[O30] Towards sustainable teaching of biosciences: integrating sustainable approaches into undergraduate teaching in higher education

Alzena Wilmot, Kara Davies, Hazel Wright and **Dylan Gwynn-Jones**
Institute of Biological Sciences, The University of Wales Aberystwyth, Ceredigion SY23 3DA
azw@aber.ac.uk; kara2.Davies@uwe.ac.uk; hzw@aber.ac.uk; dyj@aber.ac.uk

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Abstract

In response to the report by the Higher Education Academy 'Sustainable Development in Higher Education, Current Practice and Future Developments' the Institute of Biological Sciences (IBS) at the University of Wales, Aberystwyth (UWA) proposed the implementation of sustainability into the curriculum and delivery of education across the Biological Science sector. In this preliminary investigation four case studies were undertaken. In the first, a survey revealed a high level of undergraduate support for the incorporation of sustainability into the curriculum. Year 1 and 2 of study were highlighted as the key target groups for sustainability education. A further three practical case studies addressed sustainability issues in organic waste management, laboratory classes and field trips. Factors limiting progress towards sustainability teaching of bioscience were identified and solutions are proposed.

Introduction

The concept of sustainability has become central to environmental debates around the world and has been taken up by all sectors including government, business and non governmental organizations. The 1987 Brundtland report first defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). This report set out the guiding principles for sustainable development as it is generally understood today (Dresner, 2004). In order to achieve a sustainable world and minimise environmental degradation, a transition in resource use and waste management must occur locally, nationally and globally. Reducing carbon dioxide and other greenhouse gas emissions is now a high priority as global climate change has been conclusively linked to human activity (IPCC, 2007).

The future challenge of sustainability is set to dominate research and education. Universities will seek to educate the next generation of practitioners in sustainable methods. In addition science and technology will look for ways to identify environmental impacts and quantify and improve our aptitude for sustainability. The potential of educational institutions to lead the way in promoting sustainable education and research is now being recognised. The challenge for higher education is to provide all students with an in-depth understanding of sustainability and environmental issues; creating a new generation of 'sustainability literate' graduates (Dawe,*et al*. 2005). As well as teaching sustainability by theory, there is the opportunity for universities to 'walk the talk' by

demonstrating sustainability through their practices. This will provide students with a platform to integrate sustainability into their own lives and future careers.

In response to the report by the Higher Education Academy 'Sustainable Development in Higher Education, Current Practice and Future Developments' (Dawe *et al*. 2005) the Institute of Biological Sciences (IBS) at the University of Wales, Aberystwyth (UWA) proposed the practical implementation of sustainability into the curriculum and delivery of education across the Biological Science sector. The preliminary investigation incorporates the following:

1. Student baseline survey on the demand for sustainable education and delivery within the Bioscience curriculum.

2. Practical laboratory based teaching – exploring ways to reducing the environmental impact.

3. Disposal of plant/soil material from the teaching glasshouses – minimizing landfill from plant based activities and projects and creating a resource.

4. Field studies – strategic planning of field trips to minimize environmental impact whilst maintaining or improving learning experience.

Methods

1. Baseline student survey: Undergraduate students in IBS were given a sustainability questionnaire in December 2006. Of 183 student participants in the questionnaire, 118, 40 and 25 were classified as being in years 1, 2 and 3, respectively. 77 (42%) provided information on gender; 36 and 41 were males and females respectively. Any analyses including gender as a factor related to the questionnaires only. The following questions were analysed in the current study:

a. Would you like to have more information available about sustainability in your degree course? Select one or more of the following statements: i) Integrated into all aspects of studying; ii) as a separate module; iii) included in relevant existing modules; iv) Online or written guidelines to sustainable living; v) I am not interested in learning more about sustainability.

b. How do you rate your awareness/understanding of the following issues? Rate your awareness/understanding from excellent (1) to (5) poor for the following issues: i) sustainability; ii) renewable energy; iii) climate change; iv) biodiversity; v) ecological footprint; vi) carbon footprint; vii) sustainable development; viii) environmental ix) sustainability; x) renewable resources; xi) recycling.

c. Where have you have gained knowledge of environmental issues? Rate the importance to your learning from important (1) to (5) unimportant for the following: i) family; ii) friends; iii) adverts; books; iv) television; v) newspapers; vi) environmental groups; vii) journals; viii) internet; ix) school; x)university; xi) employment.

d. What of the following would you be interested in getting involved with? Select one or more of the following activities: i) recycling on campus; ii) monitoring energy efficiency; iii) volunteer conservation work; calculating CO2 emissions; iv) visits to local environmental organizations.

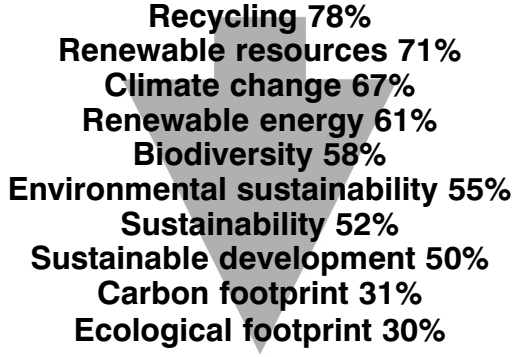

Figure 1: % of students rating their understanding/awareness of as 1-2 (above average to excellent)

2. Practical laboratory based teaching: structured interviews with fourteen academic and nine key technical staff at the Institute of Biological Sciences (IBS). Interviews were conducted from December 2006 to January 2007.

3. Disposal of organic material from the teaching glasshouses: the amount of soil/plant waste sent to landfill was calculated and various composting approaches were investigated as alternatives.

4. Field trip travel: for analyses of the environmental impacts of field courses carbon emissions were calculated for long haul (>3000 km) and short haul (0-3000 km) flights, car, bus/coaches. Calculations were based on official governmental figures (DEFRA, 2005).

Statistical Analysis

Kruskal-Wallis test for non-parametric data was used to determine year or gender differences in student perceptions pertaining to overall environmental/sustainability awareness. Willingness of students to become involved in sustainability activities was also analysed using a Kruskal-Wallis test. Spearman's Rank Correlation was used to examine the relationship between participant awareness/understanding and involvement in environmental activities.

Results

Undergraduate survey

92% of students requested more information about sustainability in their degree program. The majority of first and second year students, with 67% and 68% respectively, wanted to see sustainability integrated into relevant modules. However, the majority of third year students opted for online resources (56%).

Year of biological degree had no significant effect on student awareness of sustainability ($H = 2.59$, $D.F = 2$, $P = 0.274$). Separate analyses were conducted to examine the effect of gender on awareness of sustainability. Awareness of sustainability was not found to be significantly different between males and females ($H = 0.07$, $D.F = 1$, $P = 0.79$). Student understanding/awareness was found to be highest for recycling, renewable resources and climate change. Less than half of the students were confident with the issues of sustainable development, carbon and ecological footprinting (**Figure 1**). The role of the

FIRST	SECOND	THIRD
School 69%	University 85%	TV 62%
TV 65%	Newspapers	School 62%
Newspapers 60%	Internet 64%	Newspapers
Internet 60%	TV 61%	Internet 57%
Books 57%	Env. grps. 61%	University 52%
University 57%	Books 58%	Books 48%
Env. grps. 39%	Journals 58%	Adverts 43%
Journals 39%	School 58%	Journals 43%
Family 26%	Friends 48%	Family 33%
Friends 23%	Employment	Friends 19%
Adverts 36%	Family 27%	Env. grps. 19%
Employment 19%	Adverts 15%	Employment

Table 1: Ranked data according to year of study. % rating option as 1-2 (above average – important).

University in learning about environmental issues revealed interest in the mid range for students in year 1 and 3 and was the top priority in year 2 (**Table 1**).

Year of study had a significant effect on the willingness of the participant to become involved in sustainability activities, with year 3 being least likely to become involved ($H = 6.24$, $D.F = 2$, $P = 0.044$). However, there was not a significant effect of gender on willingness to become involved in sustainability issues ($H = 0.41$, $D.F = 1$, $P = 0.524$). Irrespective of year of degree, there was no significant correlation between participant awareness/understanding and involvement in environmental activities (year 1: $rs = 0.105$; $P = 0.203$; year 2: $rs = 0.134$; $P = 0.421$; $rs = 0.197$; $P = 0.355$).

Discussion

Student interest in sustainability is high, with 92% of the students surveyed indicating a desire to have more information available in their Bioscience degree programs. This level of enthusiasm for sustainability initiative is further supported by the student lobby universities to take on comprehensive environmental policy in with the ‘go green’ campaign (People and Planet, 2007).

From the data it was clear that certain issues of sustainability were not yet being covered as effectively as topics such as recycling, renewable resources or climate change (**Figure 1**). A program targeted at sustainable development and carbon calculating could redress this balance and move students towards ‘sustainability literacy’ (Dawe, *et al*. 2005). Students gain knowledge of sustainability and environmental issues through a range of media. The relative importance that students give to the different sources of information changes between the years. Year 2 students were shown to be more willing to become involved in environmental activities than year 3 and, in addition, year 2 tended to rank university education most highly as a means of learning about sustainability (**Table 1**). It is proposed that year 3 students would be under greater academic pressures from their degree; this may reflect their preference for resources online rather than having them added to the existing curriculum. The aim of the undergraduate student survey was to find target groups for sustainability educational programs. It could therefore be tentatively suggested that first and second year students could benefit most from having additional sustainability teaching incorporated into the degree program.

Case Study 1: *Sustainability principles applied to undergraduate practical classes*

Teaching students to be efficient and minimize waste in their practical training is essential. Consultation with teaching and technical staff led to the following areas being highlighted:

- Use of non-disposable plastics/glassware
- Wash and re-use wherever possible
- Turn off non-essential equipment if not in use
- Choose energy efficient equipment when replacing
- Source local materials
- Recovery of solvents (re-distil)
- Making solutions and buffers in-house in bulk
- Preferential use of least toxic materials
- Signage to reduce waste through confusion
- Plastic, paper, glass and organic recycling in lab
- Engage students in tidying and recycling activities

An explanation of sustainability practices can often be incorporated into standard health and safety guidelines and training.

Case Study 2: From landfill to compost for UWA staff

The department is looking at alternative ways of "disposing" of the plant/soil material. The procedure for safe disposal is to autoclave all experimental material at 126ºC for 3 hours. All material goes into a skip along with all other waste for landfill. By on-site recycling of organic and soil waste, estimated at half the total waste, there is a potential saving of 50% on skip hire each year.

The autoclaved material needs to be left for a period of several months to be repopulated by micro-organisms and to re-aerate (Zipperlen, 2006). The plant/soil material is piled up in bays constructed from recycled palettes. By using a cool composting method only minimal effort is needed, the work is done by micro-organisms, worms and fungi. Staff at the University have expressed interest in collecting and using the compost on their domestic gardens.

Case Studies 1 and **2**

Tackling a change of teaching methods in order to facilitate a move towards sustainable teaching of biosciences then raises many other issues. Information about sustainability does not necessarily lead to behavioural change (Collins, *et al*. 2003). An integrated approach is needed that tackles the reasons for unsustainable behaviour (Velazques *et al*. 2005). Some of the problems that teachers and technicians have cited as limiting their ability to work sustainably are summarised in **Table 2**.

It is important to target behaviour and awareness of waste and resource use at an early stage of a scientist's career. Scientific laboratories are complex environments and consume high quantities of resources. Energy requirements can be ten times higher per m2 than in an office space (James *et al*. 2007). The use of disposable plastics and experimental kits leads to high wastage and it is unfeasible to reuse much of this due to contamination with potentially dangerous substances. Solutions and reagents are often wasted due to inappropriate labelling or lack of communication. Re-use and recycling of chemical wastes from laboratories has been implemented in certain institutions along with an awareness campaign and suitable labelling (Serra *et al*. 2003). Many of the waste streams are inbuilt into the laboratory environment but there are others that can be improved through behavioural changes and small alterations in infrastructure (**Case Study 1 and 2**). Financial restraints can be a catalyst in a shift towards sustainability through the implementation of increased efficiency, resource minimization and waste reduction measures throughout the University (Comm and Mathaisel, 2005).

Field trips are often the most rewarding and inspiring part of learning. However, the impact of field trips does need to be considered in terms of sustainability. The human impact of students and researchers on fragile ecosystems can be minimized by limiting access to particular areas and carefully choosing 'sacrifice areas' for the highest level of activity (Tejedo *et al*. 2005). Environmental impacts of travel to study sites should be considered in terms of greenhouse gas emissions. According to the latest IPCC report continued

LIMITATIONS	POSSIBLE SOLUTIONS
Time - implementing new structures and practices difficult when added to a full workload. *Resources* - financial constraints often limit new developments. *Tradition* - there can be strong resistance to changing teaching practices. *Information* - there is a lack of easy to use guidelines for sustainable practice *Motivation* - sustainability issues may not seem relevant to the individual, or they may feel that it is not their role to be teaching it. *Curriculum* - there are particular constraints in teaching biosciences, students need to be taught methods relevant to future employment.	• Online resources • Best practice guidelines • "Green Laboratories Manual" • Review of staff workloads • Evaluation of the curriculum • Secure funding • Sustainability training for staff • Support from management • Sustainability group • Permanent member of staff to facilitate the transition to sustainable teaching.

Table 2: Factors limiting progress towards sustainability teaching of bioscience at the Institute of Biological Science at UWA

greenhouse gas emissions at or above current rates would induce many changes to global climate systems over the next century (IPCC, 2007). The amount of greenhouse gasses that we are putting into the atmosphere need to be 'capped' at a safe level to prevent further temperature increases.

Case Study 3 shows the travel carbon footprint of two field trips with equivalent content held at two different locations. The first, located in Indonesia and the second will be held in Pembrokeshire, south Wales. The second option is 200 times more efficient in terms of carbon dioxide emissions than travelling to Indonesia. Changing the location of the field trip to Pembrokeshire saved time, cost and considerably reduced environmental impact. In addition tutors on this course felt that an equivalent learning experience could be gained locally, further student feedback will be needed to assess impact on student satisfaction.

Following on from these preliminary case studies, several areas that need further investigation have been highlighted:

- Identifying best practices in terms of sustainability and student learning outcomes.
- A sustainability audit of the content, design and delivery of a range of modules.
- The relationship between sustainability and different modes of delivery in terms of their impact on student learning experiences.
- Engaging with students to determine the impact of the project in terms of content and delivery as assessed above.
- Collating information on suppliers assessing their environmental principles and consideration of sustainability in product design and operations.
- The development of easy to follow guidelines for academics, technicians and laboratory managers.

Developing more sustainable teaching will provide significant benefits in terms of increasing the efficiency of provision (time, cost and environmental benefits). This will also

Case Study 3: *Environmental Management Field trip goes local to reduce carbon footprint*

2005 Indonesia and back	2007 Pembrokeshire and back
Total distance travelled: **16,344** miles	Total distance travelled: **168** miles
Aberystwyth – Manchester by **car** 280 miles x 0.29 kg CO_2 = 81.2kg CO_2 Manchester – Jakarta by **long haul flight** 14,658 x 0.18 kg CO_2 = 2638.44 kg CO_2 Jakarta - Makassar by **short haul flight** 1406 x 0.24 kg CO_2 = 337.44 kg CO_2	Aberystwyth to Dale Fort, Pembrokeshire by **bus** 168 miles x 0.09 kg CO_2 = 15.12 kg CO_2
CO_2 emissions *per person*: **3057.08** kg CO_2	CO_2 emissions *per person*: : **15.12** kg CO_2

Travel assumptions (DEFRA, 2005)

have direct and indirect positive benefits to departments and their staff by providing a structured, user friendly methodology in which to assess opportunities and implement sustainable practices.

Conclusion

To move towards sustainable teaching in bioscience, strategies that involve students and university staff at all levels are required. There is potential for the department to lead by example by implementing a strong environmental policy that guides the University towards a low impact learning environment. From the student perspective there is support for a transition towards sustainability. The first two years of study are potential target groups for sustainability education, thus increasing the level of 'sustainability literacy'. A move towards sustainability will require some behavioural adjustments and alterations in infrastructure. Education, training and support for teaching and technical staff is needed in order to implement any change. With escalating energy costs, and forthcoming regulatory requirements, it is essential that higher education rises to meet these challenges.

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