Sustainability in Engineering Education and Knowledge

ENGINEERS AUSTRALIA



SEEK 6 - May 2008, Volume 1, No 1

A newsletter for Environmental Engineering Educators from Engineers Australia's College of Environmental Engineers

A new year of challenges, changes and beginnings...

Welcome to a new look SEEK. My role as the editor has begun with ongoing dramatic environmental change and many challenges to face in the near future. Embedding sustainability into undergraduate and postgraduate engineering courses is the primary interest for many readers of this and other editions of SEEK. But how is this fundamental need being addressed? An array of initiatives and delivery methods are required to ensure fundamental principles of sustainability are addressed and divulged to our future leading engineers. This edition brings to light some of the ways this can be addressed and embarked upon. Nurturing the principle of sustainability in all undergraduate engineers is paramount to ensure future leaders have the strategic skills required to tackle the world's ever increasing environmental problems.

In this edition Roger discusses the need for engineers to be skilled in four areas of expertise, all of which are required to be embedded in undergraduate engineering courses. Cheryl raises the time-lag dilemma we face and expresses the need for rapid embedment of new principles into undergraduate courses. Tony introduces a Masters of Design Futures which focused on design for the future for the creation a sustainable world. Last but not least, David introduces ideas from the College Board which, if implemented, might assist in ensuring the delivery of sustainability in courses through both accreditation and voluntary mechanisms. To assist in developing these initiatives the College proposes to convene a workshop back to back with the AaeE Conference to be held in Yeppoon, 7-10 December this year (see conference advert on page 4). The College will be reporting progress to the Conference and I look forward to meeting with many of you in Yeppoon.

If you have any feedback on any of the articles presented or you have an article that you wish to be included in the next edition feel free to contact me. Multiple ideas and thoughts will only strengthen the path in ensuring this important work is completed.

Rachelle Willis MIEAust
Editor SEEK, YEA College of Environmental Engineers

Interested? See page 8 for more details

Image of graduates: www.acis.pamplin.vt.edu

Engineering Education for Sustainability!

Assoc. Prof. Roger Hadgraft

Our world faces many challenges – climate change, drought, flooding, poverty, urban slums, water shortages, severe pollution, substance abuse, homelessness, profligate resource use, megacities, peak oil, land salinity, AIDS, malaria, and so on. It is already acknowledged that we are consuming the earth's resources faster than natural systems can recycle them[1] and that we are 'putting such a strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted'[2].

Within this scenario, what sort of engineers do we need to be educating for the 21st century? What capabilities will they need? What will their focus be?

We need a *new focus* for engineering, recognising that solving technical problems is no longer enough. In fact, many of the *predicaments* we now face will not be solved by technical means, but by social means. If engineers are to play a role in these issues, they will need much more than technical skills.

Consider water shortages in our major cities. In the 20th century, the solution was often to just build a new dam to satisfy growing demand. Increasingly, there are no new dam sites available or governments are reluctant to build on those that are available for fear of the environmental consequences (and the electoral backlash that may result). *Demand management* is a solution. This can be done in a number of ways, for example, through pricing, education or regulation. Increasing the price of water can change an industry's usage, where a small investment can lead to substantial changes in total water use, with consequential cost savings. Pricing has little effect on domestic consumption. Education (advertising) encourages domestic users to take shorter showers, install water efficient devices, check for leaks, etc. Regulation can restrict water use through limiting outside water uses such as garden watering, washing cars, filling pools, etc.

Thus, engineers must be skilled in *four* areas of expertise – the triple bottom line (economic, social and environmental) plus the technical. Solutions come from the economic (pricing), social (education, regulation), environmental (changing gardens to use less water) and the technical (more dams, fewer leaks, recycling, desalination). Engineers must now be skilled in all these areas, not just the technical.

If we look in more detail at how an engineer solves problems, she might use a process like this:

- Start with a client *need* and *goals* (criteria);
- *Plan* to undertake the work;
- *Research* to understand the problem, (leading to) the problem definition and scope;
- Identify *alternative solutions*;
- *Analyse* the options against the criteria and *choose* which is preferred;
- *Check* for correctness and a match with client needs; and
- *Recommend* a solution and document.

So, if this is the basic process that engineers use to solve problems, then the *skills* they need are: planning, research, problem definition, creative alternative generation, understanding and engagement in identifying selection criteria (using sustainability principles), analysis, decision making and report writing. These are the *new basics*.

Compare this list with the *old basics*, which includes mathematics, physics, chemistry, applied mechanics, fluid mechanics, thermodynamics, etc. These map onto the new basics through the *analysis* phase. It is clearly time to rethink how we practise engineering education.

Traditionally, we have used a long sequence of technical courses followed by a capstone design course. At a number of universities, more integrated curricula have been implemented, bringing technical and process skills together in each semester. This is sometimes called a project-oriented or *project-based curriculum*.

In first year, for instance, students could do projects to develop their conceptual design skills and help them understand the engineering design process within a sustainability context. These projects would be an opportunity to develop skills in project management, teamwork, written communication, oral presentation, debating, research and computing.

Later year projects should give students opportunity in *each semester* to integrate their technical skills with sustainability. However, the choice of project is almost always technical, at the moment, so students come to see themselves as technical problem solvers, instead of seeing the solution of problems within a social, environmental and economic context.

Second year projects in civil engineering could include the structural design of steel-framed and concrete-framed buildings. In third year, students could take a sustainable infrastructure design course, using sustainability concepts to develop a green design. In final year, students could design a suburb or small town, integrating all the technical elements within a sustainability perspective.

It is important to dissolve the distinction between process and technical skills, since they must be complementary. In this arrangement, the curriculum would start with the predicaments (rather than the discipline knowledge). Students uncover the technical skills as they engage with the predicaments. To make sure that they 'cover' all the important 'topics' a curriculum checklist could be used.

To develop the new basics, we need to model engineering education on engineering practice. This means that students must spend much of their time in complex problem solving rather than exercise solving. This is problem based learning (PBL). Without this approach, how will students ever see the complexity of real engineering problems, such as water supply, energy production, food production, etc?

How will we implement these changes? The most recent Review of Engineering Education suggests that universities must band together to develop learning materials to support students. There is now a great opportunity for SSEE members to work together with AAEE members to develop engaging project scenarios for project work from first to final year. These projects would develop technical skills as well as engineering process skills. A Sustainability Special Interest Group has been formed within AAEE to enable this liaison with SSEE. For more information, please contact me (roger.hadgraft@unimelb.edu.au).

References

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2. Millennium Ecosystem Assessment Board. *Living Beyond Our Means: Natural Assets and Human Well-Being*. 2005 [cited 2005].

Roger Hadgraft

Roger Hadgraft is a civil engineer with more than 15 years involvement in engineering education research focussed on problem/project-based learning and the use of technology to support learning. He has worked at Monash University and RMIT embedding graduate capabilities, specifically through a stream of project-based courses/subjects in civil, chemical and environmental engineering. Roger is the 2008 President of AAEE and is currently the Director of the Engineering Learning Unit at the University of Melbourne.

Chairman's View

Adj Prof. David Hood

I was delighted to see the ATN Group of universities sign a Declaration on Sustainability earlier this year in Perth. This declaration commits the group to a number of reportable actions for sustainability across the operations of their campuses and in the delivery and content of their academic programs.

The Declaration states that signatories must prepare for a changing future by building capacity to measure, monitor, and address the impacts of our ecological footprint, and notes that as partners of government, industry and business, and local communities the universities will play a lead role in inspiring a sustainable future.

The declaration then sets out six Principles to guide action by signatories as follows:

1. Promoting learning and teaching which addresses sustainability;
2. Promoting and creating opportunities for social outreach and community engagement in sustainability;
3. Integrating sustainability into decision making, management and university operations.
4. Fostering a culture of continuous sustainability improvement;
5. Creating University communities that that can proudly declare a contribution to sustainability; and
6. Collaborating with each other on sustainability activities and research.

I know of one case where an Engineering Faculty is now mobilising resources to ensure that it delivers on the declaration, and that it supports campus wide action across its university.

This is an encouraging move forward with respect to inculcating sustainability across all disciplines of engineering. However, without demonstrated commitment and encouragement from Deans and the Heads of Schools we run the risk of rhetorical only support with little real change in programs. For instance, I am disappointed to see some Faculties positioning sustainability within elective subjects, with little integration across their courses or its relation to others subjects.

Image of wave divider: www.designblog.org

It's very disheartening to hear latter year engineering students advise that they have not heard of a Code of Ethics for engineers, and that they did not connect sustainability with an ethical dimension.

On the global scale it is also disappointing to note that less than a third of Australia's universities have signed the Talloires Declaration of ULSF (University Leaders for a Sustainable Future). ULSF was founded over 16 years ago, but seems not to have gained the traction here that it enjoys elsewhere throughout the world. In a similar way to the ATN Declaration, Talloires spells out ten actions for signatories to pursue. Notably it calls for the creation of an institutional culture of sustainability within all universities.

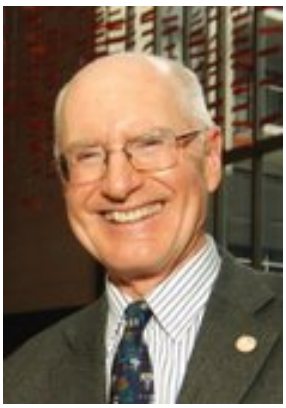
To assist in moving faculties toward a sustainability culture and the integration of sustainability into all subjects, the College will be examining mechanisms that might help. I have suggested that we approach the issue on two levels – the first being a mandating of minimum sustainability standards, or requirements through Engineers Australia's accreditation process. This will ensure that all programs in all disciplines deliver a desired minimum level of sustainability competence. The second level might be the availability of a voluntary sustainability rating for undergraduate programs. Such a rating system would reward those programs that seek to go well beyond the accreditation requirements, and would indicate to students and industry which courses were delivering graduates with the best, world leading grasp of sustainability and engineering's role therein. Such a voluntary system might build upon the TNEP sustainability audit process recently implemented by a couple of faculties. I would welcome thoughts on this dual approach to inculcating sustainability into our undergraduate programs.

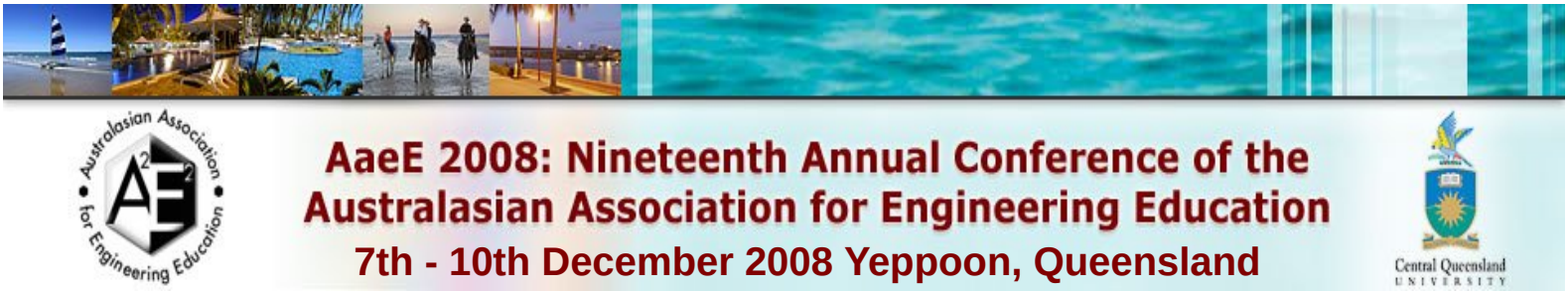
2007 Australian of the Year, Tim Flannery recently called on universities to disclose their sustainability position in order that students might be better able to assess which Faculties are really serious about sustainability. "*….Each year, ever more aware and committed young people choose which university they will attend. If they knew how far from sustainable most of these institutions were, many would be horrified and would probably alter their choice.*" Tim said. "*Students deserve to see a full assessment of the sustainability ranking of the institution they attend, and such information should be published in a newspaper such as The Age*." He added.

Meantime the College has also established sub-committees to:
a. revise and reissue the guidelines on Environmental Engineering programs;
b. review the engineering competency standards (Stages 1 and 2, and EngExec); and
c. assist with the development of new Stage 3 standards for professional engineers.

Again, I would welcome your input on this work. Please contact me or SEEK Editor Rachelle Willis.

David Hood FIEAust CPEng
Chairman, College of Environmental Engineers
davidahood@mac.com





The **AaeE 2008** will be held at **Central Queensland University**, Yeppoon, Queensland
7—10 of December 2008.

Some of the major themes include: Educational Research & Methods, Graduate Attributes, Work Integrated Learning and many more.
Expression of interest is now open and a call for papers has been issued with **papers due 31st July 2008**.

The Time-Lag Dilemma

Ms Cheryl Desha

As I sat in the auditorium at the Delhi Sustainable Development Summit in January this year I was surprised to hear Professor Jeffery Sachs declare that in order to respond to the challenge of climate change, '*... what is needed is good arithmetic, and good engineering and good economics, all combined.'* Followed by, '*We haven't done the work on that yet. But that is the work that we need to do in the next 2 years in my view – to show a path'* [1]. These statements coming from a world renowned economist, author and special advisor to United Nations Secretary-General, surprised me as he had effectively brought engineering up onto the centre-stage along with economics and then made the point that we have no time to loose in bringing them together. I had expected the Professor to talk about economics and industrial policy however his strong statement on the role of engineering had me questioning, '*Can engineering rise to this challenge in time?*'

This left me in quite a reflective state and at the end of the day's proceedings as I left the venue and made my way through the Delhi streets to my hotel, I began to consider the timeline Sachs was calling for, and the capacity of the engineering profession globally to meet the challenges of climate change and sustainable development. This is crucial to my research and I would like to briefly share my thoughts on the questions, *'What role can we as lecturers and curriculum developers play in equipping our students to address the challenges of climate change and sustainable development? And can we equip them in time?'*

Researching the leading reports on the topic, it appears that this level of urgency has been strongly echoed by a number of recent scientific and economic bodies and networks who have called for quite short timelines for action to address the challenge of climate change. These include the Stern Review [2], the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report [3], and the United Nations Environment Program (UNEP) 4th Global Environment Outlook Report [4]. The consistent message across these reports is that significant capacity-building across the professions is required, and that it needs to be rapid and accelerating. I knew that there had been a number of calls over the last two decades for capacity-building to develop engineering professionals, such as the World Federation of Engineering Organisations (WFEO) 1992 Arusha Declaration [5], the 1997 Engineering Education and Training for Sustainable Development Conference [6], the 2002 WFEO Report to the UN World Summit on Sustainable Development [7], and Forum for the Future's 2003 Engineer of the 21st Century enquiry [8]. Within Australia, Engineers Australia has also been playing a part in for calling for action since the mid-nineties, where David Hood played a significant role [9]. However, I hadn't realised that this view was now being so strongly expressed across the professions and by significant scientific networks and bodies.

To date the curriculum renewal progress has been largely *ad hoc* and fragmented [10]. To an extent this is understandable as the complex and gradual nature of curriculum renewal means that on the whole what is taught in universities lags behind industry best practice. However in the case of sustainability this needs to be addressed, as it is particularly important for education about best practice to lead sector-level implementation. Engineering educators are now faced with a dilemma that they may not be able to equip graduates with the necessary knowledge and skills to address climate change and sustainable development in time. This is due to the fact that timeframes to renew curriculum are now comparable to the estimated timeframes to address critical environmental issues. Indeed, depending on the educator's approach, curriculum renewal timeframes may even miss the opportunity to address key environmental issues altogether. My team and I have coined this the '*Time-Lag Dilemma*' [11], which is also illustrated in Figure 1 (over page).

Image of earth: lifestylelivingglobal.com

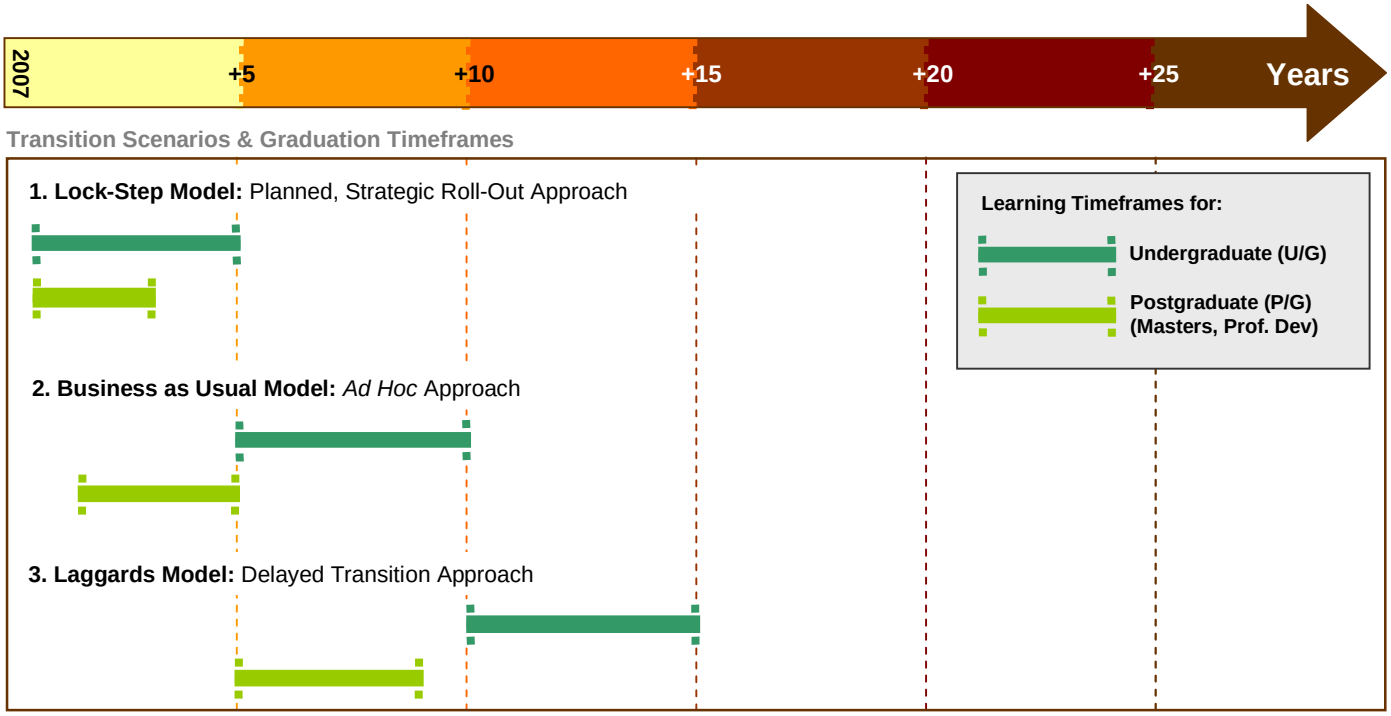


Figure 1. The Time-Lag Dilemma

Researching the approaches universities can adopt, broadly speaking, higher education institutions appear to have historically followed three main paths in responding to the need for curriculum renewal, in the face of changing knowledge and skills in the field:

1. *Laggards Model:* The institution does not respond to the change in the field of its of its own accord, but rather it delays any changes until there is a formal requirement to do so (for example due to accreditation requirements, executive management directives, Industry mandate etc). This approach exposes the institution to potential accreditation difficulties in the future, reduced industry appeal for graduates, reduced enrolments as students realise that the courses are outdated, and diminished access to research funding as the research proposals can no longer keep pace with the field.
2. *Business-as-Usual Model:* The institution responds to the change in the field, but only just enough to keep pace with its competitors. This approach exposes the institution to the potential for fragmented and overlapping curriculum development between discipline areas, gaps in curriculum resulting in potential accreditation issues, and new curriculum that does not necessarily meet the immediate needs of graduating students or future employers. There is subsequently the potential for reduced industry appeal and reduced enrolments, and financial implications from inefficiently allocating faculty resources.
3. *Lock Step Model:* The institution responds to anticipated changes in the field, choosing to undertake a strategic and systematic process of rapidly embedding the new and emerging principles, knowledge and application across the program/s offered. This approach minimises the potential for mismatching or misstiming the curriculum transition, student expectations and subsequently enrolments, and positions graduates to better meet changing industry demand.

Returning from Delhi I took another look at the various calls for action and was reminded that the IPCC cautioned in 2007 that we have a seven year window to achieve significant reductions in greenhouse gas emissions if we are to keep our global temperature increase under 2 degrees Celsius [12]. The IPCC presented scientific evidence to suggest that we have a limited timeframe within which we can halt further greenhouse gas accumulation in the atmosphere, preserving the planet's ability to regulate temperature within habitable boundaries [13]. Consider that it takes an average of three to five years to produce an engineering graduate, followed by at least three years of graduate professional development within the workplace leading up to independent status and possibly Chartered status where they can begin to effect change.

This is up to seven years, which is the same as the size of the window highlighted by the IPCC. As a sustainable engineering educator, it is sobering to appreciate that today's undergraduate students will not even start to influence change in addressing greenhouse gas (GHG) stabilisation within that timeframe.

So if stabilisation is in fact required in the next seven years as the IPCC puts forward, then today's undergraduates will miss the window to contribute to the stabilisation of greenhouse gas emissions. However they will play an important role in their careers to innovate and implement solutions to sustain efforts in emissions reduction over the coming decades to enable society to reduce emissions to at least below double pre-industrial levels, as many are now calling for. This does not mean that we can relax and leave undergraduate education for later. Given that it will take about a decade for graduates to be in significant decision making positions, higher education institutions have an immediate responsibility to equip today's undergraduates with new knowledge and skills. Indeed, the College of Environmental Engineers has been advocating change in undergraduate programs across all disciplines since it was founded eight years ago. We should remember also that the challenge of stabilising and sustaining emissions reductions is just one of the major challenges of sustainable engineering we will face in coming decades. If our profession is to join economists and indeed other professions 'centre-stage' to address climate change, the time-lag dilemma within our higher education system needs to be strategically addressed.

Given the increasing global concern about the impacts we are now seeing related to climate change, and the increasing potential for ecosystems to reach collapse thresholds, it is likely that we will experience either an abrupt environmental incident or an abrupt regulatory/market shift within the next decade which will drive the higher education system to transition to education for sustainable development. What gives me hope is that undertaking such a renewal of education will not only better prepare the profession to contribute to society's needs this century; it is also good business for the education institutions. Those who do address the time-lag dilemma will find themselves in a strong student recruitment position in addition to creating research possibilities for enhancing successful precedents in embedding sustainability within engineering curriculum. Those who rigorously research and trial elements of rapid curriculum renewal will not only position themselves at the forefront of research and teaching but will pioneer the curriculum renewal path that the 'business-as-usual' and 'laggard' institutions will be clamouring for in the not too distant future.

As I intend to use these reflections to direct my PhD research over the coming two years I would be grateful for, and look forward to, any comments (supportive or critical!) from readers (c.desha@griffith.edu.au).

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Education Director, The Natural Edge Project (TNEP); Lecturer, Griffith University. TNEP is currently hosted in-kind by Griffith University and the Australian National University, originally incubated as a special interest project within Engineers Australia (2002-2006).

Cheryl Desha is a lecturer in Griffith University's School of Engineering, in formal collaboration with The Natural Edge Project (TNEP). TNEP is an independent Sustainability Think-Tank administratively hosted by Griffith University and the Australian National University (www.naturaledgeproject.net), operating as a partnership for education, research and policy development on innovation for sustainable development.

Master of Design Futures – A trail-blazing degree

Adjunct Professor Tony Fry

During this century humanity could well confront challenges unsurpassed since its response to a changing climate 12,000 years ago. This is when, in the 'fertile crescent' of the Middle East, the transition from nomadic to sedentary life was initiated. Today, we are now perhaps on the edge of a movement from cultures of settlement to those of unsettlement. Certainly the impacts of climate change are still in an early stage and while some of its consequences are predictable it will undoubtedly take us into the domain of the unknown.

What is already clear is that the problems to be confronted are not just those conventionally understood as environmental. Certainly they are relationally connected. For instance, the still growing impacts of climate change links to an increase in natural resource related conflicts, potentially hundreds of millions of environmental refugees together with major redistributions of populations, as well as a whole raft of serious urban and rural development problems. Likewise, global inequality is indivisible from the proliferation of ecological damage. Moreover, the combination of a growing global middle class, a significant percentage of the world's poor trapped in their poverty and a still dramatically expanding world population poses major questions of the planet's carrying capacity.

The rate at which the condition of unsustainability is expanding, and becoming structurally embedded, is totally outstripping the creation of responses, technically, culturally and politically. Moreover, much that travels under the heading of 'sustainability' is still token, partial and underdeveloped. In fact, both in the built environment and in industrial production what is often being sustained is the unsustainable.

This is not an acceptable situation. If we are to have any choices about the form of the future we want for our selves, our children and those who come after them then 'we' have no option but to act with greater imagination energy and purpose.

To be in a position to act is to be in a position of privilege. Certainly with the advantages that Australia enjoys there comes ethical responsibilities to create and share pathfinding solutions nationally and internationally. 'Design Futures' is a way to name and develop this activity. It demands new thinking, ways of organising, practices and an enormous amount of grit and creativity. It means facing problems in all their horror and not being defeated by them. It means coming to understand that a significant part of the history of humanity, across all of its diverse cultures, is a history of attaining what seemed at the time to be 'the impossible'.

The one year Master of Design Futures program (with an additional one semester honours option) is being offered by Griffith University Queensland College of Art from July 2008 is one contribution to advancing design futures. It is open to any graduate from any discipline, including those of design, architecture and engineering as long as they have at least one and a half years professional experience. The program aims to trail blaze new kind's knowledge and practices (which it names and explores as 'redirective practices'). Its leadership ambitions are not just within Australian but internationally. In so doing, everyone who experiences the program will acquire not just an understanding of Design Futures but knowledge and skills able to open a new or supplemental an existing career path.

Besides providing conventional lectures and tutorials the program will also include a number of intensive 'hot-house' events. Individual research projects will be chosen in consultation with a research supervisor on the basis of self-selection or from a pool of options. These projects will be biased toward the application of ideas developed on the course to 'live' situations. The program's course elements are:-

- Investigative Procedures in Design
- Rethinking Context & Practice
- Strategic Design Thinking
- Design, Sustainment & Futures
- A Design Research Project

For more details see: www.griffith.edu.au/qca/design/programs/designfutures

Tony Fry

The course is led by Adjunct Professor Tony Fry. Tony is an internationally recognized design theorist, writer and educator. As a designer and consultant he has worked on many government and industry projects and has been a member of several award winning design teams. He has also consulted for IEAust and other professional organisations. His latest book *Design Futuring* is to be published in Australia, the UK and USA in November. Individuals and organisations wishing to contact him can email him at tonyfry@teamdes.com.au