Towards the Sustainable Teaching of Bioscience

Project Coordinator: Dr Dylan Gwynn Jones
Research Assistant: Alzena Wilmot

Institute of Biological Sciences
University of Wales Aberystwyth
Ceredigion SY23 3DA

Email: dyj@aber.ac.uk
Website: www.aber.ac.uk/ensus

Prifysgol Cymru Aberystwyth
1872 The University of Wales

The Higher Education Academy
CENTRE FOR bioscience

Abstract

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 Aberystwyth University (AU) proposed the practical implementation of sustainability into the curriculum and delivery of education across the Biological Science sector. The aim of this research was to investigate environmental performance, sustainability and potential improvements to current teaching practices in the biosciences. Using a series of case studies and wider research we considered lectures, handouts, extra reading, tutorials, practicals and field courses. We also discuss whether blended learning may represent a possible approach in terms of fulfilling student expectations, whilst introducing sustainability into the curriculum and operations.

Research revealed that improving the environmental performance of undergraduate teaching was complex and required long term and progressive implementation. The energy use for lectures and practical classes was relatively low compared to other University activities. However, significant improvements could be introduced through behavioural changes and consideration of equipment standby functions in laboratories. Reuse and recycling in the laboratory environment could only be partially achieved due to possible conflicts with health and safety and the cost balance in terms of time taken to wash reusable vessels. At the same time, a case study also revealed the potential for composting (in place of landfill) for some waste streams in Bioscience Departments.

Large class and laboratory sizes were sustainable in terms of resource use but only as part of a blended learning environment with support sessions, workshops and formative learning. The issue of student handouts and online learning resources were considered. In terms of carbon emissions it was found that double-sided printing of concise handouts on recycled paper represented the most effective compromise in terms of student satisfaction and environmental performance.

Finally, we investigated foreign travel and the significant learning miles involved with field course activities. We proposed that carbon footprints should be quantified and minimised (via appropriate travel) and Departments should at least consider educationally equivalent field courses in the UK.

Acknowledgements:
We thank the Centre for Bioscience for supporting AW to conduct these case studies. We also would like to thank all the lecturers and technicians at Aberystwyth University who participated. In particular, we would like to thank Dr Hazel Wright, Dr Aileen Smith, Dr. Andrew Walker, Dr. Jo Porter and Dr. Jo Hamilton for helpful input into the project. Finally, we thank staff from the 15 anonymous Universities for their contributions to the field course travel study.

INDEX

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). 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 linked to human activity (IPCC 2007).

The potential for educational institutions to lead the way in promoting sustainable education and research is recognised. The challenge for higher education is to provide all students with an understanding of sustainability and environmental issues; creating a new generation of 'sustainability literate' graduates. As well as teaching sustainability in 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.

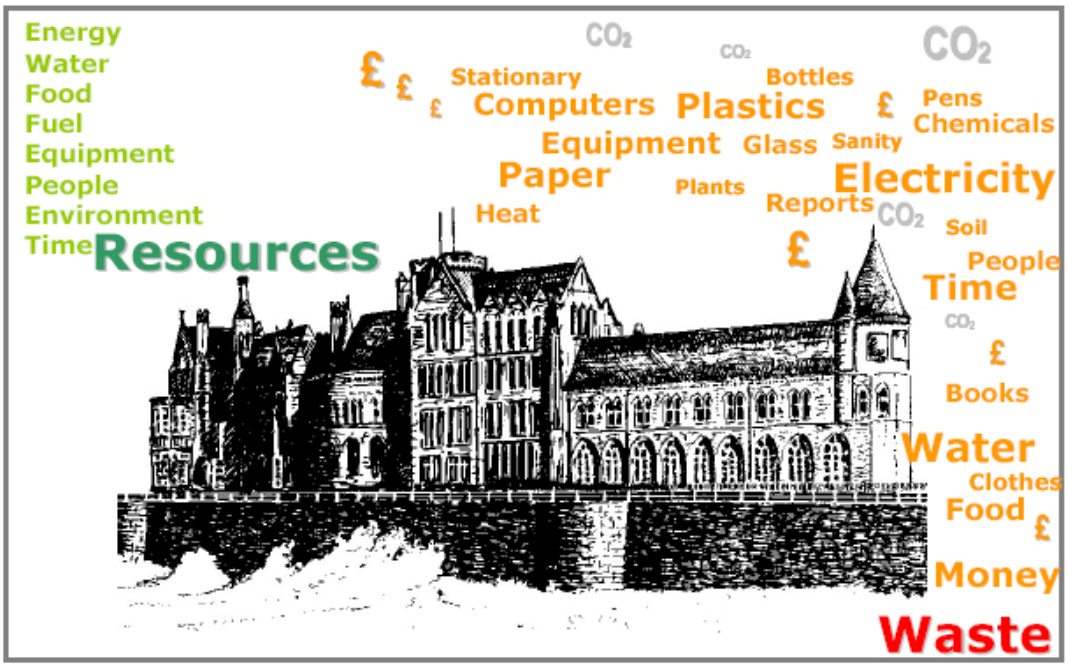

Fig. 1: The 'leaky ship' scenario illustrates resources (green) that are potentially wasted (orange) through lack of planning and simple conservation methods.

A significant proportion of universities are now working towards improving their environmental performance (People and Planet 2007). Such large organizations can potentially have a significant environmental impact. The 'leaky ship' example (see Fig. 1) takes the resources that are brought into the institution and gives examples of waste products that are generated. To reduce wastage, or plug the leaks, three main concepts need to be implemented.

1) The quantity of resources being used needs to be **reduced**,
2) These resources should be maximized once in the system and **reused**,
3) When it is no longer a resource then it should be **recycled**.

In assessing the various possibilities to be more sustainable in undergraduate teaching we considered lectures (for example, PowerPoint), handouts, extra reading, tutorials, practical and field courses. We considered whether blended learning represents a possible approach in terms of fulfilling learning outcomes whilst introducing sustainability into the curriculum and operations. Throughout, we have made the *realistic* assumption that ultimately practicing sustainability is not the highest priority for Departments in terms of delivering teaching in the biosciences.

Introduction to Aberystwyth University

Aberystwyth University is situated on the isolated but picturesque coast of Mid Wales. It has over 7,000 registered students, including over 1,100 postgraduates across eighteen academic departments. The Institute of Biological Sciences (IBS) is based in the Edward Llwyd and Cledwyn buildings on the main University campus overlooking Aberystwyth and Cardigan Bay. There are 28 core-funded academic staff and 8 Contract Research staff supported by 37 technicians and five admin/secretarial staff. The University has made substantial investment in the Institute in recent years, allowing it to remain competitive both nationally and internationally. The majority of the teaching and research laboratories within IBS have recently been modernised and re-furbished.

The University is "...committed to developing our Learning and Teaching Strategy to develop a strategy for embedding Education for Sustainable Development and Global Citizenship (ESDGC) across the curriculum and for training and supporting staff to address and deliver the requirements of ESDGC." (For further information see: Aberystwyth University 2006; Aberystwyth University 2007a).

MATERIALS AND METHODS

Case Study 1: *Students and Sustainability*

1.1 Baseline undergraduate student survey (from Wilmot *et al.* 2007)**.** Undergraduate students in IBS were offered 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 these 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 issues ix) sustainability; x) renewable resources; xi) recycling.

c. *Where have you 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; iv) television; v) newspapers; vi) environmental groups; vii) journals; viii) internet; ix) school; x)university; xi) employment; xii) books.

d. *Which 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; iv) visits to local environmental organizations; v) calculating CO_2 emissions.

Statistical Analysis: A 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.

1.2 Practical class exercise in incorporating sustainability into undergraduate teaching

Integrating sustainability into relevant modules was trialled on year 3 students (in collaboration with Dr J Porter, AU). Every year bioscience students take part in a seminar to discuss the pros and cons of the science of genetic modification. In 2007 17 students participating in the debate were asked to incorporate sustainability into their arguments.

Case Study 2: *Greening Lectures*

2.1 Lecture room equipment and lighting were measured using a hand held plug in energy meter (Maplin Model 2000MU, China). Where this was not possible energy ratings were taken from manufacturer literature or websites.

2.2 Assessment of the energy used to read a 10 page document comparing electronic viewing to printing the document. This was calculated according to the following assumptions: Computer 100 W and Monitor 73 W (for 20 minutes to read 10 page document); Printer 223 W (for 1 minute to print 10 page document); Energy to produce 1 sheet of standard printing paper 17 W; 1 sheet recycled paper 12 W (from www.eu-energystar.org)

2.3 Photocopying energy use using a standard photocopier (Konica model 7135) copying duplex was measured using a hand held plug in energy meter (Maplin Model 2000MU, China).

2.4 Student opinion on handouts following a lecture on Sustainability and Human Behaviour by Ms. Alzena Wilmot. Year 3 students were asked to discuss the sustainability of using online resources instead of printed handouts in lectures.

Case Study 3: *Making sustainable use of teaching laboratories*

3.1 Laboratory energy audit: data were collected in collaboration with the Dr H. Wright (AU). Equipment was measured using hand held plug in energy meters (Maplin Model 2000MU, China).

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

Case Study 4: *Field Work footprints*

4.1 UK field course study

Universities offering the undergraduate degree C100 Biology were contacted by phone and asked for a) destination of field trip and, b) method of travel to field site.

Fifteen Universities provided details of the field trips offered to undergraduate biology students. Analyses of the environmental impacts of field courses carbon emissions were derived from official governmental figures (DEFRA, 2005).

4.2 Local vs. abroad field courses:
Two educationally equivalent field courses (30 credits MSc level, similar learning outcomes) to Indonesia and Pembroke were compared in terms of carbon emissions.

4.3 Travelling to field sites in a sustainable way
In September 2007, 20 third year AU students were asked to find their own way to a field course location abroad (Initiated Dr. Gareth Griffith AU). Students were asked to travel from their home towns in the UK to the Burren in the West of Ireland using the least amount of carbon per kilometre.

Case Study 5: *Going local – a focus on purchasing*
5.1 List of purchases for teaching in biosciences was provided by Institute of Biological Sciences Procurement Department. Each supplier was researched online or contacted by phone for location of main depot. Number of orders from each supplier was calculated using the online map service maps.google.co.uk. Analyses of the environmental impacts of purchasing were based on official governmental figures (DEFRA, 2005).

Case Study 6: *Composting waste*
6.1 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.

RESULTS
Case Study 1: *Students and Sustainability (1.1)*
92% of students showed an interest in having more information about sustainability in their degree programme. 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%).

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

FIRST	SECOND	THIRD
School 69%	University 85%	TV 62%
TV 65%	Newspap. 64%	School 62%
Newspap. 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%	Employ 36%	Friends 19%
Adverts 36%	Family 27%	Env. grps. 19%
Employ 19%	Adverts 15%	Employ 19%

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 were found to be highest for recycling, renewable resources and climate change (Recycling 78%; Renewable resources 71%: Climate Change 67%; Renewable energy 55%; Sustainability 52%; Sustainable development 50%; Carbon footprint 31%; Ecological footprint 30%). Less than half of the students were confident with the issues of sustainable development, carbon and ecological footprinting. The role of the 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.

Year 3 students were the 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).

1.2 Practical exercise in incorporating sustainability into undergraduate teaching

In 2007 students 17 participating in class Genetic Modification (GM) debate were asked to incorporate sustainability into their arguments. Feedback from the seminar was positive with 14 of the 17 students saying that it increased their awareness of sustainability. This was further broken down into particular issues previously identified as important to increasing student sustainability literacy.

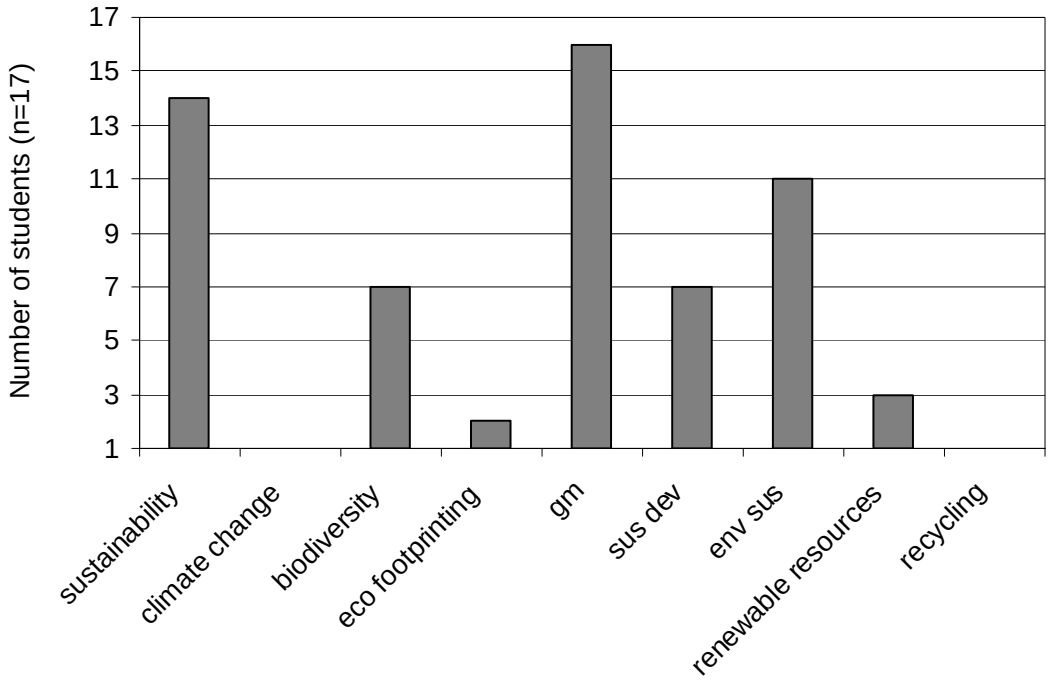

Fig. 2: Number of students (n=17) who rated their knowledge as increased during the seminar in the following categories: sustainability, climate change, biodiversity, eco footprinting, genetic modification, environmental sustainability, renewable resources and recycling.

All but one student participated in the feedback from the seminar (see Fig. 2). Of those who participated, all increased their knowledge of GM. 14 also felt that their

awareness of sustainability had increased and 11 felt that their awareness of environmental sustainability was improved following the debate. Biodiversity, eco footprinting, sustainable development and renewable resources were also cited by some students as important. None of the students felt that the debate increased their awareness of climate change. Students cited the following as the most important part of the seminar that increased their knowledge of sustainability: discussion; debate; personal research; looking at the long-term effects of GM; seeing different perspectives.

Incorporating aspects of sustainability into debate and discussion is one way of increasing student awareness of global environmental issues. There are many resources available to teachers wishing to integrate sustainability into their curriculum. Some useful resources can be found in the *useful links* section (page 21).

Case study 2: *Greening lectures*

There has been a general shift away from the traditional chalk board teaching with students writing notes. PowerPoint now dominates as the provider of lecture material. At first glance these modern efficiencies might appear as improvements. However, there are misconceptions that many modern approaches contribute to more efficient and possibly sustainable teaching. For example, basing lectures on PowerPoint might be paperless and effective but benefits and pitfalls exist in the delivery of good lecture material (Jones 2003).

2.1 Lecture room equipment and lighting

Jones (2003) comprehensively discussed the flexibility of PowerPoint and its "use and misuse". The assumption was made here in the current study that the majority of lecturers would employ PowerPoint for presentations. However, we are not suggesting that all lectures should be PowerPoint driven.

There is a degree of energy waste in lecture theatre if lights, computer and overhead projectors are left on when not in use. We compared energy use in various lecture theatres and estimated that a 120 m^2 lecture theatre would consume approximately 1.88 Kw of energy when in use and not a great deal less with equipment on standby and the lights left on at 1.55 Kw (Table 2). Lecturers often dim lights during lectures and switch them full on when departing. A dimmed light lecture used 0.96 Kw representing the lowest energy use. Caution should be exercised in switching the audio-visual equipment off between lectures as this could present problems for subsequent lecturers. Some types of projectors also experience short lamp lives if regularly switched on an off.

Overall, the amount of power use to deliver lecture is relatively small, particularly compared to other resources used (heating, infra-structure etc).

2.2 Assessment of the energy used to read a 10 page document

Jones (2003) provided an excellent framework for maximising what students gained from the PowerPoint experience. He highlighted that students often did not write if presentations were too diverse and that there was always a demand for handouts. The question of who took the burden of paying for printing handouts was also discussed. Jones (2003) suggested that web based handouts could be condensed and only include essential material to reduce printing.

As a practical exercise the most efficient method of reading a ten page document was assessed (Fig 3). A direct comparison was made between the energy used to produce the paper and for the printer to print on it. Paper printed double sided or single sided on both standard and recycled paper was estimated. This was compared to reading the document directly online (electronic viewing). Electronic viewing of the document used two thirds less energy than producing the paper and printing.

However, reading on line does have possible health and safety implications also students also often comment that they find it hard to read materials on line.

Table 2: Examples of energy use in three different lecture theatres in the Institute of Biological Sciences, AU.

Lecture Theatre size	Equipment	How many?	Energy (W)	Total (W)
54 m^2	Lighting: fluorescent tube (1200mm)	14	36	504
	Projector Projector (Standby mode)	1	150 53	150 53
	PC Tower PC Tower (Standby mode)	1	100 57	100 57
	 PC Monitor PC Monitor - non LCD (Standby mode)	1	73 3	73 3
	TOTAL			**940**
120 m^2	Lighting: fluorescent tube (600mm)	80	18	1440
	Projector Projector (Standby mode)	1	150 53	150 53
	PC Tower PC Tower (Standby mode)	1	100 57	100 57
	 PC Monitor PC Monitor - non LCD (Standby mode)	1	73 3	73 3
	TOTAL			**1876**
250 m^2	Lighting: fluorescent tube (1200mm)	31	36	1116
	Safety lights	4	8	36
	Projector Projector (Standby mode)	1	150 53	150 53
	PC Tower PC Tower (Standby mode)	1	100 57	100 57
	PC Monitor PC Monitor - non LCD (Standby mode)	1	73 3	73 3
	TOTAL			**1588**

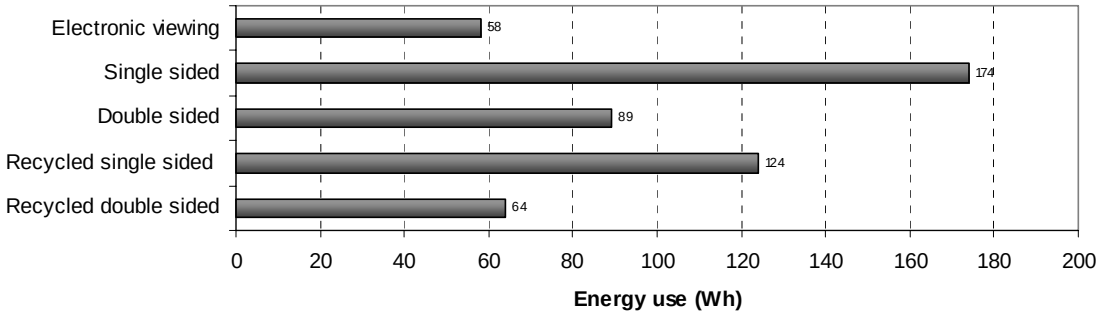

Fig. 3: Energy used to "read" a 10 page document.

Printing double sided (duplex) and printing duplex on recycled paper reduces the energy cost. Although not mentioned in this table it is possible to save resources and energy cost by using waste paper that has only been printed on one side.

If the paper is going to be reread and referenced more than three times then it becomes more efficient to print the document (assuming the PC and monitor are

turned off whilst it is read). If only a small part of the article is of interest then there is little point in printing the whole document.

2.3 Photocopying handouts

As many handouts are photocopied we also estimated the energy consumed by photocopying a sheet of A4 paper using a standard photocopier. This was done duplex and took 20 watts per sheet of double sided photocopying paper (including paper production). In energy terms this was significantly higher than printing and electronic viewing.

2.4 Student opinion on handouts

Following a lecture on Sustainability and Human Behaviour delivered by Ms. Alzena Wilmot (AU) for the third year Animal Behaviour module, students were asked to discuss the sustainability of using online resources instead of printed handouts in lectures. The following comments were made:

- "Blackboard is useful if the lecturer puts the material there but not all of them do"
- Online resources are "not more sustainable because then I just print the copies myself, and then we have to pay for printing."
- "Why do none of the university printers print double-sided? This would halve the amount of paper printed."
- "University printers waste a page by printing a page with your name on. Why not include an automatic header on printouts instead, perhaps?"

These comments reflect some key issues relating to using online resources (Jones 2003). Most students use the resources if available but the use of Blackboard by lecturers is uneven across the modules within the same degree program. An argument in favour of placing study material online is that it saves paper, but students in this discussion felt that it just transferred the responsibility and cost of printing to them. Thus it would not have any actual benefit in terms of paper saving for handouts. The students also came up with some very practical suggestions that could easily be implemented in institutions such as setting printers to duplex as default and getting rid of the extra sheet dividing work. These changes could have a substantial cumulative saving effect. Since July 2007 all printers now print duplex as Aberystwyth University in response to a general review on printing and energy use (Aberystwyth University 2007b).

Case Study 3: *Making sustainable use of teaching laboratories*

Scientific laboratories are complex environments and consume high quantities of resources. Because of their specialist nature, teaching equipment and consumables are often sourced from all over the world. Laboratory energy requirements can be ten times higher per m^2 than in equivalent office space (James *et al*. 2007). The use of disposable plastics and experimental kits leads to high wastage and it is not feasible to reuse materials due to the risk of contamination. Solutions and reagents are wasted unless carefully labelled and stored appropriately. 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.

3.1 Energy audit

Within biosciences it is difficult incorporate general changes to laboratory practices due to prescribed protocols and time constraints. However, it is possible to target energy wastage when equipment is left on (standby or other) when the laboratory is not in use (e.g. lunchtime, overnight). Below are a few typical pieces of equipment and their energy use when not in use or on standby mode.

Table 3. Examples of overnight energy wastage in the laboratory through an inappropriate use of the standby facility

[1]All values for equipment energy use taken in collaboration with Dr. H Wright, AU

[2]Overnight figures are based on a 12 hour period.

[3]CO_2 conversion is based upon official UK data from the Department of Environment, Food and Rural Affairs, revised March 2001.

[4]Yearly values assume a daily value of 12 hours energy wastage for 365 days of the year.

Equipment[1]	**Kw overnight**[2]	**Kw Per year**[4]	**kg CO_2 overnight**[3]	**kg CO_2 per year**[3,4]
Small desktop centrifuge	0.054	19.71	0.023	8.40
Electronic Balance	0.056	20.44	0.024	8.76
Bench Autoclave	0.552	201.48	0.237	86.51
PCR Machine	0.420	153.30	0.180	65.70
pH Meter	0.012	4.38	0.005	1.83

When attempting to communicate information on energy wastage it is important to convert certain abstract terms into numbers that have more practical meaning. For example, in Table 3 (above) a small desktop centrifuge (an item that almost all bioscience students or researchers are likely to encounter frequently) uses 19.71Kw if left on every night for a year. According to DEFRA (2005) guidelines leaving a small bench autoclave on overnight, for a year, emits the same amount of CO_2 as driving about 300 miles in an average car. When this is scaled up to an entire laboratory this study highlights that energy wastage from leaving equipment on overnight can be significant.

3.2 Student practical laboratory classes and structured interviews

Practicals are highly valuable in terms of student learning experience. Brown *et al*. (2005) surveyed practical experience in bioscience students from four Universities and found that graduates considered themselves poorly prepared for their career in terms of practical skills. The graduates had also been disappointed by the level of practicals experienced during their degrees. The same survey highlighted that practical experience was the most valued and transferable in terms of graduate careers.

In terms of sustainability a practical class uses more resources (energy, water, staff time) than a lecture. The cost and environmental impact of laboratory consumables and preparation time demand that resources are used sensibly. Hughes (2004) suggested that in order to reduce practical time constraints alternative parallel non practical sessions could be offered. This could involve a literature reviews with formative learning. From a sustainability perspective this approach could reduce the environment costs. He further argued that fewer biology students enter vocations using laboratory skills in the biosciences and that resources could be targeted towards individuals that use them in the future. Focussing resources at a select group of students is controversial and would reduce contact time and resource investment. New audio-visual equipment can also help reduce environmental impact by videoing activities. For example, it is possible to make a single video of a dissection rather than large class student dissections.

There is potential within practicals to reduce waste. It is important to raise student awareness of waste in a laboratory setting. If all resources are presented to students and cleared away by technicians at the end of the practical they will spare little thought to the resources used. Teaching students to be efficient and minimize waste in their practical training represents good laboratory practice and can be beneficial in terms of environmental, economic and time efficiency.

Through interviews with staff and technicians potential practical methods of saving resources were identified (Table 4). In the second column of the table barriers to implementing these changes are cited.

Table 4: Potentials and barriers to more sustainable practice in leaching laboratories as identified by teaching and technical staff.

Potential	**Barriers**
• Use of non-disposable plastics/glassware	• Initial cost, additional cleaning time
• Wash and re-use wherever possible	• Concern over cleanliness
• Turn off non-essential equipment if not in use	• Lack of organization between users
• Choose energy efficient equipment when replacing	• Initial cost
• Source local materials	• Scientific consumables / equipment not available locally
• Recovery of solvents (re-distil)	• Time, resources
• Making solutions and buffers in-house in bulk	• Time, lack of storage space
• Preferential use of least toxic materials	• Research needed
• Signage to reduce waste through confusion	• Significant reorganization required
• Plastic, paper, glass and organic recycling in laboratories	• Concerns over contamination
• Engage students in tidying and recycling activities	• Could create more rather than less work for technicians

Many of these suggestions should be implemented in terms of best practice such as correct signage and turning off equipment when not in use. Others require an adjustment in priorities. These could be incorporated into health and safety training.

Case study 4: *Field work footprints*

4.1 UK Field course study

Field trips are often the most rewarding and inspiring part of learning. There are also significant benefits of immersing students into a new environment, both in the UK or abroad. However, the impact of field trips does need to be considered in terms of sustainability. For those Universities situated near useable field sites (as is AU), there is the opportunity to locate field trips in the area. However, not all Universities are close to suitable sites. Appropriate field locations are not the only factor, field course locations may be selected on the basis of recruitment potential rather than the biology studied. We investigated field courses offered in all Biology Departments in the UK and calculated the distances completed.

All Universities contacted sent their BSc Biology students on at least one field trip during their undergraduate degree. The fifteen Universities participating in the study put forward a total of 43 field trips planned for 2008 (Fig 4). Of these courses 60 % would be to sites within the UK and with one notable exception all these trips were by coach, minibus or train. There was one field trip that would fly students within the UK if costs were more favourable. Overseas trips made up 40% of the total field trips. Just four of these journeys were completed using a combination of ferry and coach or train. 13 trips involved travelling significant distances across the globe. As can be seen from Figure 4, although travel by air represents just 35% of total trips, it produces vastly more CO_2 emissions than any other mode of travel.

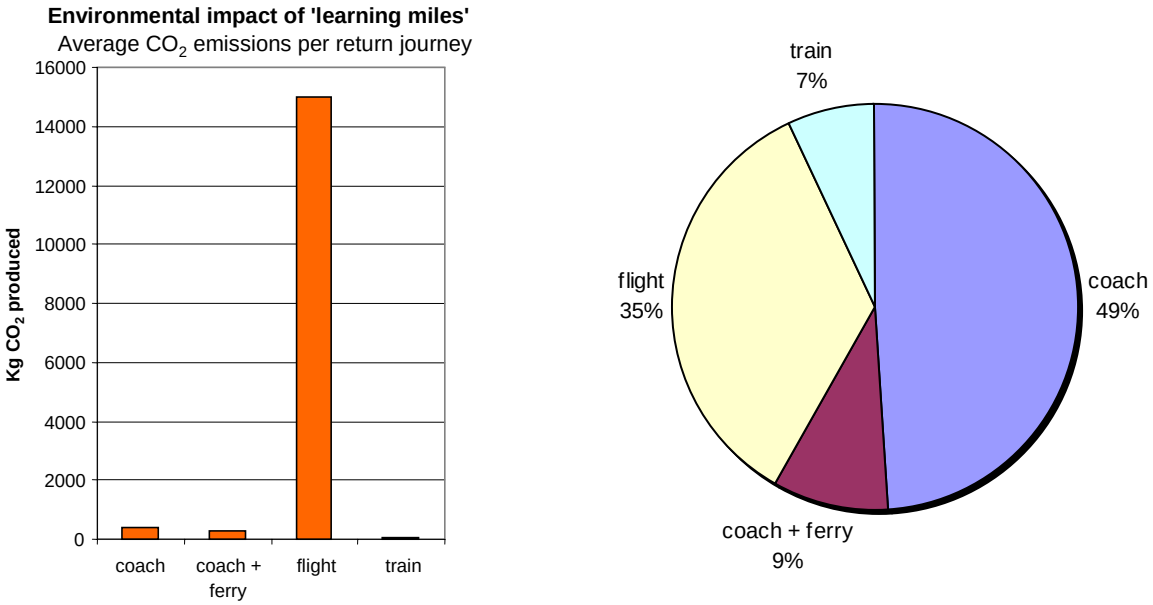

Fig. 4: 15 UK universities have planned a total of 43 field trips for 2008 for their BSc in Biological Sciences students. The pie chart show the percentage of journeys made by coach, coach and ferry, air and by train. Cumulative carbon emissions from all the planed trips are shown in the graph on the left.

In this context we can identify with the term learning miles, which in this case represent distances travelled to undertake field work. These learning miles represent a significant contribution to greenhouse gases and teachers should consider distances to field sites and modes of transport. Students are often expected to fund and find their own ways to field locations. Unfortunately the cheapest routes, such as budget flights, may be the least sustainable in terms of carbon emissions. However, as certain examples have shown, it was possible to travel by ferry and coach or train to most European sites from UK Universities. Environmental as well as financial cost should be considered when deciding on method of travel to field sites.

4.2 Local *vs.* abroad field courses: Table 5 above shows the travel carbon footprint of two field trips from AU with equivalent content held at two different locations (local vs. abroad).

Table 5: Environmental Management Field trip goes local to reduce carbon footprint. Travel assumptions (from DEFRA, 2005)

2005/6 Indonesia and back	**2006/7 Pembrokeshire and back**
Total distance travelled: **16,344** 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 CO_2 emissions *per person*: **3057.08** kg CO_2	Total distance travelled: **168** miles 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*: : **15.12** kg CO_2

In 2005/2006 the Environmental Management field course was conducted in Indonesia but in 2006/2007 this was replaced by an 'educationally equivalent field course in Wales (see Table 5). This made the field course over 200 times more efficient in terms of carbon dioxide emissions. Changing the location of the field course saved time, cost and considerably reduced environmental impact. However, the scope for marketing the course was reduced and the experiential dimension may have been reduced. Feedback from both field courses were positive (2005/6 and 2006/7) but they could not be directly compared as they were experienced by different students.

4.3 Travelling to field sites in the most sustainable way

In September 2007, 20 third year AU students were asked to find their own way to a field course location in the Burren, Ireland using the most sustainable travel (initiated Dr. Gareth Griffith AU). This exercise encouraged the students to consider the environmental impacts of their travel and made them aware of carbon emission calculations. 15 students achieved journeys of less than 0.15 kg CO_2 per km using overland and sea public transport. However, five students incorporated air travel and used more than for times the carbon for their journeys.

Case study 5: *Going local - a focus on purchasing (5.1)*

Implementing a green purchasing policy is not as simple as writing and publishing a list of best practice. Research is needed to discover where the problems lie, to find the environmentally sound producers and products and to locate local producers. Potential for alternative experimental procedures to minimize the use of non-toxic products are required and further research is needed on this topic. This is further complicated when considering purchasing for bioscience teaching and research. It is important to keep up to date with current practices and to train young scientists in the most up to date techniques.

The procurement for one year by the Institute of Biological Sciences (IBS) for the purposes of teaching was analyzed (2005/6, see Fig. 5). Distances from supplier to the university were calculated as were number of trips to deliver orders. This diagram is misleading to some extent as many of the suppliers had depots in the UK but the products may have been shipped or air freighted from overseas. It does, however, illustrate to some extent the purchasing habits.

Analysis revealed that 95% of the products were purchased from the UK whilst only 11% of suppliers were based in Wales and just 5% of orders were made to companies in Wales (inset Fig. 6). There is clearly a potential to increase purchasing within the local area although this depends on the availability of products. Aberystwyth does face difficulties in finding local suppliers due to its geographical location and lack of suppliers. Departments situated near to large industrial centres will have greater access to materials locally although the supplies themselves may have been manufactured outside the UK.

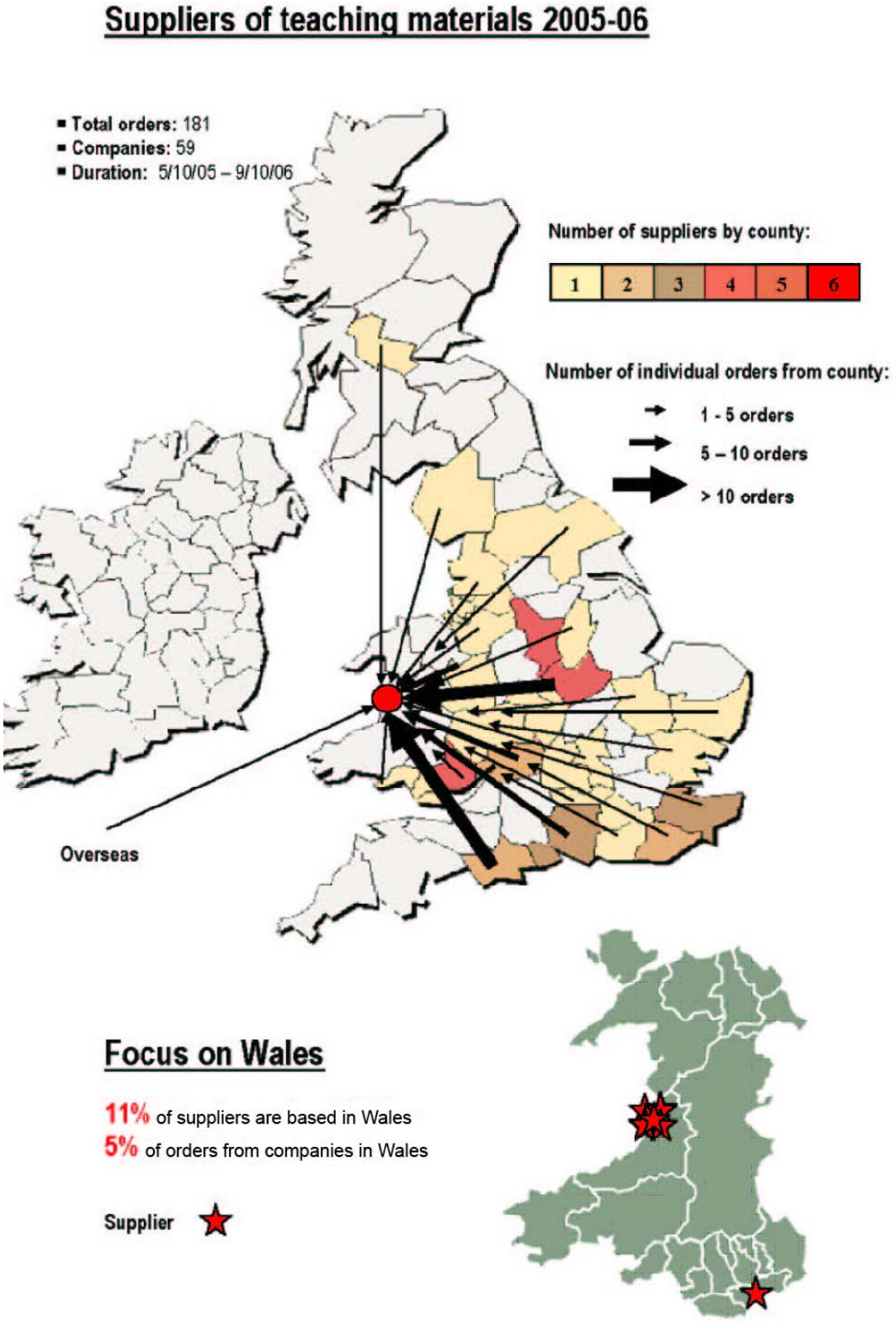

Fig. 5: Purchasing of teaching materials 2005 – 06. Number of suppliers per region and number of trips to deliver goods to IBS, AU. Inset below number of suppliers in Wales from who deliver goods to IBS, AU.

Case study 6: Composting waste - *using composting to deal with organic waste*

6.1 Disposal of organic material from the teaching glasshouses

Composting diverts waste from landfill and the reduction of water and soil pollution produced by the decomposition of organic material in the anaerobic conditions of a dump site. Currently the teaching glasshouses at the University produce plants for research and undergraduate practicals. Approximately 1000 Kg of waste is produced each month. Per volume the waste generated is at least 50% organic material and a further 25% is biodegradable (paper pots, card etc). Much of the remaining material including plastic pots could be recycled.

Waste product	Can it be composted?
Peat compost	**Yes**
Plant material	**Yes**
Autoclaved plant material	**Yes** (if plastics separated first)
Plastic containers of various volumes	**No** (could be recycled)
Paper and cardboard	**Yes** (mixed in with organic waste provides carbon source)
Furniture and lab equipment	**No** (could be recycled)

Table 6: Potential for composting to deal with waste products from the greenhouses

There is a complication when dealing with plant waste material from experiments, particularly if transgenic material is propagated on the premises. Such material has to be dealt with according to health and safety regulations. At present the procedure for safe disposal is to autoclave all experimental material at 121ºC for 40 minutes. All material is then placed into a skip for landfill.

In this case study, separating organic matter for composting reduced the annual cost of skip hire (emptying) by £800 whilst providing a source of compost. However, waste separation involved technical time and the balance of costs is still under Departmental consultation. In the meantime, Aberystwyth University recently purchased a "Rocket Composter", to deal with kitchen waste and any other sources of local organic waste (Aberystwyth University 2007c).

CASE STUDY 7: *Blended learning and sustainable teaching – a review*

In this study blended learning was defined as *"A combination of face to face and technology based learning*" (Stubbs et al. 2006). Blended learning has received much attention by the Centre for Biosciences in relation to lecture size and attendance (e.g. Jones 2003; Wood 2007). Could this type of provision represent a possible way forward in reaching the goal of sustainability in teaching biosciences? Large lecture classes utilise fewer resources but there is concern that the educational value may be experience be lessened. Hughes (2004) reports on the shift in practical work towards less contact and hands on experience. Electronic resources and computer aided learning (CAL) are now an integral part of University teaching and may be filling the experience / resource gap. Pereira *et al.* (2007) suggested that learning experience and performance could be improved via a blended approach in teaching human

anatomy. At the same time they reduced contact hours by over 20% by targeted learning but also emphasised that resource creation, organisation and maintenance were significantly increased using a blended learning approach. Stubbs *et al.* (2007) experimented with blended learning and what they termed "lean delivery". They presented very clear guidelines on what they term the "INS" of such delivery (INS – meaning what to include). In such learning environments they highlighted that students needed to be weaned away from their expectations moving towards CAL but also highlighted the importance of regular engagement.

Technology may be filling this gap in provision but educationally it is important that students engage actively with materials provided. Ellis *et al.* (2006) proposed the use of learning through discussion in a year 2 Psychology module and used tutorials, group learning and on-line discussion. They also highlighted the importance of analysis of experience and synthesis during face to face interactions. Hejmadi (2007) proposed that blended learning involving CAL teamed with experiential workshops improved learning and reduced contact and assessment time.

Whatever the design of a module or course, resources have to employed (time, energy and consumables). The discussions about blended learning and practical experience are ongoing and enter into debates about educational priorities and resource investment within Universities.

CONCLUSIONS

Priorities, opportunities, constraints and some resistances and were identified at all levels in this study. A student might be discouraged from recycling if the facilities are not available. A technician may prefer to purchase reusable glassware but is constrained by time (to buy) and cost (to clean and reuse). A dissertation student may be aware that certain procedures are wasteful but feel that they are unavoidable. Equally a lecturer may be requested to employ electronic resources to supplement teaching. Overall, in any Department it is important to open good lines of communication to discover the limiting factors in implementing sustainability. A 'sensible', gradual and integrated approach is recommended accepting the complexity of sustainability and that many individuals (at all levels) may not buy into the concept. Overlaid on top of the need to be sustainable are changes and challenges in education enforced by University demands to be research competitive and the shift in education fed by the growing use and accessibility of electronic resources. Blended learning has been proposed as a possible way to achieve this mix. For the 'I-pod' generation" (Smith 2005) maybe electronic resources should be used to supplement and support teaching but the experiential "hands-on" component should also be maintained. Technicians can green laboratory practictals through sustainable procurement and resource management but the element of time and money represent significant barriers. Lecturers can also reduce the environmental impact of field work by delivering courses locally but this can reduce the attractiveness of their Department in terms of marketing and recruitment.

There may be resistance to sustainable practices in bioscience departments yet sustainable practices can often increase efficiency and more importantly reduce operational costs. To move towards sustainable teaching in bioscience, strategies that involve students and university staff at all levels are required. There is potential for bioscience departments to lead by example by implementing a strong environmental policy that guides the University towards a low impact learning environment. A move towards sustainability will require behavioural adjustments, investment in infrastructure and training and ultimately commitment from staff at all levels in the design and implementation of Sustainable Learning and Teaching Strategies.

BIBLIOGRAPHY

Aberystwyth University (2006). Strategic Plan 2006 – 2011. Education for Sustainable Development and Global Citizenship (online). Available from: www.aber.ac.uk/en/strategic/strategic_plan_06_en.pdf (accessed 1st January 2008).

Aberystwyth University (2007a). Policy statement (online). Available from: http://www.aber.ac.uk/safety-environment/docs/public/aberenvpolicyengnov2007.pdf (accessed January 2008).

Aberystwyth University (2007b). Aber news: Cutting paper usage (online). Available from http://www.aber.ac.uk/aberonline/en/archive/2007/12/uwa15307/ (accessed 1st January 2008).

Aberystwyth University (2007c). Aber news: Compost corner (online). Available from: http://www.aber.ac.uk/aberonline/en/archive/2007/12/uwa13207/ (accessed 1st January 2008).

Brown CA, Calvert J, Charman P, Newton C, Wiles K and Hughes I (2005). Skills and Knowledge Needs Among Recent Bioscience Graduates — How Do Our Courses Measure Up? (on line). *LTSN Bioscience Bulletin* Vol: 6-2. Available from http://www.bioscience.heacademy.ac.uk/journal/vol6/beej-6-2.htm (accessed 1st January 2008).

Dawe G, Jucker R and Martin S (2005). Sustainable Development in Higher Education: Current Practice and Future Developments *(on line)*. *The Higher Education Academy (HEA). Available from: http://www.heacademy.ac.uk/resources/detail/ourwork/tla/sustainability/sustainable_development_in_HE* (accessed 1st January 2008).

DEFRA (2005). Guidelines for Company Reporting on Greenhouse Gas Emissions Annexes updated July 2005 (online). Available from: http://www.defra.gov.uk/environment/business/envrp/pdf/envrpgas-annexes.pdf (accessed 1st January 2008).

Ellis RA, Goodyear P, Prosser M and O'Hara A (2006). How and what university students learn through online and face-to-face discussion: conceptions, intentions and approaches. *Journal of Computer Assisted Learning* 22: 244-256.

Hejmadi MV (2007). Improving the effectiveness and efficiency of teaching large classes: Development and evaluation of a novel e-resource in Cancer biology. *LTSN Bioscience Bulletin* Vol: 9-2. Available from http://www.bioscience.heacademy.ac.uk/journal/vol9/beej-9-2.htm (accessed 1st January 2008).

Hughes I (2004). Coping strategies for staff involved in assessment of laboratory write ups. *LTSN Bioscience Bulletin* Vol: 3-4 Available from *http://www.bioscience.heacademy.ac.uk/journal/vol3/beej-3-4.htm* (accessed 1st January 2008).

Intergovernmental Panel on Climate Change (2007). Climate Change 2007: The physical science basis. Summary for policy makers. *IPCC Fourth Assessment Report*.

James P, Dockery M and Hopkinson L (2007). Sustainable laboratories for universities and colleges - lessons from America and the pharmaceutical sector (on

line). *Higher Education Environmental Performance Improvement (HEEPI)* - Final Report. Available from (http://www.heepi.org.uk/) (accessed 1st January 2008).

Jones A (2003) Editorial: Attendance at classes: what is the real situation (on line). LTSN Bioscience Bulletin Vol: 2. Available from: http://www.bioscience.heacademy.ac.uk/journal/vol2/beej-2-0.htm (accessed 1st January 2008).

Jones AM (2003). The use and abuse of PowerPoint in Teaching and Learning in the Life Sciences: A Personal Overview (on line). *LTSN Bioscience Bulletin* Vol: 2: 2-3. Available from: http://www.bioscience.heacademy.ac.uk/journal/vol2/beej-2-3.htm (accessed 1st January 2008).

Pereira JA, Pleguezuelos E, Meri A, Molina-Ros A, Molina-Tomas MC and Masdeu C (2007). Effectiveness of using blended learning strategies for teaching and learning human anatomy. *Medical Education* **41:** 189-195.

People & Planet. The Green league 2007 (on line) Available from: http://peopleandplanet.org/gogreen/greenleague2007 (accessed 1st January 2008).

Stubbs M, Martin I and Endlar L (2006). The structuration of blended learning: putting holistic design principles into practices. *British Journal of Educational Technology* **37** (2): 163-175.

Smith D Anxious life of the 'Ipod' generation. Sunday Times August 21 2005. *Timesonline* Available from: l(http://www.timesonline.co.uk/article/0,,2087-1743391,00.html) (accessed 1st of February 2008).

Wilmot A, Davies K, Wright H and Gwynn-Jones D (2007). Towards sustainable teaching of biosciences: integrating sustainable approaches into undergraduate teaching in Higher Education. *Proceedings of the Science and Learning Conference 2007*: O30: 182-188.

Wood E (2007) Editorial: Time-saving strategies for improving value of assessment (on line). *LTSN Bioscience Bulletin* Vol: 9-0. Available from: http://www.bioscience.heacademy.ac.uk/journal/vol9/beej-9-0.htm (accessed 1st January 2008).

World Commission on Environment and Development (1987) Our Common Future. WCED. *UN Conference on Environment and Development*.

USEFUL LINKS

Carbon Trust www.carbontrust.co.uk

The Environmental Association for Universities and Colleges www.eauc.org.uk

Higher Education Environmental Performance Improvement www.heepi.org.uk

Higher Education Academy www.heacademy.ac.uk/sustainability.htm

Labs21 UK www.labs21.org.uk

People and Planet www.peopleandplanet.org

WasteWatch www.ecocampus.co.uk/downloads/Wastewatch.pdf

Welsh Institute for Sustainable Education http://wise.cat.org.uk/wise/

Ecoversity www.brad.ac.uk/admin/ecoversity

Technical guidance and consultancy

The Centre for Alternative Technology for free information on all topics relating to sustainability and a consultancy service for bigger projects www.cat.org.uk

Dulas Ltd design and install a range of renewable energy technologies including: wind, hydro, solar, and biomass wood energy. www.renewable-resources.com

Environmental Management Systems (certification schemes)

EcoCampus www.ecocampus.co.uk

Greendragon www.greendragonems.com

Eco-Management and Audit Scheme www.emas.org.uk

ISO 14001 www.iso14000-iso14001-environmental-management.com

Envirowise www.envirowise.gov.uk

For further sustainability links relating to Climate change, Greening the Office, Transport, Water, Waste, Energy, Biodiversity, etc. go to the University of Wales Aberystwyth Environmental Sustainability pages: **www.aber.ac.uk/ensus/resources**