Designing the Future

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***Abstract**: While there have been improvements in Australian engineering education since the 1990s, there are still strong concerns that more progress needs to be made, particularly in the areas of developing graduate competencies and in outcomes-based curricula. This paper reports on the findings from a two-day ALTC-funded forum that sought to establish a shared understanding with the 3 stakeholders (students, academics and industry) about how to achieve a design-based engineering curriculum. This paper reports on the findings from the first day's activities and reveals that there is a shared desire for design and project-based curricula that would encourage the development of the 'three-dimensional' graduate: one who has technical, personal and professional and systems-thinking/design-based competence.*

Introduction

This paper presents selected findings from a two-day ALTC-funded regional forum held in April 2009 at the University of New South Wales, Australia, as part of the ALTC project "*Design based curriculum reform within engineering education"*. A forum was proposed for the project because of its effectiveness in focusing stakeholders towards the systemic issues necessary to improve design pedagogy throughout the curriculum (Dym, 2005). The forum brought together 40 leading academics from around Australia, 40 industry representatives primarily from within the Sydney basin and 20 senior students, to reconceptualise engineering curricula around a design core. An engineering design approach was used to consider how a curriculum based strongly around engineering design, that is: problem solving, engineering application and practice, might be achieved. While the forum had many aims, on the first day participants engaged in a structured workshop to identify emerging trends and needs, individual and organisational responses to these challenges, and from this, to specify the competencies which graduate engineers require. It is these findings which are the focus of this paper.

The current ALTC project builds on the outcomes and recommendation of a previous ALTC project report entitled "*Engineers for the Future: addressing the supply and quality of Australian engineering graduates for the 21st century*" (King, 2008). This report reveals that whilst progress has been made in addressing the concerns raised in a 1995-96 review of the national engineering education system (IEA, 1996 in King, 2008), there are areas that have not progressed as expected. The areas relevant to this project are:

- High levels of student attrition
- Lower incentives within the system for improving teaching than for developing research
- Effect of research appointments over teaching appointments and barriers to promotion
- Concerns that the balance of subjects within current engineering curricula are not adequately matched to graduates' and industry's current and future needs

It is the last of these areas that this forum sought to address synergistically with recommendation 3 of the preceding ALTC project report (King, 2008):
"Engineering schools must develop best practice engineering education, promote student learning and deliver intended graduate outcomes. Curriculum will be based on sound pedagogy, embrace concepts of inclusivity and be adaptable to new technologies and inter-disciplinary areas."

The forum focused on the following milestones within this recommendation:
- Increasing employer satisfaction with engineering graduates
- Increasing graduate satisfaction with educational experiences and transitions to employment
- Increasing recognition and empowerment of engineering educators within universities.
- Systematic and holistic educational design practices with learning experiences and assessment strategies that focus on delivery of designated graduate outcomes (King, 2008).

The first day's workshop activities were developed in order to converge quickly on a shared understanding of the required graduate competencies, without churning over old ground.

Methodology

A unique aspect of this forum was the active involvement of a broad cross-section of participants from industry (37%), academia (49%) and students (14%) totalling 80 in all. The participants generated a significant amount of data (286 lines of comments) from three activities. The comments were later transcribed and triangulated with onsite contemporaneous summaries from several researchers and references to the literature. The data was inductively analysed to reveal emerging themes/categories which were subsequently refined by construct validation (Trochim, 2006). The categories were examined from Activity 1 through to Activity 3 with the intention of identifying relationships which might suggest a narrative. That is, were there any obvious implications for curriculum reform emanating from the data? The results were also examined to determine whether the activities were sufficient as a convergent process for connecting future and current needs to competencies.

Day 1 session 1 consisted of keynote presentations followed by the three workshop activities. Each activity was introduced by the session convenor, with the focus question on a slide projected onto the screen. Participants were organised into 10 tables of 8, roughly distributed according to the overall demographics of the workshop. Each of the tables had butcher's paper, whiteboard pens and a scribe nominated by the group. Each activity had approximately 30 minutes discussion and scribing, after which a spokesperson from each table verbally summarised their results to the rest of the forum. At the end of each activity the butcher's paper was collected.

After the forum the comments were transcribed and then classified into categories by a domain expert. Two other researchers then separately classified the responses and agreed on the resulting categories with minor revisions. The classifications of comments within each category were then refined by the domain expert and one researcher; during this process the category descriptions were further refined either by aggregation into a dominant descriptor or through decomposition into complementary descriptors.

For example, *"need for increased breadth and depth of engineering degrees"* was decomposed into (1) *Breadth of knowledge base,* (2) *Depth of learning/authenticity* and (3) *Changing curriculum* to suit the interpreted emphasis/intent of particular comments. The refinement process was cross-checked and correlated by both main researchers. The categories were then tallied to reveal the top six themes, and the process was repeated with Activity 2. For Activity 3, the responses to the required graduate competencies were mapped against the CDIO syllabus (Crawley, 2001) as this taxonomy provides up to 4 levels of increasing specificity, allowing for a more accurate representation of the transcribed comments. The resulting competencies were then tallied to arrive at the top six.

Results and Analysis

There were a substantial number of categories (24 in total) identified from the transcripts as indicated in Table 1.

Table 1 Total Identified Categories

Social Awareness	Public Perception
Breadth of Knowledge Base	Increased Specialisation
Practical Experience	Design
Environmental Awareness	Rapid Changes in Technology
Effects of Globalisation	Engineering Systems
Scale or Scope of Engineering Problems	Professionalism
Research/Teaching Dilemma	Changing Student Demographics
Mobility and Transferable Skills/Qualifications	Lifelong Learning
Depth of Learning/Authenticity	Engagement
Changing Engineering Definition	Changing Engineering Problem Focus
Changing Academic Demographics	Changing Curriculum
Pathways to Engineering	Communication

Activity 1 asked the participants: *What emerging trends in the environment are having an increasing impact on engineers and engineering organisations?* The top six emerging trends are shown in Table 2.

Table 2 Activity 1: emerging trends – top 6 categories

	%	category
1	22%	impacts of globalisation
2	21%	environmental awareness
3	18%	breadth of knowledge base
4	18%	engineering systems
5	13%	rapid changes in technology
6	13%	research/teaching dilemma

In activity 2 the participants were asked: *How are you (and your organisation) dealing/coping with the pressures to survive and thrive in this emerging environment? How are engineering educators adapting? How are universities adapting?*

This question was asked to prompt the participants to reflect (individually or organisationally) on the strengths/strategies and/or weaknesses/gaps that exist in response to the opportunities or threats presented by the external environment. The question was posed in this way in the expectation that gaps in the competencies of employees and future graduates would be identified in the subsequent activity. The top six responses are shown in Table 3.

Table 3 Activity 2: responding to change – top 6 categories

	%	theme
1	29%	changing curriculum
2	18%	practical experience
3	18%	impacts of globalisation

4	12%	research/teaching dilemma
5	12%	navigation (pathways to Engineering)
6	11%	breadth of knowledge base

In the final workshop activity in session 1, participants were asked: *What capabilities will employees, and specifically graduate engineers require if they are to effectively contribute to their organisations and communities into the future?*

Table 4 Activity 3: top 6 graduate capabilities

	%	CDIO	capabilities
1	26%	2.4	personal skills & attitudes
2	19%	3.2	communication
3	17%	4.4	designing
4	14%	3.1	teamwork
5	12%	2.3	systems thinking
6	12%	4.3	conceiving & designing engineering systems

From the resulting analysis it would appear that the questions served to focus the participants' attention effectively on the three dimensions: emerging trends; organisational responses; and graduate competencies. However, it should be noted that the responses to Activity 2 were framed more as needs/gaps than responses. While at first glance there appears to be very little commonality indicated by the dominant categories across the three activities, there is some degree of convergence from the general to the specific; moreover, it is often easy to infer whether the source of the comments is from either industry or academia. In terms of temporality, the comments are strongly focused on current issues rather than envisaging issues far into the future. For example in Activity 1 the impact of globalisation category is strongly industry focused, reflecting their awareness of the increasing internationalisation of business and the threats this poses to Australian engineering industry.

Table 5 Activity 1: Impact of Globalisation comments

Growth of China/India/Russia	Connectedness of all economies
Rely on outsourcing	Diversification of clients
Multi-cultural and multi-disciplinary	Cheap labour

In Activity 2, the industry participants clearly communicated the ways in which their organisations are responding, with the overwhelming majority of responses identifying outsourcing work requiring specialist knowledge in order to remain globally competitive and the consequent risk that this poses to the company:

Table 6 Activity 2: Impact of Globalisation comments

Outsourcing/alternative suppliers for services	Industry relying on outsourcing to solve problems
Global hiring and outsourcing	Increased outsourcing of expertise
Automotive is outsourcing more detailed work and industry is multidisciplinary	

In Activity 3, there was a particularly strong preference (45%) for improved personal and interpersonal skills and attitudes as well as a broad range of communication skills. This aligns well with the competencies required of a graduate who enters Australian engineering companies nowadays. These companies are becoming increasingly integrated into the global supply chain as local subsidiaries of large multi-nationals with head offices, manufacturing and distribution points that are more often than not geographically distributed worldwide. As little as 10 years ago, a new graduate could expect to settle into a narrow and junior role of technical problem solving for 4 or 5 years while they learned the ropes. However, the increasing availability of low cost technical expertise in the areas of detailed analysis and information technology from India and China now provides a far more attractive economic option. Therefore, today's graduate can look forward to quickly transitioning to what was once defined as a management role that involves communicating with and coordinating large numbers of people through a range of media, such as emails, letters, documentation, technical meetings and drawings. This viewpoint is supported by preliminary research into what engineers actually do in industry, suggesting that a far broader range of knowledge and skills are utilised, focused primarily on communication and coordination (Trevelyan, 2007). If we add the remaining competencies, identified as *systems and holistic thinking*; *framing and solving complex problems (designing)* and *teamwork*; and envisage what would be required to address these requirements, a picture emerges of a curriculum that is likely to be unrecognisable by academics and students within Australian universities today.

Discussion

From this analysis emerges a clear preference expressed by industry, students and academics for the three-dimensional graduate as opposed to the “traditional stereotype of the asocial [two-dimensional] geek” (Wulf & Fisher, 2002, p. 2). Of special note was the frequent occurrence of comments relating to ‘big picture thinking/holistic thinking’. This is not to say however, that a dilution of in-depth technical knowledge is acceptable. The core technical knowledge which forms the backbone of the traditional engineering curriculum is assumed as given. With this in mind, the three dimensions can be seen as: technical; personal and professional; and systems thinking/design-oriented competence.

Interestingly, the most strongly identified theme in Activity 2 (Table 3) was in the area of “changing curriculum”, both in the context of what needs to happen and perceived shortfalls of the traditional curriculum model. The comments relating to changes in curriculum are predominantly expressed as what needs to happen/is not happening (14 needs, 8 observations). Sample comments in this theme include: *some unis have reduced contact hours; pressure on curriculum; universities and engineering educators are adapting very slowly – maybe too slowly?* These comments demonstrate awareness both that changes in curriculum need to be made, and that institutional barriers including an over-emphasis on research to that of teaching are preventing changes from occurring. From the overall thematic analysis of these responses, it is clear that the main needs identified are in the areas of curriculum, (including breadth of knowledge base), practical experience and perhaps research/teaching dilemma (in the realm of valid/authentic teaching/learning experiences, which are not necessarily found in the researcher’s arsenal). Overall, approximately 70% of the comments focused on needs in the areas of teaching, learning and curriculum.

Throughout the responses to the activities there are also two viewpoints which perhaps define the boundaries of the solution space and which complicate any proposed curriculum response. The first view is that the 4 year undergraduate professional degree program is simply not capable of addressing the long list of higher order Engineers Australia Stage 1 Professional competencies; this is also reflected in the literature: “it is unrealistic to attempt to develop strong management capabilities without seriously impeding the development of the foundation technical competencies, which are crucial for the engineering graduate” (College of Mechanical Engineers, 2007, p.2). This view however, presupposes a traditional curriculum where these management skills are provided as “broad courses in management areas...” (College of Mechanical Engineers, 2007, p.2). One of the main points in our project is that we see academics viewing this issue as one which can be solved by extending the degree to accommodate additional content.

The other view being put forward is towards a more fundamental rethink of the curriculum, bringing into question the seemingly inviolate belief in establishing the foundations of mathematics and science before practice and professionalism. In this (integrated or network curriculum) approach “the goals for student learning are integrated under the overarching goal of professional formation, positioning students to continue their development” (Sheppard et al., 2009, p.191) as lifelong/self-learners in the same manner that will be expected of them upon graduation as exemplified by the Engineers Australia Continuous Professional Development (CPD) requirements. A logical approach, (although involving a radical challenge to the dominant paradigm) is to restructure the curriculum, maximising the degree of alignment and integration between depth and breadth, for example through design and project based learning models. This allows the retention of a 4 year degree program which can capture the growing market niche.

Conclusions

For those involved in engineering education many of the reported findings from the forum, while interesting, are not front page news. The desire for a more three-dimensional engineering graduate has been the focus of several national and international reports, all with almost interchangeable titles (*Educating Engineers, Engineers for the future, Educating Engineers for the 21st century).* The novelty and value of the findings lie firstly in the fact that this consensus came from a shared understanding arrived at conjointly by the three key stakeholders within the context of the ALTC Forum, and especially that the voice of the students was seen to be of equal weight with those of the other stakeholders. Secondly, this understanding emerged from a qualitative analysis of the workshop activity responses, allowing a narrative of sorts to emerge. Finally, and perhaps most importantly, the willingness of the three stakeholders to participate in such a forum demonstrates most cogently the need for a [re]design curriculum in engineering. Our project will continue to explore these issues in more depth.

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