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# A Y2K Imperative: the Globalisation of Engineering Education*

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The UNEP-WFEO sponsored conference held in Paris during September 1997 concluded that there was much to be gained through the international benchmarking of engineering degrees. A key outcome from this conference, which was attended by academics and business representatives from 27 countries, was a template for an international engineering degree. This paper explores the rationale for such a degree, highlights the advantages of *internationalisation*, analyses the environment that made such a proposal possible, and contemplates the probable nature of any obstacles to the implementation of such a program.

## INTRODUCTION

Over the last decade, there has been growing concern about three specific areas of engineering education:

- The ever increasing amount of engineering information to be included in a curriculum of no more than four years.
- An increasing requirement for engineers to accept accountability for their actions. This extends beyond the traditional professional-client relationship to one encompassing society and the environment.
- A growing need to adopt a universal consistency in engineering education, ie one that extends beyond the traditional *Washington Accord* which exists for developed, English speaking nations.

These concerns are manifest in a paradigm shift that reflects the way in which we, of the late twentieth century, perceive our surroundings. This new-found consciousness has particular relevance in technological, social, cultural and environmental systems, and these deserve further discussion:

- Technological

  The rapid growth of information technology since the 1970s has resulted in the globalisation of knowledge. It is now exceedingly difficult to suppress information or knowledge; ie there is an immediacy in the manner in which concepts and events are disseminated to the world.

- Socio-cultural

  The mid twentieth century marked a move away from traditional imperialism, the ’70s, ’80s and ’90s being characterised by the loss of empires of the then *Great Powers*. The results of this were twofold, an initial exuberance, generated from a new independence, and an inexorable change from politico-military to monetary subjugation. The latter we now recognise as the ubiquitous global market (and economy). The effect of the global market is similar to military dominance, but with one mitigating component: the concomitant development of information technology, where information is exchanged globally without significant hindrance. This has acted somewhat as a brake on elements deleterious to the biosphere and humanity.

- Environmental

  That the global environment is under threat is now widely accepted. Indeed, as we approach the new millennium, humanity is confronted with the alarming knowledge that all aspects of our biosphere are

* An expanded version of a keynote address presented at the *2nd UICEE Annual Conference on Engineering Education* held in Auckland, New Zealand from 10 to 13 February 1999. This paper was awarded the UICEE diamond award (first grade), by popular vote of Conference participants, for the most significant contribution to the field of engineering education

degrading. Although some of this degradation may be attributed to *natural* phenomena, eg effects of volcanism, much can clearly be attributed to human activities [1-3]. In New Zealand, the impetus for greater environmental stewardship is manifest in legislation through the Resource Management Act [4]. This Act requires all those who use and develop physical and natural resources to do so in a sustainable way, such that appropriate resources remain for future generations, and adverse environmental effects of any activity be mitigated or avoided. Penalties for non-conformance include imprisonment for up to two years, a fine up to NZD200,000.00 and further daily fines of up to NZD10,000.00 if the offence persists (RMA 1991: section 339).

The need for change has also been strongly voiced in Australia, and this is no more evident than in the comprehensive review of engineering education carried out in 1996 for the Institution of Engineers, Australia [5]. A series of recommendations, resulting from the work of *ad hoc* task forces set up, identified the following as critical factors for the engineering profession:

- There is increasing globalisation of industry, commerce and the professions.
- There are increased community expectations of professionals.
- Deregulation of key service industries is either occurring or planned.
- A more competitive business environment now exists, favouring small to medium enterprises.
- We are functioning under new management structures, built on telecommunication and information systems.

In particular the report focuses on the public perception of the engineer, acknowledging that past perception(s) have not always been favourable. Engineers are viewed as having a pivotal role in providing the interface between the community and technology. However, to best achieve this, they must be effective communicators as well as being able to demonstrate a high level of technological competence.

## IMPLICATIONS FOR Y2K

Engineers of the new millennium will be required to fully appreciate the *consequences* of their professional activities. To do this, they will need a broader education than is currently offered by many engineering faculties. In particular, the new engineer will need to work as a member of multidisciplinary teams that include scientists (eg ecologists and chemists), planners and economists. In light of this, engineers will need to demonstrate good communication and management skills.

Adoption of a *systems* approach to engineering and engineering *learning* is a most appropriate way to facilitate the development of those skills required to be effective *team players* [6]. It is also through systems thinking that concepts such as morality and ethical standards can be introduced. In short, this will provide engineers with an *intellectual template* with which to assess the validity (and appropriateness) of their actions.

Johnson alludes to the current ethnicity and gender imbalance that pervades much of the engineering profession/industry in Australia [5]. It is through greater involvement of these minorities that the educative process will be enhanced, and this will effect a more widespread acceptance of the greater role engineers must adopt in community affairs.

## THE WASHINGTON ACCORD

The Washington Accord, drawn up in 1988, is an agreement between the professional engineering bodies of Australia, Canada, Eire, Great Britain, New Zealand and United States of America. More recently, this has been expanded to include Hong Kong-China and South Africa. The Accord serves to benchmark both engineering degrees and the path to professional registration between the signatories. The net result has been a partial internationalisation of the profession, such that appropriately qualified members of one Professional Engineering Institution be admitted, upon application, to the relevant grade of membership of another Institution within the Accord *without* further examination or interview.

The underlying rational for the agreement was the high level of mobility of today's professional engineers and the international delivery of engineering services.

## THE 1997 PARIS CONFERENCE

Not surprisingly, the Washington Accord provides a significant strategic advantage to engineers from the *English speaking nations*[1]. This led to the dedication of an *ad hoc* workshop at the 1997 conference on Engineering Education and Training for Sustain-

[1] At present, moves are underway in Mexico to develop an accreditation system for engineering programs that will allow Mexico to apply for membership of the Washington Accord. If successful, Mexico will be the first *non English speaking nation* to join the consortium [7].

able Development held in Paris [8]. The objectives of this workshop were to:

- investigate the feasibility of an internationally benchmarked engineering curriculum; and
- produce a template for a *generic* program for the first year of an *international* Bachelor of Engineering.

Whilst the impetus for the conference was the integration of sustainable practice within all branches of engineering, the opportunity for developing a uniform standard in undergraduate engineering degrees, both in curriculum and assessment, was not missed.

A consequence of discussion at the conference was the view that sustainable practice would only eventuate if it was an integral part of *all* undergraduate engineering programs. Not surprisingly, a key outcome of the conference was a new template (Table 1), which is the basis for the first year of an international, generic engineering degree.

The primary difference between the two models is the way in which the new curriculum would encourage students to assess the place of the professional engineer in society and the environment critically. It is intended that this would be achieved by adopting a systems (or more holistic) approach to addressing problems and designing solutions.

Others have elegantly described the proposal as a move from *technical rationality to reflective practice* [9]. This is a significant paradigm shift from the traditional reductionist approach to engineering education [10]. If the new model is to be a success, it would also need to involve a greater integration of subjects, eg a recent student survey highlighted a need for concern at the way in which general courses such as mathematics are perceived (by students) as separate from specialist engineering courses, such as soil mechanics. (In the past, I have had to re-teach some soil mechanics students the use, ie contextual application, of fundamental mathematical tools such as simultaneous equations ... this within weeks of their having studied the theory in formal mathematics lectures).

Although the Paris conference addressed only the first year of the BE, economies of scale through common courses may also be anticipated in subsequent years (Table 2).

## THE PARADIGM CHANGE

It is of value to examine both the traditional and the new engineering curricula from an Input-Output-Outcome perspective (an *IOO model*). The traditional

Table 1: The proposed structure of the 1st year of an international engineering degree developed at the UNEP-WFEO workshop. This year is *generic* and as such will have appeal due to economies of scale. Courses in the new structure incorporate strong elements of systems thinking and sustainable practice: subjects that are not part of a traditional engineering degree.

| Old curriculum | New curriculum |
|---|---|
| **Physical Sciences**<br>• mathematics<br>• physics<br>• mechanics<br>• chemistry<br>• *logi*c | **Modelling**<br>• analytical<br>• computational<br>• conceptual<br>• introduction to systems |
| **Natural Sciences**<br>• biology<br>• geology | **Natural Systems**<br>• biological cycles and systems<br>• geophysical & geological cycles and systems |
| **Engineering materials**<br>• introduction to properties, use and production | **Engineering materials**<br>• introduction to properties, use and production |
| **Communication**<br>• written and oral presentations | **Communication**<br>• negotiation<br>• graphics |
| | **Strategic Solutions**<br>Introduction to:<br>• cleaner production<br>• life cycle management<br>• environmental management systems<br>• resource efficiency<br>• environmental design |

Table 2: Possible post first year common courses in a Bachelor of Engineering. There is opportunity to adapt part of each course to address concerns more pertinent to a *branch of engineering*.

| Course | Key elements |
|---|---|
| **Engineering Systems** (2nd or 3rd year) | Application of engineering principals in systems modelling |
| **Philosophy & Ethics** (3rd year) | The role of the professional, development of *notions of morality*, making choices, accountability |
| **Engineering Research & Development Methodologies** (3rd or 4th year) | Design, implementation & management of engineering projects; developing self discipline, meeting deadlines |
| **Assessment of Environmental Effects** (4th year) | Designing solutions; strong case study focus |

curriculum (Figure 1) has a very strong technical bias; this was appropriate at the time it was developed, where the ultimate focus was on the utilisation of nature's resources for man's benefit. Indeed, the Institution of Professional Engineers New Zealand's crest reflects this imperative:

> *Sable within an orle argent charged with another wavy azure and both affixed thereto by three chains in parlie the sun in splendour or* (ie the sun in chains - signifying man's domination of nature).

In the new proposal (Figure 2), environmental elements such as cleaner production and resource management are incorporated within an engineering context. Further, it is anticipated that much emphasis be placed upon *case studies*, where students are exposed to real (local) issues in engineering.

## PROBLEMS

It is presumed by some that a non-threatening, Utopian educational system would permit individuals to reach their true potential. This is a nonsense. Without stress, there is little incentive, without incentive, no innovation, and without innovation, stagnation. Fortunately, engineers are pragmatists and can view progress as a child of necessity, particularly since *positive* socio-cultural and technological metamorphoses traditionally follow periods of social stress.

It would perhaps be reasonable to assume that competition is good for progress. Ironically in New Zealand, where the secondary education environment currently lauds *co-operation* at the expense of *competition*, the *deregulation* of tertiary education has introduced a strong element of destructive inter-institutional competition. To succeed, universities will need to attract students (at the expense of others) from a finite pool. If programs offered by *adjacent* institutions are fundamentally the same, we can expect rationalisation, redundancy, and a move towards educational monopoly. This destructive form of competition places the very fabric of our current tertiary education system at risk.

## OPTIONS

If engineering education is to flourish in New Zealand, it will primarily be through adoption of sound, consistent, core engineering standards within the curriculum. In an environment in which it is certain that resources will remain scarce, we must be creative and develop *Centres of Excellence* within engineering schools. These centres, initially established to reflect regional strengths and needs, should complement each other, whilst still permitting the competition necessary to

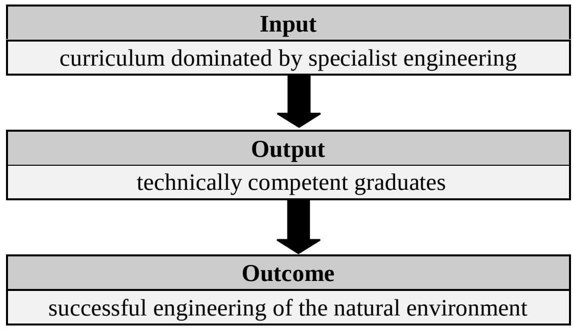


Figure 1: An *IOO model* of a traditional engineering degree. The curriculum was particularly designed to produce graduates with a high level of technical competence. The focus was on *output*, and the ethos reductionist, rather than holistic, reflecting the urgency with which society dictated engineering *tame nature*. Elements such as sustainable practice were either not envisaged, or deemed inappropriate.

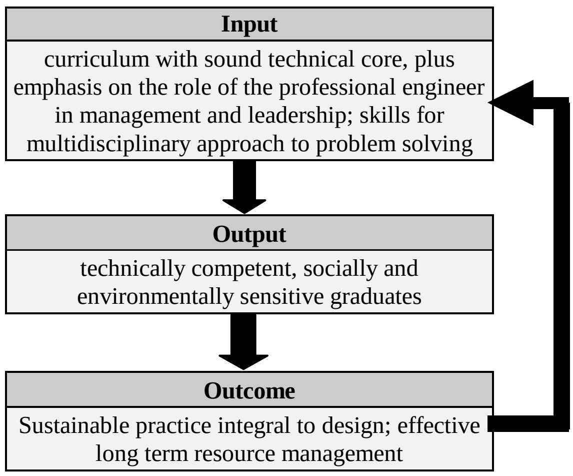


Figure 2: An *IOO model* of the *new millennium* engineering degree. The feedback loop (right hand side) measures effectiveness of the program on the basis of outcomes, such that input is being continuously modified.

effect good engineers. (We will need to be creative in the manner in which healthy competition is inculcated within the learning environment). Larger universities, like Auckland, will need to accept that *Centres of Excellence* will be developed within some of the smaller schools. It is anticipated that these centres will nurture specialist engineering courses, giving each school a unique character. Exchange of staff, and higher levels of student mobility can be anticipated. Scarce resourcing, currently channelled into institutional marketing, will be diverted into the learning environment, attracting the best young minds into the profession.

We can of course expect increasing utilisation of technology in education, and with this, extensive development of Internet learning. There are, however, flaws in adopting a totally computer-based learning program, especially if we wish to produce engineering graduates who are good communicators. The value of *live* components in our education system should never be underestimated, for it is in these situations that teachers can provide an insight into the essence of engineering: a passion and enthusiasm to design a better future.

## EPILOGUE

The reasons why individuals embark upon tertiary studies are clearly diverse. Those that elect to follow a professional program are likely to have a predilection for that profession, or are motivated by employment opportunities and remuneration.

Amongst the key functions that society deems universities accomplish is a *love of learning*. The opportunity for this must not be diminished, although it must be placed in perspective. Our institutions must provide engineering students with:

> *knowledge and the means to understand knowledge,* and *to instil an attitude towards a lifetime love of enquiry in learning*, whilst ensuring *that the educative process will provide graduates with the means of maintaining an appropriate standard of living* [11].

As we enter the 21st century, we can expect a continuing change in the engineering education paradigm. With a greater emphasis on systems thinking, the boundaries between the *established* disciplines within engineering will become less relevant. Although there will be a need for specialists, multidisciplinary approaches to problem solving will become the norm. Factors that continue to stimulate this are predominantly environmental: there are too many humans, and we are competing in a realm of fixed (or diminishing) resources, and in the process we are doing irreparable damage to the environment. For engineers to have a realistic opportunity to effect change for the better, they will need to be both international in their outlook, and multidisciplinary in their practice.

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## BIOGRAPHY

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He has professional interests in environmental engineering, professional ethics, engineering education and resource management. He is a member of the

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John has authored more than 100 publications and technical reports in his fields of interest. His most recent publications demonstrate a growing focus on sustainable practice and social responsibility within the engineering profession.