the different disciplinary *ways of thinking and practising* of university teachers.[22] These characteristic ways of behaving, whether in research or teaching, are taken for granted and difficult to change. Individuals rationalize and maintain the social systems they create in a process that Anthony Giddens calls *practical consciousness*.[23] To change the social systems individuals need to develop discursive consciousness in discussion and critical examination of the systems with their peers.

In respect of sustainability, a collegial process to identify institutional stakeholders and a framework of underpinning values, including fairness and justice, would provide a context for examining policy and practice documents and identifying contradictions. Government research funding opportunities that conflict with sustainable practice, for example, provide dilemmas for researchers who may be under pressure from institutional managers to secure funding regardless of long-term goals for the planet. There is no escaping the political nature of discursive consciousness. Students would benefit from opportunities to collectively examine accepted ways of thinking and practising in the discipline through authentic problem-solving activities.

Promoting Interdisciplinarity

The complexity of industrial society means that a systemic approach to sustainability necessarily requires an interdisciplinary approach, with disciplines working together to address a single issue. While government is recognizing, through its Environment Research Roadmap, the need to consider whole systems, it is currently calling for a multidisciplinary approach, where disciplines work alongside each other.[24]

According to Good,[25] an interdisciplinary approach is difficult to achieve because it requires members of one discipline to see an issue from the perspective of another, but it provides insights not otherwise achievable. Historically, new research and development has occurred at the boundaries of disciplines where practice is least stable. Practitioners are most vulnerable at the boundary of their discipline and it is here their respect for practitioners of other disciplines is greatest.

Tertiary teachers wanting to develop interdisciplinary coursework would find it useful to work with one or two other enthusiastic staff through an integrated approach to a common problem. Incorporating the approach into an existing course establishes a model for addressing sustainability across the curriculum, and is likely to be more easily adopted than a new course. A series of required sequential interdisciplinary papers or modules on sustainability through the three years of an undergraduate programme is another option, but it can imply that sustainability is a topic for specialists and that the disciplines themselves do not need to change.

Collaborating in Community Projects

Community projects include collaborative research and development initiatives in which research institutes, tertiary education organizations, business and industry, local government, and not-for-profit organizations work together to develop sustainable practices, including carbon management. These projects, and student research and community placements, not only improve research connections and community linkages but enhance the sustainability literacy of all participants. Participants have the opportunity to experience the development of sustainability fully, through examination of interconnected environmental, human, social, technological, and economic systems in real-world contexts.

The establishment of Regional Centres of Expertise for Education for Sustainable Development (RCEs), under the auspices of the UN University, is an international initiative to meet the goals of the UNDESD.[26] The aim is to coordinate local partnerships of tertiary education organizations, local authorities, schools and not-for-profit organizations to conduct research and build capacity for education for sustainability. To date 55 RCEs have been established around the world, though none of these are in NZ.

Modelling Sustainable Behaviour

Probably the strategy most readily undertaken is modelling sustainable behaviour in everyday practice: in personal life, *e.g.*, sustainable transport, fair-trade purchasing; professional life, *e.g.,* recycled stationary, video conferencing; the laboratory, *e.g.,* recycling, saving power; and by encouraging corporate responsibility, *e.g.,* sustainable procurement, encouraging biodiversity. These all these serve to raise awareness, the need is to change the core assumption of the validity of material consumption and the current orthodoxy of economic growth.

Conclusion

There are encouraging signs of the infusion of sustainability in undergraduate chemistry courses in a few universities. Across the universities surveyed, however, the pattern of environmental chemistry courses could be considered tokenism. Most chemistry students will continue to complete undergraduate study without ever formally examining sustainability issues. These students enter the workforce without the understanding of systems theory or the developed reflective thinking abilities that would allow them to address the sustainability issues that they will surely face.

Helping students understand fundamental processes is familiar territory to chemistry academics. However, in order to allow such understanding to contribute to the development of sustainability literacy, students need the opportunity to explore the relationships between these processes and the processes and systems accessible through other disciplines. Moreover, new perspectives critically reflecting upon taken-for-granted practice are needed. Such interdisciplinary innovations provide opportunity and challenge to traditional undergraduate teaching practice, not least in terms of large classes and full courses. They require reduced content, critically reflective investigation, collaborative project work, and greater opportunity for discussion and debate. The changes also have the potential to provide deeper understanding in general and to address the ongoing issue of the perceived difficulty of chemistry, which continues to discourage so many potential students.

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Correction to Article

Protecting Cultural Heritage: Reflections on the Position of Science in Multidisciplinary Approaches *This Journal*, (**2008**, *72*, 75-77) ran with incorrect captions under each Figure. The images and correct captions are shown below. The publishers apologse unreservedly.

Fig. 1. Dyes in Preolumbian Peruvian textiles (reproduced with permission from the Royal Institute for Cultural Heritage, Brussels): A combination of medium destructiveness and high resolving power allowed for the identification of biological sources used for dyeing, and revealed changes in use as a function of cultural periods - see ref. 12.

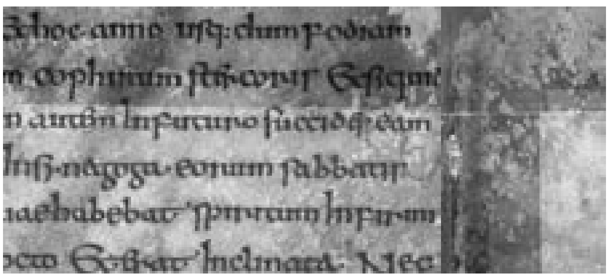

Fig. 2. High-level destructiveness analysis of synthetic membranes without touching the 8th century parchment of the Codex Eyckensis (reproduced with permission from the Royal Institute for Cultural Heritage, Brussels). This revealed a polyvinylchloride polymer with 30 % (w/w) monomeric plasticizer; after removal of the membranes, the Codex could be conserved by the application of an innovative parchment leafcasting technique – see ref. 13.