

## **Cradle to? Introducing ‘Environmental Issues’ into the teaching of Engineering Materials**

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**Abstract:** In a recent restructuring of subjects taught in the Materials degrees during the 1st year of studies at the Department of Engineering Materials of the University of Sheffield, it was decided to introduce a module that dealt with Environmental issues. The module was aptly named ‘Cradle to? - Materials and the Environment’ and was delivered to a class of 21 students through 24 lectures and 3 tutorial/problem classes in the course of a semester.

As a module with content very pertinent to current issues and prominent in the public arena and media, the course has received unexpectedly mixed reviews having run for the first time in 2009. The module somehow failed to capture the imagination of the undergraduates against the expectations of the members of staff that put it together. We look into the possible reasons of why this might have happened and propose ways to rectify the negative aspects as experienced by the students who took the module.

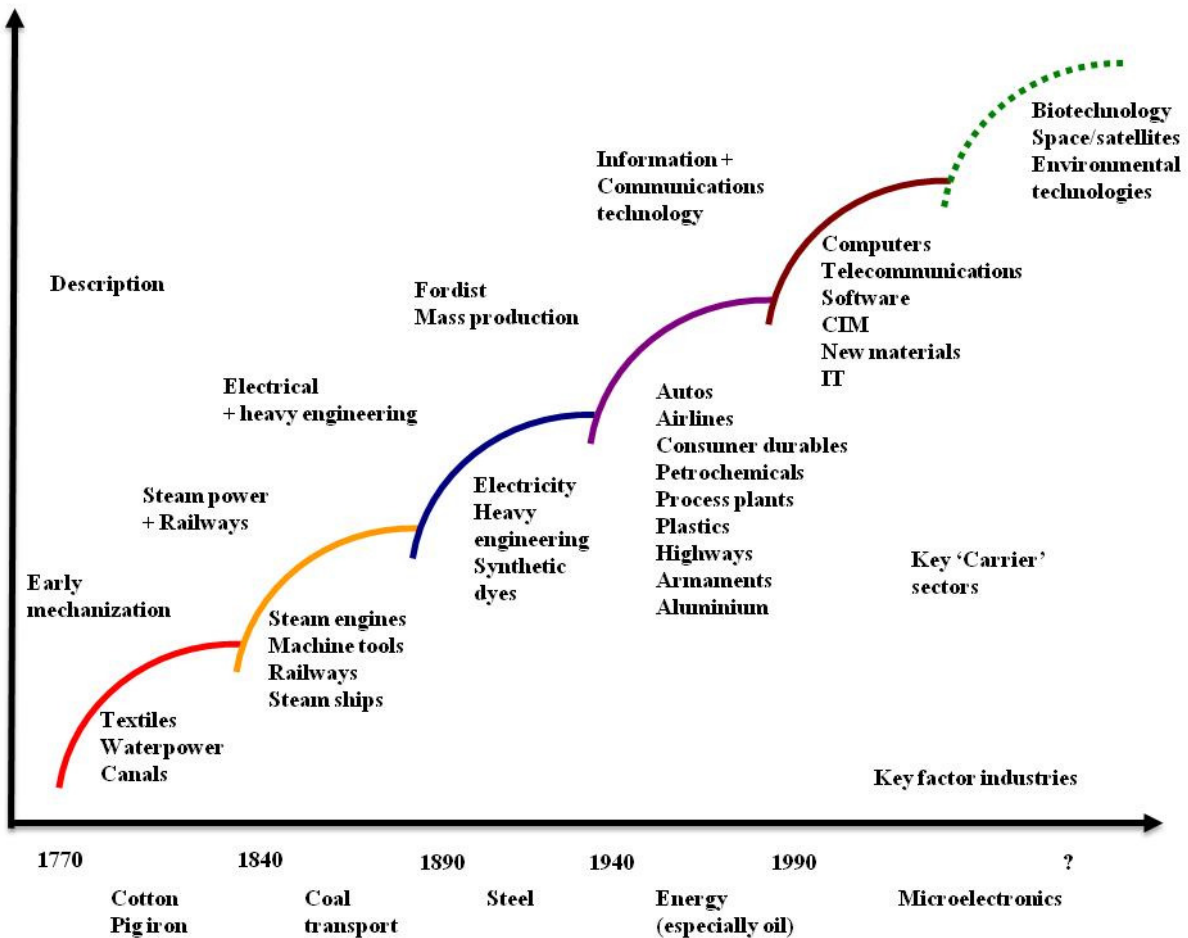
Keywords; engineering education, environmental issues, materials, sustainability, energy.

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### **1. INTRODUCTION**

*1.1 Environmental Issues and their Teaching in Materials Science and Engineering:* Undoubtedly technological developments have been key factors in the prosperity that has been achieved and experienced by the developed nations over the last century. However, it has become apparent that humanity cannot continue on the extravagant usage of the finite material wealth of the planet, and that future prosperity and economic growth will be driven by developments in information technology, biotechnology and materials science and engineering, especially in relation to the environment. Furthermore, it is also clear that such developments must be not only sustainable but spread more equitably amongst all humanity.

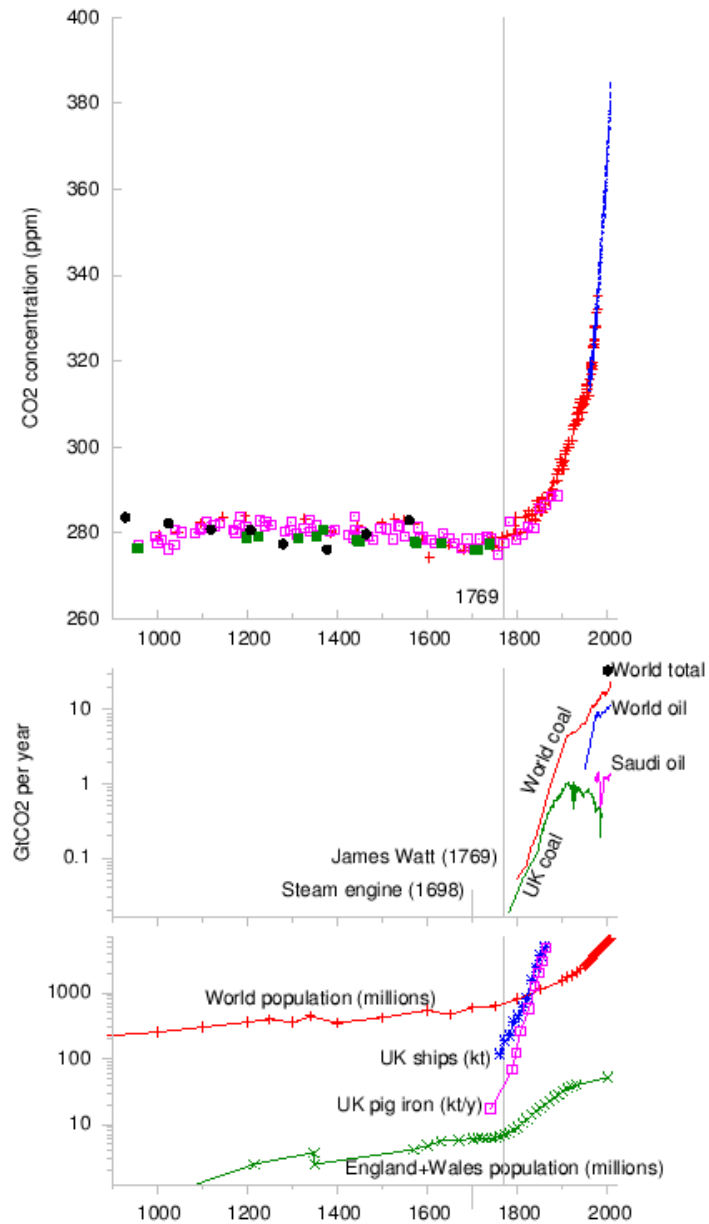
Figure 1 gives a graphical representation of the major technological developments from the time of the Industrial Revolution of 1770's to the present as well as hazarding a guess as to the possible forthcoming technological wave to involve bio-technology, aerospace and environmental technologies.



**Figure 1 Technological waves of revolutionary development originally proposed by Schumpeter as adapted by Dodgson (2003)**

The three parts of Figure 2 show some worrying trends: the upper graph shows carbon dioxide (CO<sub>2</sub>) concentrations (in parts per million) for the last 1100 years, the middle graph shows (on a logarithmic scale) the history of UK coal production, Saudi oil production, world coal production, world oil production, and (by the top right point) the total of all greenhouse gas emissions in the year 2000. All production rates are expressed in units of the associated CO<sub>2</sub> emissions. The bottom graph shows (on a logarithmic scale) some consequences of the Industrial Revolution: sharp increases in the population of England, and, in due course, the world; and remarkable growth in British pig-iron production (in thousand tons per year); and growth in the tonnage of British ships (in thousand tons). In contrast to ordinary graphs, the logarithmic scale allows us to show both the population of England and the population of the World on a single

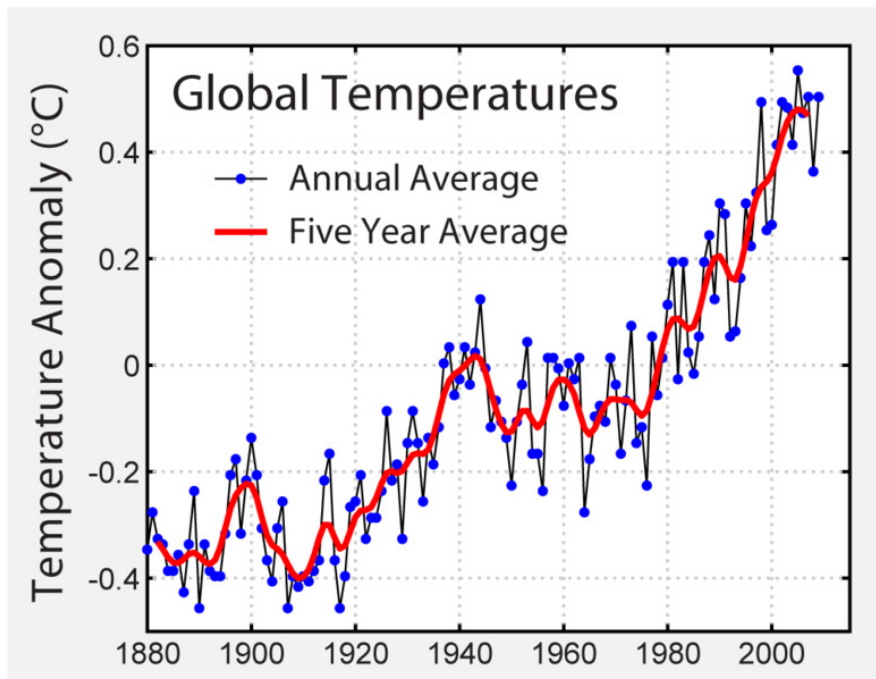
diagram, and to see interesting features in both. The graphs leave no doubt that we have been on a steep climb in all of them and continue to do so in most of them, MacKay (2009). These trends leave no doubts that humanity needs to change the way it treats the planet and many of the people who inhabit it. For millennia, mankind has had an ever increasing need for energy initially relying on heat from the sun and biomass as food and firewood, the use of other animals as agricultural labour, harnessed the power of moving water, and the winds but until this point our use of energy had been largely sustainable—with the possible exception of excess forest cutting—and our impact on the planet was only of a local nature. The industrial revolution's requirement for much larger amounts of power in locations far from any natural resource necessitated a radical change. Fossil fuels (first coal, then oil) proved ideal for providing this power. Unfortunately the emissions from their use have altered not only the local environment but the atmosphere itself, and the concentration of carbon dioxide has risen from 280 parts per million to 370 today—a level unknown for millions of years. Because carbon dioxide acts as an insulator, this has slowly warmed the planet, in turn melting ice and raising sea levels (Figure 3).



**Figure 2. Trends of CO<sub>2</sub>, World population, and production of fuels from the time of the Industrial Revolution to the present MacKay (2009).**

It has taken us a long time to realise the seriousness of the situation. The basic phenomena and its consequence were first described in 1859, and now terms such as global warming and climate change appear regularly in the media and political debates. For any degree of equality humanity

needs to be using more energy, not less. Yet failure to reduce our emissions of greenhouse gases will lead to a level of climate change that will affect the wealth and survival of many of the poorest people on the planet and harm the economies and landscapes of the wealthiest. The only sensible solution would appear to be that we use energy more efficiently in the short-term and that we give up our reliance on fossil fuels in the medium term.



**Figure 3. Trends in mean temperature variations over Land & Ocean since 1880**  
([http://en.wikipedia.org/wiki/Temperature\\_record](http://en.wikipedia.org/wiki/Temperature_record))

Ashby (2004) discussing materials and product design states that: “Good design works. Excellent design also gives pleasure. Materials, are the foodstuffs of design, and processes the ways of preparing the materials for consumption. You don’t need new materials to create exciting new designs. The element of satisfaction is central to contemporary product design. It is achieved through an integration of good technical design to provide functionality, proper consideration of the needs of the user in the design of the interface, and imaginative industrial design to create a product that will appeal to the consumers at whom it is aimed. Materials play a central role in this. Functionality is dependant on the choice of proper material and process to meet the technical requirements of the design safely and economically. Usability depends on the visual and tactile properties of materials to convey information and respond to user actions. Above all, the aesthetics, associations and perceptions of the product are strongly influenced by the choice of the material and its processing, imbuing the product with a personality that, to a greater or lesser extent, reflects that of the material itself. Consumers look for more than functionality in the products they purchase. In the sophisticated market places of developed nations, the “consumer durable” is a thing of the past. The challenge for the designer no longer lies in meeting the functional requirements alone, but in doing so in a way that also satisfies the aesthetic and emotional needs. The product must carry the image and convey the meaning that the consumer seeks: timeless elegance, perhaps; or racy newness”. One Japanese manufacturer goes so far as to say: “Desire replaces need as the engine of design”.

Although this is a beautifully written essay on the crucial interplay of design and materials, today's experiences make it imperative that our design concepts move with the times, i.e. as the work by Lagerstedt (2003), it is stated that "Design for the Environment is also known by numerous other names such as: Green Design, Eco-Design, Sustainable Design, Environmental Conscious Design, Life Cycle Design, Life Cycle Engineering and even Clean Design".

## 2. THE COURSE

The content was divided into three main areas, each to be undertaken by a different member of staff. The subjects were delivered using traditional delivery modes of teaching and each section was supplemented by a 3 hour tutorial session.

*2.1 Energy balances and Energy cycles:* Energy & Materials, Energy usage in a modern economy, Energy and the environment, The Greenhouse Effect, Materials and energy conservation, Materials and energy production: the case of solar power, Materials and the Environment- mining and extraction, Measuring the impact, Materials and sustainability.

*2.2 Energy and Materials:* two case studies: Producing goods, Production of Aluminium, Production of Steel, Transport, Market size, PET production, Natural Gas.

*2.3 Life Cycle Assessment:* Setting the scene, Materials and the Environment, Prerequisites to Life Cycle Assessment, The Materials Life Cycle, Eco-attributes of Materials, Eco-informed Materials Selection, Examples, Materials for a Sustainable Future. Recommended book: Materials and the Environment, Eco-informed Material Choice, Ashby (2009).

Although it was clear that there will inevitably be some repetition of the various concepts included under the three headings, it was felt that: a) this is not a bad thing to have as it helps with consolidating understanding and b) as each area was delivered by a different member of staff, there will inevitably be a different perspective brought into play, which is also not a bad thing to have when introducing such systemic concepts.

As well as the individual assessments based on the problems classes (worth a total of 20% of the marks) the students were required to undertake a group project (worth 80%). Each group was to investigate the lifetime materials and energy flows for the item given against that group's name. Their findings were to be presented as an A0 laminated poster prepared using Powerpoint. The posters should be produced in electronic form and then sent for printing. Guidelines for producing their posters were available under MAT1920 on Muse. The posters were to be assessed at a poster session, when all students were required to be present to answer questions relating to each poster. In addition to the poster, each group should also produce an agreed statement assessing the contribution of each member of the group to the project. Finally each person should each produce a short (maximum 1000 words) report summarizing the aspects of the project that they worked on.

The actual problems classes were exactly what is denoted by the title; problems classes with students having to perform calculations or write short essay type answers to various questions.

This part of the module it was to provide both a forum for the students to engage with what had been said in class as well as demonstrate to the member of staff responsible that they had engage with the subject.

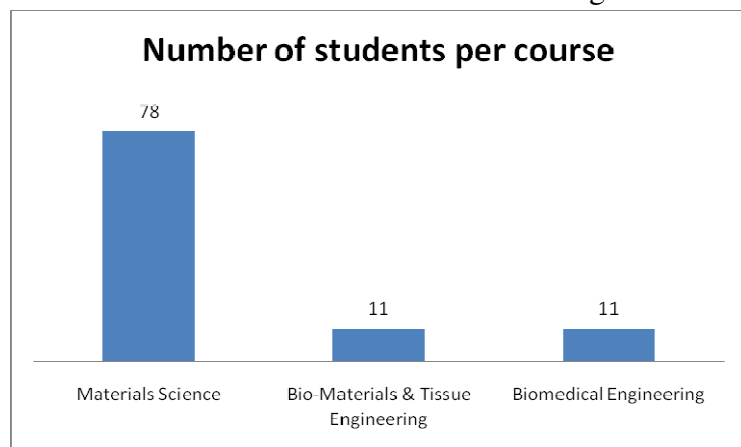
The author, having discussed the module with the students decided to change the content of his part of the module as follows: Lectures: 1. Setting the scene, 2. Energy revisited, 3. Taking another look at design, 4. The materials Life Cycle, 5. Sustainability issues, 6. Looking at another discipline 'city planning, urban design, and these types of 'fuzzy' ideas that help govern community quality of life' – (Prof. Marc Schlossberg, University of Oregon), 7. Sustainability, the Gripple Way (Gripple Ltd), 8. Eco-informed Materials Selection.

Problems Class: Groups were given a sub-assembly made of component parts and were requested to: 1) Draw and complete a streamlined LCA matrix for it, 2) Draw a life cycle diagram showing an inventory compilation, and 3) Re-design the part to be more eco-friendly and give your reasons why you think it will be so. The total report to be submitted should be no more than 3 A4 pages.

### 3. THE RESPONSE OF THE STUDENTS

The group of 1st year student that took the module was a mix of three Materials degree streams as shown in the adjacent figure.

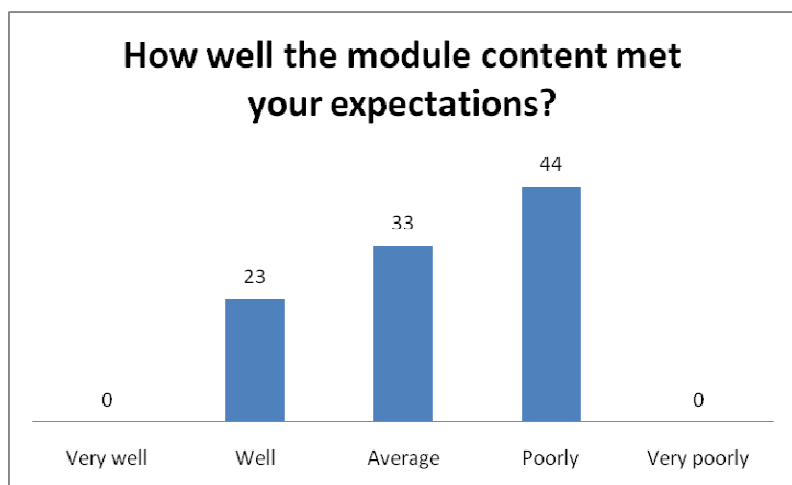
The students' overall response was positive, although not very forthcoming as only 44% of the total were involved in the feedback. However, a number of points were raised that require further attention.



#### 3.1 The content:

Subject too dry. Module should be optional as it is not as essential to 1st year students as other modules are. The same information repeated over 24 lectures! Too much data. Lectures very similar. Need more variety. Problem classes need to be longer. Problem classes good although a little tedious!

#### How well the module content met your expectations?



#### 3.2 The assessment process:

The assessment could have been done better with smaller units throughout the module rather than one big project at the end. Final group project work responsible for most of the module marks.

#### 3.3 The practicalities:

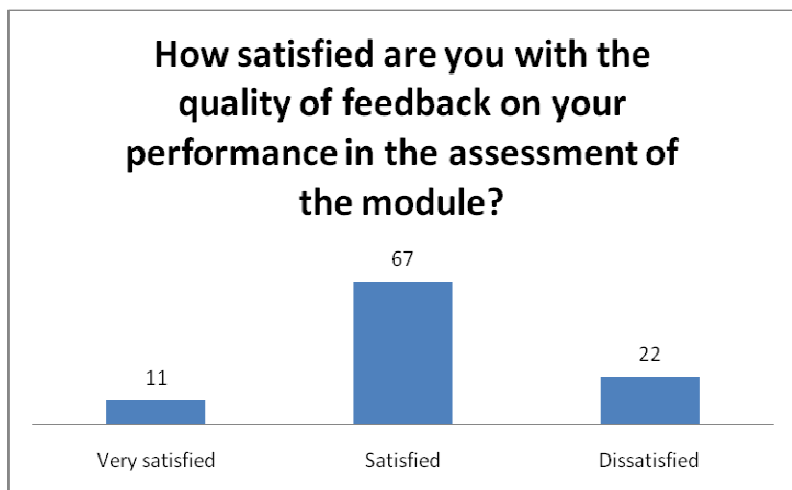
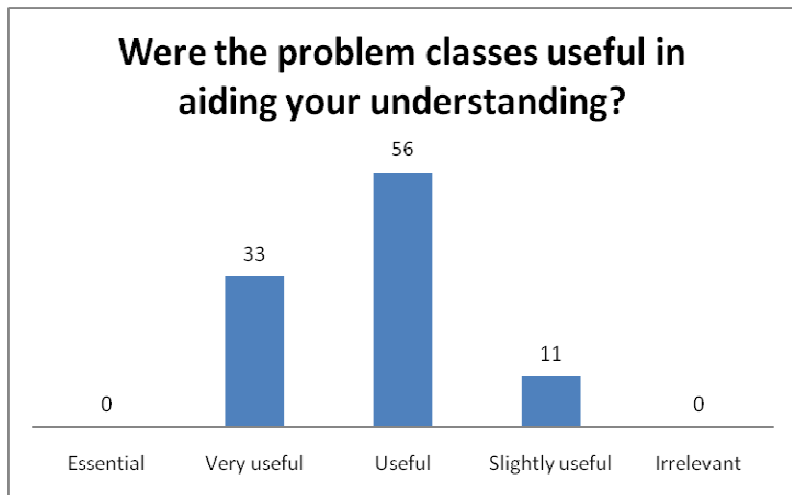
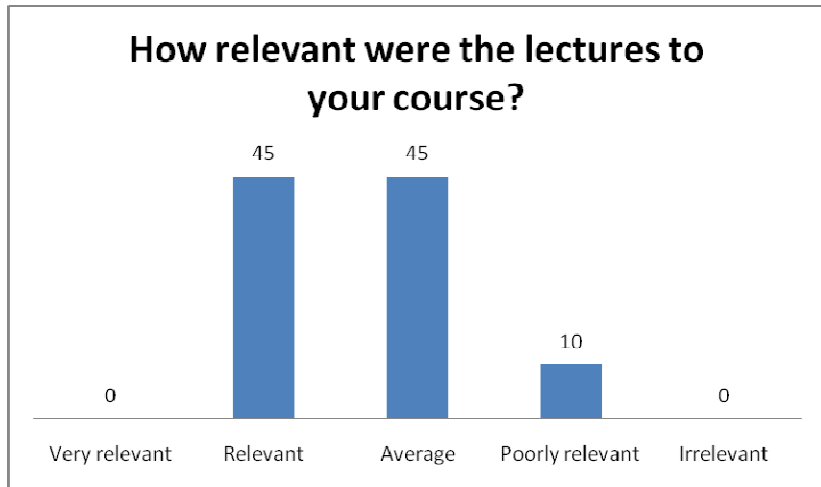
Time tabling has effect on

attendance (mounting work load towards the end of year meant that it was not worth it to wait for 3 hours when a piece of work is due in the next day!)

It is clear that the linkage of this particular module to the rest of the course materials was not made explicit to the first cohort of students, although it might have been obvious to the educators. From a delivery point of view, the module delivered what it set out to achieve, i.e. make the students aware of the issues and provide them with the factual information that will allow them to make informed choices. However, the module failed to excite and engage them. Why?

Could it be that we used a 12th Century model for teaching the engineers of the 21st century, Felder (2006). Was it a case that we did try to tell them too much rather than actively engage them in the process? There is no doubt in our minds as educators that for students to learn in a meaningful manner they must be actively engaged in the learning process but what stop us achieving it? Is it a case that the time available to educators in HE establishments to achieve all that is asked from them leaves them no opportunities other than being adequate? I do not doubt that we are all fully committed and concerned with the well being and learning of our students but becoming outstanding teachers in today's University teaching environment is not easy; maybe it never was.

Being a world-class researcher is a full time job in itself, as is being an exceptional teacher. Add the increasingly



to educators in HE establishments to achieve all that is asked

bureaucratic nature of academia, the extra administrative duties, compounded with increasing pressures because of the current economic state of affairs demands staff reductions and it becomes easier to see why we might have failed to actively engage and excite our students. After all we are only human and there is such a thing as work overload.

Nevertheless, there is a need to balance the various demands made on us and ensure success with the equally important tasks of research and teaching. Maybe we do require some support to achieve that and it might involve major attitude adjustments by our employers and ourselves; they have to provide the resources in recognition of our considerable efforts and we have to ensure that we are not just going in and giving good lectures but we use the various innovative educational methods available to us. Maybe it is time to re-evaluate the publish or perish syndrome that pervades our research activities over that of the intellectual curiosity in the hope of improving society as well as the well and tried teaching methods set against those involving some loss of control to the students. Of course not every student will subscribe to this approach and once again all our teaching experimentations must be tempered by a delicate balancing act; ‘Μετρον Αριστον’ – loosely translated ‘everything in good measure is perfection’.

Having just completed the delivery of this module for the second time to a new cohort of students using the new structure outlined earlier in section 2 as well as the input of two outside colleagues (one from industry and one from another discipline) the students reaction has been very positive. They showed much better engagement with the subject and they appreciated the external points of view that provided the connections on systemic and interdisciplinary approaches. Finally the ‘hands on’ problems class seems to have brought everything talked in class together, as well as providing for the different learning styles in a class of would be engineers.

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