Sustainability by Design :

A reflection on the suitability of pedagogic practice in design and

engineering courses to the teaching of sustainable design

Authors

Mr Richard Morris	Professor Peter Childs	Dr Tom Hamilton
University of Brighton	University of Sussex	University of Sussex
Lewes Road, Brighton	Falmer, Brighton	Falmer, Brighton
East Sussex, UK. BN2 4GJ	East Sussex, UK. BN1 9QT	East Sussex, UK. BN1 9QT
Tel 0044 (0)1273 642300	Tel 01273 678793	Tel 01273 678793
fax 0044 (0)1273 642301	Fax 01273 678486	Fax 01273 678486
r.d.morris@brighton.ac.uk	p.r.n.childs@sussex.ac.uk	t.hamilton@sussex.ac.uk

Abstract

Courses in Product Design are offered within the United Kingdom at the University of Brighton and the University of Sussex and in both cases are run within engineering departments alongside traditional engineering courses. This paper outlines some of the intrinsic pedagogic practices that are employed by these, and other, design courses. It highlights why creativity is a central tenet within these courses, which has underpinned the successful bid by the universities to jointly become the UK Centre of Excellence in Teaching and Learning in Creativity (CETL in C), and why in particular creativity is a key requirement in sustainable design. It supposes why these practises might, and should, offer a suitable role model for more traditional engineering courses.

Keywords

Engineering, product design, sustainable design, creativity, pedagogy.

1.   Background

It is possible to argue that the first appearance of professional engineers began in civil engineering with the establishment in the UK of their Institution in 1828, and that the Institution of Mechanical Engineers was created later to accommodate the 'artists and gentlemen' tackling the more ephemeral

manufacturing curios of the early industrial age rather than the 'experts' who were tackling the larger and more 'important' projects such as canals. As mechanical projects grew and became more complex however, and as countries industrialised and began to compete more in the manufacturing, mechanical engineering began to become less gentlemanly and more professional, with specialisation and the adoption of a scientific approach in order to advance its knowledge. The analytical and logical route then forged by mechanical engineering developed its credence and academic respectability, but at the same time opened a gap with its artistic and creative roots.

Throughout the late 19th and 20th Century, 'design' and 'industrial design' sought to fill the artistic gap. This was however a definite 'filling' rather than bridging exercise, as the design courses remained the province of the artistic and engineering remained the province of the analytical. The Council of Industrial Design (1944) and the Crafts Councils aimed to improve the artistic side of manufactured goods, but largely excluded engineering from their remits.

The Fielden Report (1963) and the Conway Report (1969) recognised this divergence and in 1972 the Design Council was consequently created. Whilst the Design Council sought to extend the artistic into engineering, it may actually have merely polarised designers as those who wanted to work with industry and those who did not. The Finniston Report again identified the creative/analytical discrepancy resulting in the formation of the Engineering Council. The council set an underlying message of more practical application, including design, rather than pure theory which it enforced through new requirements for the education and training of engineers (Standards and Routes to engineers becoming Registered Professionals, or SARTOR). However, with a few exceptions, SARTOR merely again polarised educational courses as 'engineering' or 'design'.

Like many UK Universities, the Universities of Brighton and Sussex offer courses in both engineering and design. The University of Brighton has a long tradition of mechanical and engineering-based courses, which date as far back as 1877. It offered its first product design based course in 1995 and attracted a cohort of 7. 10 years later, it hosts 3 design courses and has 180 students accounting now for nearly half of the School's undergraduate cohort. The University of Sussex is a newer establishment, but it too has seen a growth in design courses with respect to its traditional engineering courses. In

both cases, there appears a polarisation in the courses of staff, students and pedagogy that mirrors the traditional artistic/analytical divide.

2.   Design Pedagogy

A broad approach

One of the key features of a design course is that students study subjects in breadth rather than depth. Subjects in a design syllabus might for example typically include elements of mechanical engineering, electrical engineering, arts and the humanities, business, law, accountancy, architecture and IT. The pedagogic rationale typically adopted for design based degrees is to engage students with this entire range of subjects from the outset of their studies. Each subject is then delivered in more comprehensive depth as students progress through the course. This broad but deepening approach allows students to learn and develop at their own pace, in accordance with a model of increasing cognition such as suggested by the SOLO Taxonomy [Biggs and Collis, 1982].

Many subjects can be delivered by an approach of increasing depth. For example, students can learn the rudiments of a subject at level 1, progressing to more advanced detail at level 2 and undertaking critical and analytical decisions at level 3. However, sustainable design lends itself particularly to a phased approach as it has its own clearly recognisable phases; green design; eco design; sustainable design.

Green design might be defined as a design process in which the focus is on assessing and dealing with individual environmental impacts of a product rather than on the product's entire life. Thus students can focus on improving one environmental element of a design without compromising other design issues such as cost, quality and appearance. Eco-Design can be defined as design which addresses all environmental impacts of a product throughout the complete lifecycle whilst maintaining other criteria. Hence students can tackle a fuller range of environmental issues whilst integrating these across other design issues. Sustainable design might be defined as the practice of design which embodies the principles of eco-design but includes additional considerations of social and economic well-being, such as ethics and the environment. At this stage, students should tackle the complex cognitive challenge of resolving a range of interrelated abstract and applied issues.

This broad but deepening approach is common in design based degrees and has been adopted by the consortium of European universities developing training material in eco design for design based students [EU Commission, ECO DESIGN – an innovative path towards sustainable development, 2005].

An integrated approach

From this example, it can be seen that students must not only grasp the fundamental principles from a range of subjects but must develop the skills needed to process and integrate this knowledge.

Introducing a full range of subjects from an early stage allows students to practice and develop their integrative skills but the holistic approach is often notably aided by the adoption of a Problem Based Learning (PBL) format which provides a motivational and deep learning platform in which to learn. It also has the advantage that problems (in this case design projects) can be drawn readily from the real world further engaging students with the subject matter.

This may be particularly relevant when students are removed from the subject matter, and this can be the case with sustainability. Students are raised in a consumerist and not a sustainable society. Making things, using resources, encouraging consumerism is their chosen career. Even if the environment forms a part of their thinking, they are unlikely to want to know that their design work is helping to deplete resources at an unsustainable rate, or that "there are professions more harmful than industrial design - but only a few" [Papanek, 1972].

Engaging the students with the design process first and then highlighting the environmental issues can be more effective. For example, ask a student to design a kettle and then tell them about the other 7m kettles sold in the UK last year drawing 4.2 tWh of power [DEFRA, 2006]. The more effort students put into their design then the more they may question these prepositions and the more the intended cognition may be achieved.

Reflection

Student critical analysis and self reflection is another facet of design based courses. Group based sessions, itself a feature of PBL, will in particular facilitate tacit issues which are hidden to some students but known to others to emerge as explicit knowledge for all.

This is important in sustainable design, again because of the remoteness of the subject from student consciousness. In attempting to tackle a design, students will usually prioritise the issues that they perceive as being more important and this is usually not environmental issues. Even students who do consider themselves to be environmentally aware will often dispense with sustainable design in favour of issues of functionality, cost or aesthetics.

In an experiment in 2005, a cohort of 20 design students were given a short design challenge with the weighting slanted towards sustainability. The students were then immediately set a longer design challenge which included sustainability as an assessment criterion but not weighted differently to other factors of functionality, cost, and aesthetics. Only 2 students in the group included any form of sustainable thinking in their second design [Morris, 2005].

In industry, the reward system for designers is not based on weighted assessment grades but on financial return which is geared towards consumer needs and this is rarely led by environmental considerations. Consumers buy kettles "not necessarily because they are broken but because they want the new design or colour." [Binks J]. "Consumers are looking for stylish design products in metallic finishes " [David Williams, Product Group Manager at Morphy Richards]. "Consumers are currently trading up to higher specification, higher design products." Chris Gee, Marketing Manager, Groupe SEB] . Time saving, "fast boil" kettle volumes have grown by 68% in the year to August 2003 [International Market News] even though they are less energy efficient.

Hence reflection individually or by group offers students a 'second chance' to assess issues in their design work, including the ones they have missed before or during the design and this is often likely to include sustainability.

Cross disciplinary

In studying a wide variety of subjects, design courses employ a wider variety of specialists and this facilitates a cross linking of cultures and perspectives. The conjoining of previously unrelated ideas, thoughts and concepts is well recognised as a feature of creative thinking and this is a major factor in the creative outputs arising from design students.

The design courses at Brighton and Sussex both draw heavily on expertise from outside of their respective engineering departments. In 2005, the two universities were jointly appointed by the Higher Education Funding Council for England as the UK Centre of Excellence in the Teaching and Learning of Creativity (CETL in C), based on the creative outputs of the design courses.

Sustainability is supported by this cross faculty approach. For example there is relatively new and growing field of design based on the Life Cycle Assessment (LCA) of products, which has grown out of the linking of design with the LCA techniques employed within the geo and environmental sciences [For an example, see Owens 1996]. Similarly, the knowledge obtained through interactions with social sciences allows a greater understanding of the human/product interface generating semiotic designs which can stimulate the consumer's environmental awareness.

3.   Engineering Pedagogy

The perspective on engineering courses is that engineers have traditionally been less likely to be taught using a broad and integrated approach. They are more likely to be taught in depth, rather than breadth, and in a linear, step by step fashion. There is usually a chance to practice one subject in application through a final year project, and a hope that they can integrate the remaining subjects once they reach industry. They are also less likely to adopt reflective practices. A summary of the pedagogic differences between the 2 disciplines of engineering might therefore be indicated by table 1:-

Pedagogy	Engineering	Design
Subject matter	itemised, modular	integrative, holistic
Subject range	narrow, deep	broad, shallow
Delivery	lecture based	problem based
Career	professional, employed	vocational, self employed
Creativity	problem solving	problem defining
Interface	technology	human
Projects	theoretical	applied

Table 1: Pedagogic comparators in Engineering and Design

This emphasising of theory and science within engineering, taught through a logical and rationalised approach, has been recognised as having limitations, notably within the engineering profession itself as a reduced ability to practice and apply knowledge. There are many development to address this, including for example interest in learning spaces and PBL [Molina et al, 2003]. In particular however, there has been much emphasis on increased team working, multidisciplinarity and the uptake of ICT (information and communications technologies) [Kulacki and Krueger, 1998] [Dutson, et al, 1997]. Whilst there are too pockets of activity related to creativity, there remains in many cases a scepticism towards the validity of creativity or its relevance within engineering, where it is most likely to be assigned to design aspect of engineering [Forum on Creativity in Engineering Education, 2006].

As a results, engineers are less likely than designers to be 'fashioned' as creative thinkers, outside of being taught basic creativity tools. In comparative studies, postgraduate engineering students and undergraduate design students are set the task of redefining the purpose of a product. The purpose of a product is obviously known so the exercise involves an abandoning of norms and undertaking leaps of imagination. Students must also present their findings to the cohort which magnifies the desire to conform among logical thinkers, rather than to express openly among creative thinkers. Whilst almost all of the design students are usually successful at this exercise, it is rare that the majority of engineering students are successful [Morris, 2001]

4.   Sustainability

Students on engineering and design courses hence emerge with not just different skill sets but an entirely different professional and philosophical outlook. Does this difference matter when it comes to sustainability? In terms of interest in the subject the answer might be no. There are currently 4 UK institutions of Higher Education offering degree level courses in sustainable engineering (Lancashire, Southampton, Surrey and Warwicks), and 3 in sustainable design (Central Lancashire, Surrey and Aston) [UCAS, 2006]. In terms of commitment, the answer might also be no. Good analytical engineering practice will tackle all of the facets of green and eco design such as reducing material content, lengthening product lifetimes and enabling end of life disassembly. A 1 % efficiency saving in kettles is to be welcomed.

The answer however is that the differences between the two pedagogies does matter and the reason is the sheer scale of the ecological problem. The 7m kettles sold in the UK help to consume 4.2 tWh of energy. Multiply this by the 450m kettles sold across Europe as a whole [IMN, 2004], and factor in that this is just one product, the tip of a consumer iceberg, that is draining the earth's resources at unsustainable rates. As a result, up to one third of animals and habitats may be effected with 20 % species lost in vulnerable areas within the very foreseeable future [WWF, 2000]. There are equally varied but alarming reports with respect to crops, water and disease resulting from humanities unsustainable practices.

It was initially conceived that industry needed to increase its resource conversion efficiency by a minimum factor of 4 in order to be sustainable during a period when the human population is likely to double and average living standards increase significantly. That is a 75% reduction in resource consumption for any unit of production [Lovins, 1998]. Given that western societies typically consume 20-30 times more than their less developed counterparts, the Carnoules Declaration calls for Factor 10 improvements (i.e. 90% reductions). As the scale and acceleration of the damage unfurls even this is now considered conservative. Hence, it is now considered that the world must improve by a factor of 20 within 2 generations, the so called 'Factor 20' [Roszac,T].

Whilst ecological savings through green design and eco design are therefore laudable exercises that are to be encouraged, they are not enough. 1 % is not enough. As a Guardian newspaper article neatly described, "all the organic broccoli in the world won't be enough to save the planet" [Walter, N. 2006]. Quantum changes require quantum solutions and this needs creative, not analytical, thought and this is the strength of design courses where students do not just examine how to solve a problem, but questioning the problem itself.

5.   Conclusion

Summary

It has been argued that the broad, integrative, reflective, cross-discipline pedagogic approaches used on design based courses are ideally suited to sustainable design. By reason that engineers have a different pedagogic approach, it might then be supposed that they may not be best trained to tackle sustainable design. However, the key issue is that the scale of change required by sustainable design requires creative thought and that this is where design students excel.

The engineering versus design characterisation and stereotype described here is of course a crude generalisation, which will have exceptions. The caricature and the realities of it where it exists, result in stymieing creativity and innovation by the prevention of effective interdisciplinary activity. The majority of creativity techniques such as brainstorming, synectics, TRIZ, morphological analysis and function trees, rely on the power of the collective mind. Any structure or prejudice, whether it be administrative, managerial, vested, discipline or social that acts to prevent the effective collaboration and collection of minds acts to stymie creativity.

Yet the move to take up creativity has been apparently slow in engineering courses. There are some initiatives, as already noted, yet sustainability has still to appear on the list of engineering benchmarks outside of the coverall 'social context', and ethics is only now coming onto curricula of engineering courses. The 'tradition' of engineering may be a strength, but it might also be a weakness where attitudes, cultures and methods are entrenched and slow to change.

Beyond sustainability

Creativity is not just vital for sustainability, it underpins the entire knowledge based economy. Industry has recognised this, with innovation as a commonplace key commercial strategy whether global or local. The Government within the UK too has recognised the value of the creative industries to the nation (Cox, 2005).

The international marketplace is dominated by Europe, the US, Japan and now the People's Republic of China. Indeed the so-called BRIC pack (Brazil, Russia, India and the People's Republic of China) of countries, plus Mexico and Malaysia are turning out large numbers of well-educated young people fully qualified to work in an information-based economy (Duke University (2005)). The People's Republic of China will produce of the order of 3.3 million college graduates this year, India 3.1 million, the U.S. just 1.3 million. In engineering, the People's Republic of China's graduates will number over 600,000, India's 350,000, America's only about 70,000. These figures of course require scrutiny as the original report points out:

- The statistics for India and the People's Republic of China have included four-year degrees and also three-year degrees and diplomas. These numbers have been compared against the annual production of accredited four-year engineering degrees in the US. These numbers include not only engineers in traditional engineering disciplines, but also information technology specialists and technicians, as well.

- The study shows that when the numbers are compared on a level playing field that the annual production of bachelor's and sub-baccalaureate degrees in engineering, computer science and information technology awarded per million citizens, in the US is roughly 750 technology specialists, compared with 500 in the People's Republic of China and 200 in India.

- The reported number of engineers produced by the People's Republic of China in 2004 may very well include the equivalent of motor mechanics and industrial technicians and therefore the number of 644,106 for Chinese engineers may not be directly comparable to those in the US and India.

The result when the total populations are taken into account is nevertheless worth considering. In just a few years as these individuals begin to explore their creativity and their collective abilities, it is possible that the power of the collective mind will result in an explosion of ideas, designs, business concepts and activity, just due to the numbers alone without taken into account the cultural and social contexts for the individual nations concerned. This makes irrelevant the petty groupings and divides of designers, some of whom by practice, ignorance, snobbery or a lack of ability ignore the power of analysis and engineers, some of whom by practice, ignorance, snobbery or a lack of ability ignore the principles of form and industrial design. Such marginalisations where they occur in the UK and other countries will simply result in the demise of the companies and institutions concerned at a faster rate.

Comment

There are many ways in which design and engineering can learn from, and with each other. New materials, new technologies, new communication technologies and large, integrated projects for example offer dynamic real world learning opportunities.

The Centre of Excellence in Teaching and Learning (CETL) in Creativity project at Sussex and Brighton Universities began in 2005 and is building a strategic creative environment based on the pedagogic practices of the design course. The project's remit includes enhancing creativity in engineering and a number of related projects have already been funded. These include, for example, the creation of a laboratory to encouraging creative products from the outputs of 'playing with' new technologies, and the use of technology based blogs to encourage reflective journals among engineering students. Both universities are also building technology to enable creativity zones. Further details of these activities and the CETL in Creativity project in general can be found at http://www.sussex.ac.uk/tldu/1-2-11.html.

The Bologna agreement will come into agreement across Europe in the next 10 years and may also force a re-think of academic disciplines. For the well being of students, for the future of engineering, and the future of the planet, engineers should consider the re-engagement of creative practices from where their origins began. One place to begin might be with the pedagogic practices that design course are evolving.

6.   References

Biggs, J. Collis, K. Evaluating the Quality of Learning: the SOLO taxonomy New York: Academic
    Press. 1982

Conway report. A national Design Council. Council of Engineering Institutions. 1969.

Cox, G. Review of Creativity in Business. Department of Trade and Industry. 2005.

DEFRA (Department for Environment, Food and Rural Affairs) Market Transformation Programme.
    BNCK06; Kettle Trends. 9/2/2006

Duke University www.soc.duke.edu/resources/public_sociology/duke_outsourcing.pdf. 2005

Dutson, A. Todd, R. Magleby, S. Sorenson, C. A Review of Teaching Literature on Engineering
    Design Through Project Orientated Capstone Courses. Journal of Engineering Education. Jan
    1997.

Eco Design – an innovative path towards sustainable development. EU Commission Socrates 51388-
    IC-1-2005-1-RO-Erasmus-MOD. 2005

Fielden Report, Engineering Design. Department of Scientific and Industrial Research, London. 1963

Finniston Report. Engineering our Future. Department of Industry, HMSO. 1980.

Forum on Creativity in Engineering Education, International Journal of Engineering Education.
    http://www.ijee.dit.ie/forum/forum1home.html. May 2006.

Gereffi, G. and Wadhwa, V. Framing the engineering outsourcing debate: Placing the United States on
    a level playing field with China and India, 2005.

International Market News. Slovenia Market open to Kettle Culture. Hong Kong Trade Development
    Council, 8 April 2004.

Kulacki, F. Krueger, E. Trends in Engineering Education – an International Perspective. International
    Conference on Engineering Education. 1998.

Lovins, Hunter. Lovins, Amory. Weizsacker, Ernst. Factor 4. Rocky Mountain Institute / Wuppertal
    Institute for Climate, Environment & Energy

Molina et al. New Perpectives in Engineering Education. International Conference on Engineering
    Education. Proceedings of the International Journal of Engineering Education and Research.
    2003.

Morris, R. University of Brighton, BSc (Hons) Product Design Module DP104 Innovation and XEM03
    Innovation Strategy, 2001 to 2004

Morris, R. University of Brighton BSc (Hons) Product Design, Module DP301 Project. Independent

      Assessment by Davies, S. Mortezaei, R. 2005.

Owens, J.W. LCA impact assessment: A case study using a consumer product. Intl. J. Life Cycle

      Assessment 1(4):209-217. 1996

Papanek, V. Design for the Real World, London: Thames & Hudson. 1972.

Roszac, Theodore, Gnomes, Mary, Kanner, Allen (eds). Ecopyschology. San Francisco: Sierra Book

      Clubs, 1995.

UCAS (Universities and Colleges Admissions Service). http://www.ucas.ac.uk/ 25 May 2006.

Walter, Natasha. All the organic broccoli in the world won't be enough to save the planet. Guardian

      4.03.06

WWF, Global Warming and Terrestrial Biodiversity Decline, 2000.