JLD Journal of Learning Design

Embedding Environmental Sustainability in the Undergraduate Chemistry Curriculum: A Case Study

Madeleine Schultz
School of Chemistry, Physics and Mechanical Engineering
Science and Engineering Faculty
Queensland University of Technology, Australia
madeleine.schultz@qut.edu.au

Abstract

In spite of increasing attention devoted to the importance of embedding sustainability in university curricula, few Australian universities include specific green chemistry units, and there is no mention of green or sustainable chemistry concepts in the majority of units. In this paper, an argument is posited that all universities should embed sustainable chemistry within all Chemistry courses because it is the morally correct stance to minimise the harm of climate change. Attitudes of chemistry lecturers towards integrating sustainability into their teaching have been probed and it was found, using an established model, that personal environmental perspectives are critical to their attitude. Importantly, academic staff whose research has an environmental component were more likely to incorporate sustainability into their teaching while others struggled to find ways to do so even when they believed it to be important. This paper will recommend that resources are required to assist academic staff without a green chemistry research program to incorporate sustainability into their teaching and several suggestions are provided.

Keywords
Green chemistry, environmental sustainability, climate change

Introduction

In June 2012, the United National Environment Programme released a strongly-worded report outlining the critical state of the world's environment and the lack of current effective government action in spite of longstanding, internationally-agreed goals (United Nations Environment Programme, 2012). Several tipping points have now been passed and the actions required as well as the expected consequences have become more drastic. Over time, the term "moral imperative" has been increasingly used in relation to action on climate change by a variety of people and groups. For example, Schrader (1963) explained the concept of a moral imperative, derived from Kant's categorical imperative, as follows:

> In referring to the unconditional necessity of the moral imperative it is clear that Kant meant to emphasize its status as an objective limitation on our freedom. The categorical imperative is unconditional in that it is inescapable; it expresses the law of our being as free subjects. ...We have no more option whether to be subject to the moral law than whether we are to be human subjects. (p. 69)

In the influential 2006 book, *An Inconvenient Truth,* which brought climate change into the popular consciousness, Al Gore used the phrase "moral imperative" in regard to the urgent need to act on climate change (Gore, 2006). Since then, the phrase has been adopted by others including the UN Secretary General (Lane, 2009) and the Vatican (Climate change int'l concern, a moral imperative to protect environment, Vatican states, 2007).

In spite of the strength of these statements, few people treat the need for personal action to limit climate change as urgent. In 1981, Fietkau and Kessel proposed a model (Figure 1) to rationalise personal environmental behaviour (Fietkau & Kessel, 1981) which can be applied to this situation. The interaction of the five factors shown leads to the observed behaviour. Further, the thin arrows represent mechanisms while broad arrows represent starting points to initiate change.

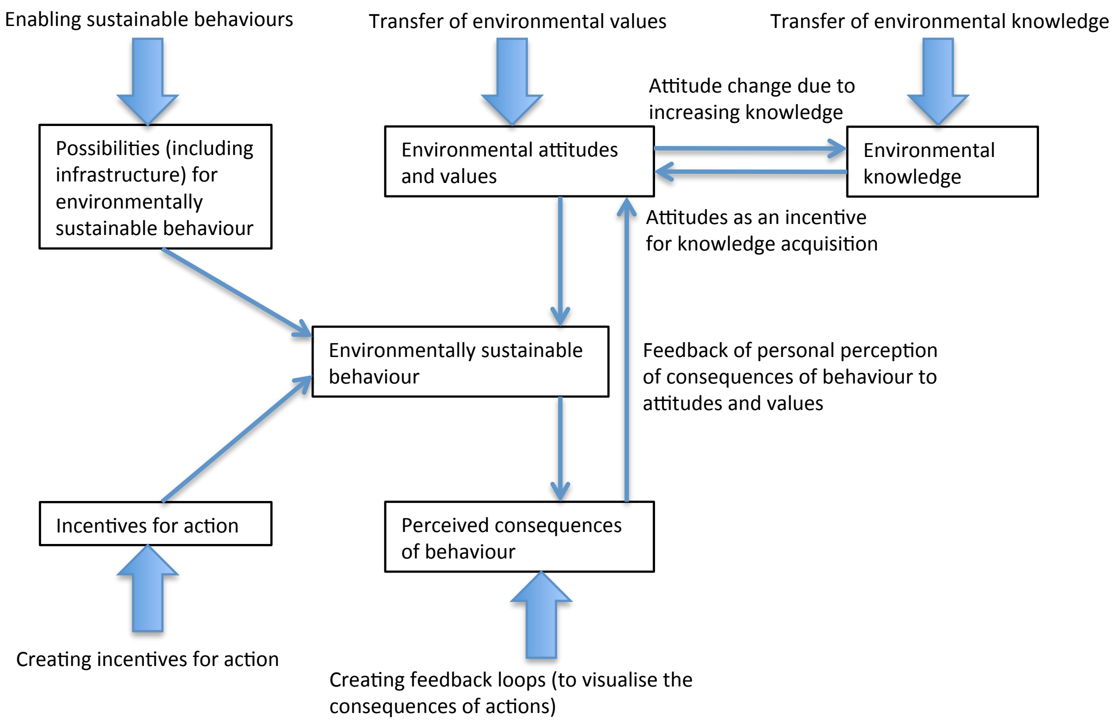

Figure 1. Scheme of influences on environmentally responsible behaviour (author's translation)

This model can be used to explain the environmental behaviour of members of the public as well as specific groups. For example, people who do not believe that climate change will affect them personally and think that mediation of climate change will impact their lives negatively choose not to act because of the lack of environmental knowledge and the perceived consequences of their behaviour. This attitude has been studied by Lorenzoni and Pidgeon (2005) who suggested that "few will take action based on a moral imperative" (p. 3): a somewhat confounding statement considering the definition of a moral or categorical imperative cited previously. Lorenzoni and Pidgeon (2005) also made concrete suggestions on how to "close the gap" between an understanding of the dangers of climate change and individual behaviour such as communicating impacts on the local area. Such communication would improve environmental knowledge and therefore modify the environmental attitudes and values, according to the Fietkau and Kessel (1981) model.

Those not acting on climate change might not do so because they feel powerless, rather, their inaction is because they do not perceive the possibilities for pro-environmental behaviour. In 2010, ABC Radio National, through the *All in the Mind* program covered the psychological aspects of climate change with psychologist Joseph Reser (Griffith University) offering that:

> ... people aren't feeling apathetic at all, they are actually quite distressed. They might not be doing anything because they don't exactly know what to do, and it does seem like a global problem, and the media seems to be giving them very mixed messages about where the scientists are at.
>
> (*All in the Mind*, 2010)

The psychologists speaking on this radio program suggested bringing climate change "home" to people locally, helping them understand without creating fear and using public figures as role models to assist the public in overcoming barriers to action. In this respect, universities have an important role to play both in education and as role models. In this paper, the possibility of individual academic staff taking action on climate change by modifying their teaching to include issues of sustainability is explored. The Fietkau and Kessel (1981) model (see Figure 1) will be used to analyse the behaviour of a selected set of chemistry academics at an ATN (Australian Technology Network) university.

Education for sustainability (EfS)

The word "sustainability" has different interpretations but most authors adopt the UN World Commission on the Environment and Development Report (Brundtland, 1987) definition, which stated that:

> Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits. (p. 16)

The Chair's foreword to the UN report (Brundtland, 1987) explained that the definition of sustainable development was chosen to contrast with the limiting use of the word "development" relating to how poorer nations progress. It is worth noting that not all authors agree with the use of the term. For example, Pittman (2004) explained that:

> In lieu of addressing the true value of diverse needs, "sustainable development" is often used to justify or disguise continuations of rapid and potentially unchecked growth. As such, I feel the word "sustainability," while potentially ambiguous, is a more suitable term for sharing meaning. (p. 201)

In this paper, "sustainability" is taken to mean the human behaviour that does not irrevocably damage the planet. Thus, it encompasses limiting pollution and waste and, most importantly, halting climate change by modifying energy sources and usage.

Awareness of the importance of the environment has grown exponentially in the past decade and many Australian universities now explicitly mention concepts such as sustainability in their graduate attributes (including Sydney University, Griffith University, Charles Darwin University, and Monash University). A notable example is Macquarie University's inclusion of sustainability amongst the core values of the Learning and Teaching Plan which states that:

> The biggest impact universities can have on the future of our planet is through approaches to learning and teaching that equip graduates with the skills they need to actively contribute to economic, social and environmental sustainability in all facets of life. (para.2)

Similarly, the Bar-Ilan University in Israel has taken a proactive approach to addressing the threats posed by climate change. The President of that university, resonating the strong statements cited previously in this paper, has stated that "Going green is not just a slogan at BIU – it is a moral imperative" (Medin, 2008, p. 1).

Sterling (2004) explained four stages of social and educational responses to sustainability in relation to their sustainability transition, their state of sustainability and their state of education. These stages are summarised in Table 1.

Table 1
Stages of social and educational responses to sustainability (Sterling, 2004, p. 57)

Sustainability transition	Response	State of sustainability	State of education
Very weak	Denial, rejection or minimum	No change (or token)	No change (or token)
Weak	'bolt-on'	Cosmetic reform	Education about sustainability
Strong	'build-in'	Serious greening	Education for sustainability
Very strong	Rebuild or redesign	Wholly integrative	Sustainable education

The Chemistry Discipline Network has recently conducted a mapping exercise leading to a snapshot of the chemistry curriculum at twelve Australian universities (Mitchell Crow & Schultz, 2012). Its findings showed that only 25% of the universities investigated had made any change at all to their "state of education" and that this, by including a few specific units about sustainability, and some sustainability concepts in other units, constitutes a 'bolt-on' response and is a weak approach indicating only cosmetic reform. Despite this, a stronger "build-in" approach is being attempted within other parts of several universities. For example, an internal email at the Queensland University of Technology from its Executive Director of Finance and Resource Planning (personal communication, October 28, 2010) announced that:

The Division of Finance and Resource Planning is introducing new procurement training that incorporates the principles of sustainability:

- meeting the users' needs;
- delivering long term value for money by considering whole of life costs;
- maximising social and economic benefits; and,
- minimising damage to the environment and health.

This shows an attempt by this part of the university to "green" its operation. The same institution has demonstrated a commitment to sustainability through the building of a 5-star Green Star rating Science and Engineering Centre (QUT, 2012). This type of behaviour by the university is very important to the attitudes of staff and students because actions do speak louder than words. Students, staff and the public are sensitive to hypocritical posturing. The positive effect of designing a sustainable building with student involvement was found at Sonoma State University in California with Rohwedder (2004) noting that, "for our students, helping to envision and design the Environmental Technology Center was a hopeful and empowering process. They saw a public institution that was for once not teaching hypocrisy and was instead attempting to 'walk the talk'" (p. 300).

In addition, Calder and Clugston (2004) have provided a fascinating account of the process of embedding sustainability at three universities in South Carolina in their book chapter, *Lighting Many Fires: South Carolina's Sustainable Universities Initiative*. They also provide a realistic assessment of the difficulties as follows:

> Reorienting colleges and universities toward sustainability is difficult, given economic and disciplinary realities. For higher education to make a significant contribution to a major societal challenge, the issue must be clearly recognized, backed by sufficient external funding, and commanding of academic prestige. Since the 1990s, education for sustainable development has been underfunded and under-supported, both within and outside of the academy. Sustainable development is not a recognized societal priority. Traditional disciplines still view sustainability with suspicion and external funding rarely supports related research and teaching. (p. 249)

The solution to many of the problems is suggested within the cited text, namely, adequate funding and recognition or even prestige for sustainable education. The US Sustainable Universities Initiative had some funding and commitment from the three university presidents to both teach sustainability and practise it on their campuses. Disciplines from English to Horticulture were enthusiastic participants and, in some cases, significant external grant funding was received for sustainability-related research. Australian universities could initiate an internal small grant system to encourage teaching and research into sustainability and an agreement with the other universities in each region would be an excellent motivation to pursue this model.

Once the decision is made to incorporate sustainability, it is essential to monitor progress to determine whether the strategies being used are effective. Roorda (2004) describes an auditing instrument to determine the status of sustainability that is in use in many Dutch universities. The instrument outlines five stages (Table 2) which parallel the four stages of Sterling (Table 1).

Table 2
Stages of sustainability for auditing instrument (Roorda, 2004)

Stage	Educational goals	Decision-makers
Activity oriented	Subject oriented	Individual staff (ad hoc)
Process oriented	Educational process	Groups of professionals
System oriented	Student oriented rather than teacher oriented	Organisational policy
Chain oriented	Seen as part of chain	Formulated qualifications of professionals
Society oriented	Long-term strategy	Contact with customers and other stakeholders

Such an auditing process is vital to determine the effectiveness of any attempts to incorporate sustainability within the curriculum and within the university culture. Australian universities should implement an audit, not just of sustainability within chemistry but university-wide, so that the impact of changes to policies and correspondingly, to current practices, can be measured meaningfully.

Reflecting the increased awareness of environmental issues in the tertiary sector, the *International Journal of Sustainability in Higher Education* was founded in 2000. Review of the articles published over the decade of its existence shows attention to the importance of embedding sustainability in curricula (Anderberg, Nordén, & Hansson, 2009), as well as strategies (Rusinko, 2010; Sibbel, 2009; Sipos, Battisti, & Grimm, 2008) and possible difficulties (Kagawa, 2007) in doing so. However, there are few papers relating to the teaching of Chemistry in the 13 years of its publication. One notable article examines the incorporation of sustainability concepts in university chemistry degrees, in this case in The Netherlands (van Roon, Govers, Parsons, & van Weenen, 2001), which is discussed in detail below. Further, the book, *Higher Education and the Challenge of Sustainability* (Corcoran & Wals, 2004), made no specific mention of approaches to teaching sustainable chemistry. However, it is an excellent resource for general approaches to teaching sustainability and several chapters are discussed below under implementation.

In the field of chemistry, the terms "green chemistry" and "sustainable chemistry" are used to describe chemistry that seeks to minimise hazardous emissions in chemical processes by designing safer chemicals (such as pesticides) that will degrade safely in the environment, and synthesising them starting from renewable feedstocks, using safer solvents and less energetic processes. This is summarised in the 12 Principles of Green Chemistry listed in Table 3.

Table 3
The 12 Principles of Green Chemistry (Anastas & Warner, 1998, p. 30)

Principle	Descriptor
Prevention	It is better to prevent waste than to treat or clean up waste after it has been created.
Atom Economy	Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
Less Hazardous Chemical Syntheses	Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
Designing Safer Chemicals	Chemical products should be designed to effect their desired function while minimizing their toxicity.
Safer Solvents and Auxiliaries	The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
Design for Energy Efficiency	Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
Use of Renewable Feedstocks	A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
Reduce Derivatives	Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
Catalysis	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
Design for Degradation	Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

Real-time analysis for Pollution Prevention	Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
Inherently Safer Chemistry for Accident Prevention	Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Since the publication of these principles (Anastas & Warner, 1998), a body of literature regarding incorporating green or sustainable chemistry into higher education has grown. In The Netherlands, a detailed examination of the definition of sustainable or green chemistry and how it can be incorporated into higher education was carried out in 2001 (van Roon, et al., 2001). The authors offered that:

> The question of how to introduce sustainable chemistry to chemistry students largely runs parallel with the discussion on the definition of sustainable chemistry. Chemistry students should, for example, learn to distinguish the optimisation of existing processes from the implementation of inherently safer and sustainable processes. (p. 176)

These authors further examine the current state of the chemical industry and identify environmental issues at all stages of the life cycle of a chemical, from extraction as the raw material in crude oil, through refining, manufacturing and consumption to dispersal and degradation. They also examine sustainable alternatives at many levels - societal, industrial, material and chemical. Green chemistry, as described above, falls within the material level, while the societal level involves a complete move away from a crude oil society to carbohydrates and reusable starting materials. The authors concluded that change is needed at all levels, and must be integrated into the education of chemists to prepare them to transition to the necessary new chemical industry. In the same year, in the leading journal *Science*, Collins argued that “when chemists teach their students about the compositions, outcomes, mechanisms, controlling forces, and economic value of chemical processes, the attendant dangers to human health and to the ecosphere must be emphasised across all courses” (Collins, 2001, p. 48).

Multiple strategies for the incorporation of the “12 Principles of Green Chemistry” (Anastas & Warner, 1998)(Table 3) into tertiary teaching were proposed in 2009 in *Green Chemistry Education* (Anastas, Levy, & Parent, 2009), a book that includes chapters on integrating green chemistry throughout the curriculum, in text books and in laboratory exercises. More recently, in 2012, one of the leading journals in the field of chemical education, *Chemistry Education Research and Practice*, published a special issue on the theme Sustainable Development and Green Chemistry in Chemistry Education (Eilks & Rauch, 2012). That issue included a review of green chemical education practice (Andraos & Dicks, 2012). The steady linear growth in the annual number of publications describing green chemistry pedagogy found by those authors is testament to its growing importance. In the same year, Fisher (2012) wrote:

> The importance of sustainability to chemistry and chemistry education is clear, the connections are real and significant, and more resources are available now than any time before. The challenge is for each of us as chemistry educators to find ways to bring that connection and context into our courses. (p. 180)

It can be seen that the field of chemistry contains many opportunities to improve sustainability (Collins, 2001) and that the teaching of chemistry can be modified to educate future chemists on sustainability (Andraos & Dicks, 2012). The previously cited report from the Chemistry Discipline Network (Mitchell Crow & Schultz, 2012) has revealed that, while 75% of universities teach a unit entitled, or containing, environmental chemistry, this is largely descriptive and analytical chemistry of the environment. Looking more specifically for green or sustainable chemistry shows that only 25% of universities cover this content at all, in most cases in the context of catalysis and industrial processes.

In this paper, the views of lecturers at one institution about including sustainable chemistry in their curriculum are examined. In analysing their responses, their personal environmental ethos was important, as was their sub-disciplinary specialisation. Their resulting behaviour has been described using the Fietkau and Kessel model (Figure 1). The paper concludes with some suggestions of approaches that will allow sustainable chemistry to be embedded into undergraduate teaching in Australia.

Results and Discussion

Interviews with chemistry academics (*n*=8) at an ATN University were conducted to determine their attitudes towards climate change and the environment, and their feelings about incorporating green and sustainable chemistry concepts within their teaching. These eight are at lecturer, senior lecturer and associate professor level and, together, they form over half of the current chemistry teaching staff at a typical Australian university. A document showing the *12 Principles of Green Chemistry* (Anastas & Warner, 1998) (Table 3) was shown to each subject prior to the interview to illustrate the concept of green chemistry, and their views on incorporating these principles as well as environmental issues and sustainability within the chemistry curriculum were canvassed.

The interview questions were as follows:

1. What do you think the university's role should be in educating students about environmental issues/sustainability?
2. How do you see your role in educating your students about environmental issues/sustainability?
3. Do you address environmental issues such as climate change explicitly in your teaching?
4. Do you mention any of the environmental issues related to any topics that you teach?
5. Do you discuss any other aspects of the relationship between the content you teach and the environment or sustainability? e.g. toxicity of lead, mercury
6. Do you think students come out of any of your units with an appreciation of the science behind climate change or other environmental issues?
7. Could you envision incorporating relevant environmental issues and sustainability into your teaching (if you do not already do so)?
8. If you were to design your units around understanding of climate change or sustainability as an outcome, what would you do differently?
9. What do you think your role should be in encouraging students to take action in relation to environmental issues or sustainability?
10. Do you think that students leave your units with an awareness of how they can take action on climate change?
11. Could you teach in a way that would encourage students to change their personal environmental behaviour?

The answers to these questions gave insight into these lecturers' views on two different aspects of teaching sustainability:

(i) the extent to which the academics see the importance of incorporating sustainability within their teaching; and,
(ii) the extent to which they currently incorporate 'sustainability' in their teaching.

The former relates to their environmental attitudes and values, while the latter shows their pro-environmental behaviour (Figure 1). All interviewees had a high level of environmental knowledge, given their educational level, and there were no direct incentives for pro-environmental behaviour.

In terms of the current coverage of sustainability, it was interesting to note that the three lecturers who already incorporate sustainability to a significant extent into their teaching are the same three (of the eight interviewed) whose research had an environmental aspect. One researches the design of new solar photovoltaic cells, one investigates the removal of organic contaminants from water, and the third quantifies pollution in waste water which is impacted by the heavier rains expected due to climate change. It is also worth noting that these three lecturers teach physical and analytical chemistry which includes the topics of thermodynamics and the measurement of pollutants. These topics may lend themselves more easily to the incorporation of discussion of sustainability than other undergraduate chemistry content; that is, there are greater possibilities for pro-environmental behaviour in the Fietkau and Kessel model (see Figure 1).

The other lecturers interviewed teach inorganic, organic and fundamental physical chemistry, where it may be inherently more difficult to include concepts of sustainability. Two of these lecturers feel that the issue of sustainability in synthetic chemistry (inorganic and organic) only arises when discussing large-scale synthesis of bulk products, while in their teaching, they are only discussing small, laboratory-scale production, where issues of by-products and energy efficiency are not important:

> *Just make them aware that processes can have an impact. We always think on a small scale, it is more on industrial scale that it is relevant. (Lecturer 1)*

> *In processes like drug discovery with a target compound, first you use any way to get there. But with scale up you look at the environmental impact, number of steps, use of catalysts and protecting groups. So in the basic theory of chemistry, it is not an issue, or in small scale processes - you only see it in larger scale processes. (Lecturer 2)*

However, the analytical chemist, whose research investigates pollution in waste water, has found ways to incorporate discussion of pollution into his introductory inorganic chemistry lectures at the first year level:

> *I do discuss [sustainability] with respect to analytical chemistry, which is mainly what I teach, I also incorporate it into coordination chemistry, when I talk about the effect of phosphates on the environment, which are components of fertilizers and detergent, their effects on the environment. (Lecturer 3)*

Thus, this person has created an opportunity to act pro-environmentally, driven by their environmental attitudes and values, and based on their environmental knowledge. While positive, this should not be the only way that sustainability is incorporated into the curriculum.

All eight interviewed said that they could envision incorporating more on sustainability, given the resources, that is, more possibilities in the Fietkau and Kessel model (Figure 1). The resources mentioned as being required are time within the curriculum, so that other material is not left out, as well as accurate information to use:

> *I guess I have an opportunity that I haven't taken advantage of - efficiency is the introduction. (Lecturer 1)*

> *There is a limit on time. I don't want to detract from the theory. I could teach more but would need to make space. (Lecturer 4)*

> *I'm not against introducing the idea, [but] within chemistry we are not equipped to teach it. (Lecturer 5)*

Regarding their role in encouraging action on sustainability, a common theme that appeared in the responses of all eight interviewees is that part of their role as science teachers is to educate students to understand the science and media regarding environmental issues. However, views differed widely as to whether this role extends to encouraging action; five said that they only teach the facts, allowing students to make their own decisions:

> *I don't think it's our role to encourage action but it's our role to enable them to make informed decisions. (Lecturer 4)*

> *If they understand the chemistry they can make their own decisions. ... it turns students off to have it in their face. (Lecturer 5)*
>
> *I am not sure that I have a role [in encouraging students to take action], not within my university work. (Lecturer 6)*
>
> *I believe that the limit of my action is to sensitise the students, what they do after that is their decision. (Lecturer 3)*
>
> *I think that the main thing we can do is inform and make them aware - the media is not the truth. They must make up their own minds - there is a role for chemists. (Lecturer 7)*

Three go further and encourage action:

> *... because it is a personal interest of mine anyway - when it comes up, I try to take the opportunity. I believe as a university staff member I should. (Lecturer 1)*
>
> *I try to encourage students to take action in their working life rather than their personal life. I preach sustainable practices in the workplace. (Lecturer 2)*
>
> *I think that as a university educator I have a role in encouraging their moral development and maturity and to me, it is a moral issue so I think I should do more than just help them to understand it, I should give them a positive view of action. (Lecturer 8)*

The former perspective has been criticised, including by Glasser (2004), who wrote:

> With regard to environmental problems, [orthodox] higher education prepares us to, at best, document nature's decline or improve our understanding of the causes of the decline. Practical problem solving is generally viewed as mundane and unsuitable for scholars whose primary purpose is contributing to the growth of knowledge**.** *Advocating for or against is seen as compromising one's objectivity as a scholar and is usually looked upon with suspicion, mistrust, and disapproval.* (p. 142, emphases added)

It is clear that this perspective is shared by many of the chemistry academics interviewed for the investigation underpinning this paper. Glasser (2004) argued that this approach is "shallow because it does not outfit us with the skills, tools and vision to probe the depths of our predicament or guide our way to a sustainable future" (p. 142). In response, he proposed a deep ecology approach to higher education, which includes "infus[ing] the entire curriculum … with a discussion of sustainability questions" (p. 144). The question is how to implement such an approach and overcome the reluctance of some of the lecturers.

Conclusion and recommendations

There is no doubt that sustainability is highly relevant to the discipline of chemistry and that there are many opportunities for chemistry lecturers to educate students about sustainability and the environment. From the industrial scale synthesis of fertilisers and personal care products to the analysis of drinking water to the development of plastics for everyday packaging, chemistry possibly impacts the environment more than any other discipline. Above, I have argued that chemistry lecturers are under a moral obligation to include coverage of sustainability within their teaching. However, this brings up a practical problem which has been clearly stated by Appel Dankelman and Kuipers (2004) in the *Higher Education and the Challenge of Sustainability: Problematics, Promise and Practice*, where they suggested that:

> Having university teachers and managers as a principal target group is no easy task. It is useless simply to organize a few workshops or training sessions for university teachers. In universities especially, teachers have something of an aversion to being trained, and above all on issues they do not necessarily see as being relevant to their own discipline.

> Nor do they want to be instructed 'top-down' on methodologies and the subject matter of their own lectures. *If we really want to be effective in integrating elements of sustainable development in overall higher education, it is necessary for the lecturer to see the specific intellectual challenges that sustainable development poses to his or her discipline.*
> (Appel, Dankelman & Kuipers, 2004, p. 213, emphasis added)

The conclusion of these authors is substantiated by the results of the interviews in this project. Those whose research (and therefore intellectual challenge) encompasses environmental issues have found it easier to incorporate sustainability into their teaching, and do so to a much greater extent than the remainder. Among those who do not have an environmental aspect to their research, some have a strong desire to effectively integrate sustainability into their teaching but have found it difficult to do so, because they do not see the opportunities within the content that they teach. Others do not see it as part of their job. A similar view of the difficulty of forcing academics to teach sustainability has been put forward by Scott and Gough (2004) who contended that:

> Teachers in universities know that their job is to promote learning *by* their students, rather than to promote sustainable development, and may well resent being told that their priorities ought to be otherwise. Thus, if sustainable development does require learning, then *learning goals* must be a fundamental part of it. Environmental, and other goals to be achieved *through* learning that experts with no contextual authority deem important, will not do by themselves. (p. 245, emphasis added)

In the context of undergraduate chemistry, this means that Learning Outcomes need to include outcomes relating to the learning of sustainability. It cannot be achieved through the latent curriculum and must be explicitly addressed. This will provide incentives for pro-environmental behaviour (Figure 1). Adequate time within the curriculum must be given to sustainable chemistry, but as explained above, this cannot properly be done by simply adding this on to the current content; it must be built-in (Table 1). An auditing process is also important so that incremental changes are not lost with staffing changes (Table 2).

The imperative to combat climate change means that universities must teach sustainability so that students carry the understanding into their working life. Many universities have made a commitment to sustainability in their planning documents and have begun implementation in some administrative units. Within chemistry, although some sustainability education currently takes place, this is not coordinated and depends on the motivation and awareness of the individual lecturers. An analysis of the mapping and interview results and literature suggests several strategies to improve the incorporation of sustainability within chemistry teaching:

- funding specifically for sustainability projects, either at the university or faculty level, so that more academics have research in sustainability, which is correlated with teaching it at the undergraduate level;
- associated prestige, so that sustainability research is not treated as the poor cousin of "real research"; seed funding from university or faculty can lead to much greater external grant success;
- modification of the undergraduate learning outcomes to include sustainability, so that there is time within the curriculum for coverage and lecturers do not feel that they are leaving out other important content;
- context-adapted resources for use by lecturers that will include sustainability in their teaching;
- an audit of the current practice throughout the discipline (and Faculty and University), to provide a baseline to measure any changes against.

The first three items on this list provide incentives for pro-environmental behaviour (and may also modify the perceived consequences); the fourth increases possibilities (Fietkau & Kessel, 1981). Environmental knowledge can be assumed, and attitudes and values are more difficult to modify, so these two of Fietkau and Kessel's factors seem the easiest targets to lead to change in pro-environmental behaviour. Implementation of these measures would increase sustainable chemistry education to at least Sterling's strong stage (Sterling, 2004), and would provide a model for other disciplines and Faculties to follow.

Acknowledgments

I would like to thank my colleagues for agreeing to participate in the interviews. I am grateful to Mandy Lupton, who encouraged me to persist with this challenging theme. I also thank Emma Rooksby, Rosalie Schultz and Janet Hope who provided thoughtful feedback at various stages of this project.

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