Chemical engineering education is challenged around the world by demands and rapid changes encompassing a wide range of technical and social drivers. Graduates must be prepared for practice in increasingly diverse workplace environments in which generic or transferable attributes such as communication and teamwork together with technical excellence are mandated by prospective employers and society at large. If academe is to successfully deliver on these graduate attributes, effective curriculum design needs to include appropriate educational processes as well as course content. Conventional teacher centred approaches, stand-alone courses and retro-fitted remedial modules have not delivered the desired outcomes. Development of the broader spectrum of attributes is more likely when students are engaged with realistic and relevant experiences that demand the integration and practice of these attributes in contexts that the students find meaningful. This paper describes and evaluates The University of Queensland’s Project Centred Curriculum in Chemical Engineering (PCC), a programme-wide approach to meeting these requirements. PCC strategically integrates project-based learning with more traditional instruction. Data collected shows improved levels of student attainment of generic skills with institutional and nationally benchmarked indicators showing significant increases in student perceptions of teaching quality, and overall satisfaction with the undergraduate experience. Endorsements from Australian academic, professional and industry bodies also support the approach as more effectively aligning engineering education with professional practice requirements.

Keywords: graduate attributes; generic skills; project centred learning; engineering education.

INTRODUCTION

Chemical engineering education is challenged around the world by demands and rapid changes encompassing a wide range of technical and social drivers. Engineers are now subject to much more flexible work assignments, taking on a variety of roles within and across organizations. Planner, designer, constructor, operator, manager, community liaison officer are just some of the roles. Engineering has always been a multidisciplinary profession but now this aspect is even more relevant as engineers routinely work alongside town planners, health professionals, biologists, local communities and the legal profession. Today’s graduate faces increasing process complexity and new processes, the merging of former disparate areas, highly integrated industrial projects, increased work assignment flexibility, increasingly multidisciplinary projects and increased communication needs. The focus at the workplace can be incredibly broad. Engineering is now ‘contested terrain’ and many academic educators are still working to an old paradigm often divorced from reality and reluctant to admit it (Williams, 2003).

This paper discusses the need for new approaches to chemical engineering education and presents a case study showing how these drivers for change can be seen as a framework for initiating and guiding curriculum change to more effectively align educational practices with professional and societal demands. Chemical engineering at The University of Queensland (UQ) now uses a Project Centred Curriculum (PCC) that systematically and strategically introduces different programme-wide curriculum design methods and teaching practices to address the demands arising from rapidly changing workplace and societal environments.
BACKGROUND: THE MOTIVATION FOR CHANGE

The Engineering Profession's Perspective

There is a global paradigm shift from solely content to outcomes driven engineering education which underpins much of the educational reform currently being undertaken by universities, government and professional organizations around the world. In Australia, a national review of Australian Engineering Education (IEAust, 1996) called for change in the culture of engineering education. It reported an emphasis on technical skills and not enough cognizance of the broader role of engineering practice. Engineering education was challenged to become more attuned to community and global concerns, including political and cultural sensitivities, sustainable development and environmental issues. The review also called for graduates who were better communicators, team workers, effective independent learners, creative and innovative problem solvers. In line with the review recommendations, accreditation of engineering professionals in Australia is now based on demonstrated development of graduates with attributes reflecting these values as shown in Table 1. In the USA, the Accreditation Board for Engineering & Technology (ABET) introduced EC (Engineering Criteria) 2000 in 1997, criteria for accrediting engineering programmes. This signalled a similar shift and introduced accreditation based on outcomes rather than inputs, thereby enabling flexibility and the intention to drive innovation in engineering education (ABET, 1997). In the UK, organizations such as the Institution of Chemical Engineers (IChemE) also introduced accreditation processes based on learning outcomes including awareness of the broader contexts of engineering practice (IChemE, 2001). Similar drivers are also evident in other European countries, including Scandinavia where there is no accreditation of engineering degrees. Alliances between industry and university are being used to guide curriculum reform. For example, the CDIO™ (Conceive, Design, Implement, Operate) initiative is aimed at the realignment of engineering education and practice (CDIO, 2005a). CDIO™ was first implemented in aerospace, mechanical and electrical engineering, and is now being migrated to other disciplines including chemical engineering (Vigild, 2005). The condensed CDIO™ syllabus (CDIO, 2005b) identifies 73 desired items in four overarching themes of: Technical Knowledge and Reasoning; Personal and Professional Skills and Attributes; Interpersonal Skills—Teamwork and Communication; Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context.

The Higher Education Perspective

Australian universities including The University of Queensland (UQ) also claim broad generic graduate attributes as outcomes of their educational systems. These attributes are meant to transcend disciplinary knowledge and contexts. For example, The University of Queensland in 2001 articulated the development of a set of graduate attributes that specified broad core knowledge, skills, attitudes, values and qualities all of which are compiled as a list of essential outcomes for all university studies irrespective of discipline (UQ, 2001). Table 2 shows the abbreviated list of UQ attributes which are mapped to UQ course descriptions (UQ, 2000). The marketing by universities of such attribute statements is part of the changing higher education landscape in Australia. Various national surveys and reports to the Australian Government Department of Education, Science and Training (DEST) including Employability Skills for the Future (Australian Chamber of Commerce and Industry & Business Council of Australia, 2002) and Employability Skills (Allen Consulting Group, 2004) chart a national interest in identifying, recording and developing employability skills needed by Australian industry and business in the future. The Employability Skills for the Future report of March 2002 identified eight key skills which together with personal attributes are consistent across industry sectors and which may be seen as universal ‘indicators of employability’. These also transcend disciplinary boundaries and are seen as an important issue for future development in the educational sector where there is likely to be increasing accountability for student learning in these areas. At the same time, declining financial support from governments and deregulation of the nationally funded tertiary education sector, sees students making increased contributions to their education costs. Tuition fees introduced in 1989 (Higher Education Funding Act, 1988) were until recently nationally controlled and uniform. From 2005 universities may also levy additional fee increases up to a marginal maximum of 25%. Such changes impact universities’ attempts to attract the best and brightest students and differentiate themselves in an increasingly competitive and discerning market.

These lists of attributes are also reflections of the desires and needs of the community, industry and employers, and

<table>
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<tr>
<th>Recommendation 3.2:</th>
<th>That engineering schools demonstrate that their graduates have the following attributes to a substantial degree:</th>
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<tr>
<td>(1) Ability to apply knowledge of basic science and engineering fundamentals,</td>
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<tr>
<td>(2) Ability to communicate effectively, not only with engineers but also with the community at large,</td>
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<td>(3) In-depth technical competence in at least one engineering discipline,</td>
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<td>(4) Ability to undertake problem identification, formulation and solution,</td>
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<td>(5) Ability to utilize a systems approach to design and operational performance,</td>
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<td>(6) Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member,</td>
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<td>(7) Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development,</td>
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<td>(8) Understanding of the principles of sustainable design and development,</td>
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<td>(9) Understanding of and commitment to professional and ethical responsibilities,</td>
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<td>(10) Expectation and capacity to undertake lifelong learning.</td>
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the changing workplace and social environments in which our graduates work and live. They are also intended to inform curriculum design and delivery in an even broader sense than employability alone.

These attributes irrespective of their source can be clustered into three categories:

- Internal Knowledge which relates to knowledge acquisition and cognition,
- External Wisdom which relates to the application of that knowledge and creativity, and
- Personal Connections meaning engagement with society, within a discipline, across disciplines and society at large.

The first of these categories relates to the understanding of data, information and concepts within a specific discipline area—forming frameworks of understanding and systems thinking. Knowledge in itself is often sterile. The application of that knowledge to the identification of key challenges and the development of innovative solutions relates to wisdom, whilst the third category addresses the abilities to engage with a broad constituency of people to effect meaningful solutions and change (Cameron, 2004).

All need to be addressed by today’s engineering curricula.

**Engineering Education: Do We Measure Up?**

Despite this trail of reviews and reports identifying changing times and needs of engineering, education including chemical engineering education is still reported globally as failing to deliver on these challenges. The recent report (World Chemical Engineering Council, 2004) on a survey of 2158 young chemical engineers in 63 different countries claims that chemical engineering education is still too research oriented and has evident shortcomings with respect to important skills and abilities needed in employment. This is associated with declining employment in industrial research and growing involvement in a broad range of alternative employment options. The survey found that an appreciation of the potential for research and an ability to apply knowledge of basic science are the two attributes rated as more important during education than employment. It also lists other attributes required to a greater extent at work than are developed during education. The report identified the most important abilities for employment as:

- ability to work effectively in a team;
- ability to analyse information;
- ability to communicate effectively;
- ability to gather information;
- self learning ability

All were identified as needing further attention in the engineering education sector.

In Australia, a national report to government *Employer Satisfaction with Graduate Skills*, (ACNielsen Research Services, 2000) reported that the greatest skills deficits in new Australian university graduates generally were in the areas of creativity, oral business communication and problem solving. Engineering graduates were perceived to be poor in all of these and significantly in many other areas especially interpersonal skills (ibid, p.viii), critical and independent thinking, and comprehension of business practice and motivation (ibid, p.26).

The challenge for educators confronted with these pressures is to recognize the current trends of the market place and to introduce curriculum development that takes account of these changes. We must find ways to transform engineering curricula if our graduates are to continue to be in demand. If not we are doomed to irrelevance as students vote with their feet and move to different areas.

**METHODODOLOGY: CURRICULUM TRANSFORMATION**

Attribute statements are a product specification or a set of requirements. They can be seen as opportunities and guidelines for educational innovation. But how does one turn the words into reality? How do we move from a purely content driven education to one built around requirements that are both outcomes and content based?

It is our experience that curriculum designed ‘top down’, starting with key graduate attributes is an effective ‘systems approach’ to providing a unifying and coherent framework for course development. This design approach systematically provides learning experiences that are realistic, relevant and generates stimulating opportunities to address these attributes. Attributes are associated with clusters of learning objectives, each of which are linked to learning activities, assessment activities and measures of achievement. These processes contribute to the definition and demonstration of the attributes according to the pedagogical model shown in Figure 1 (Humphries and Jolly, 2003).

The identification of learning objectives is in essence a definition of the ‘content’ of a curriculum. However, the linking of these to attributes via learning activities and assessment criteria and standards, both formalizes the ‘content’ and characterizes the educational ‘processes’ that can be used to appropriately target the attributes.

We argue that both ‘content’ and ‘process’ must be an integral and interdependent part of curriculum design as the nature of the attribute profoundly affects the processes through which it can be targeted. Consider for example the attributes from Tables 1 and 2 relating to knowledge of field, depth of knowledge and ability to apply fundamental knowledge. No one questions the continuing need for technical knowledge—it is essential, but assessing knowledge is relatively straightforward. The traditional-instructor centred approach to education so pervasive in engineering schools produces graduates with acceptable technical knowledge. Where engineering schools need to improve in particular is in the development of skills in communication, problem solving, independent and critical thinking and interpersonal qualities (ACNielson Research Services, 2000). However, developing and assessing skills is much more complex and requires different educational processes. We cannot produce graduates capable of effective team
Chemical engineering at UQ reviewed the engineering education literature, consulted widely with various stakeholder groups and has responded to the challenge of embedding the development of graduate attributes by using an integrated project centred curriculum. The following case study describes the project centred curriculum, presents data assessing its effectiveness in delivering graduate attributes and concludes with an evaluation of the approach.

OUTCOMES AND ANALYSES

Project Centred Curriculum: The Design

Project Centred Curriculum (PCC) (Crosthwaite et al., 2001; Crosthwaite and Cameron, 2005a, b) is an integrated, whole-of-programme approach to curriculum design. The goal is to provide a structured sequence of professional practice simulations as a vehicle for systematic and simultaneous development of graduate attributes, both technical and generic. The simulation of professional practice scenarios is a means to provide realistic and relevant contexts for the integration and development of attributes. Our understanding of the term attribute is significant in this respect. Barry (2004) identifies four classes of conceptions of graduate attributes commonly held by academics. The four classes are a progression from:

1. Foundation skills which are expected and separated from discipline skills;
2. Personal skills which are considered important, but are still separate and independent of discipline;
3. Clusters of personal attributes, knowledge and skills separate from, but enabling the application of and not seen as independent of discipline knowledge; and
4. Abilities essential to and integrated with discipline knowledge and learning.

It is the intention of PCC to engage students at levels 3 and 4 of this attribute progression. Hence the importance of adopting curriculum design and teaching strategies that integrate skills and practice applications in a disciplinary practice context. Given that The University of Queensland’s engineering degrees are delivered as a campus-based education, the most practical approach to achieving this is team project work as simulation of professional practice.

The innovation is the inclusion of a spine of project work that spans the entire programme and is supported by and integrated with all core teaching and learning activities. Engineering degrees in Australia are 4 years (eight semesters) of full-time study. PCC mandates that each semester, one compulsory course is project centred. That is, it specifies particular instructional processes as part of the curriculum design. This means that teaching and learning activities in project courses, including assessment, are centred primarily on a substantial team project(s). The sequence of project centred courses (see Figure 2) is the key to the whole of curriculum approach to the cumulative development over 4 years of both discipline specific technical and transferable generic graduate attributes. Its central position in the curriculum is evident by the project component accounting for one quarter of the entire programme. It is a structure that makes limited, but effective use of projects.
rejecting the need to transform the whole curriculum to problem based mode.

Projects are designed to be substantial pieces of original work that simulate real engineering practice using topical tasks and problems sourced from industry and research. They encompass real scenarios that incorporate diverse factors, views and perceptions and therefore provide opportunities to develop both technical and generic skills in communication, teamwork and independent learning in a professional practice context. Projects are undertaken over a period of around 6–13 weeks by a team typically consisting of four to six students. The projects are designed to elicit research or discovery based learning. There is no pre-determined or known specific outcome. For example students studying mass and energy balances undertake a competitive role play where they prepare a proposal to undertake a multi-site audit of a prospective client company’s dryers. They must demonstrate both technical knowledge and competencies relating to mass and energy balancing and an ability to sell their team and its case to the client through oral and written presentations. Teaching in the course explicitly prepares students in these areas and there is a clearly articulated expectation that success is dependent on both technical, and communication abilities. Students enthusiastically embrace the role plays, and they are effective in the simultaneous development and practice of technical, communication and interpersonal skills.

Future papers will describe in more detail the characteristics, implementation and assessment of these projects and the project courses. Projects are also a vehicle for integrating content and skills development from other concurrent and previous courses as shown in Figures 2 and 3. This establishes a unifying teaching and learning framework across discrete course modules and enables articulation of connections that were previously not evident to students (Smith and Watt, 2000). Management and quality control of the 4-year curriculum is also undertaken collaboratively using the model shown in Figure 3.

As students move through the programme, the projects progressively increase in the extent of open-endedness, ambiguity, uncertainty, complexity, technical challenge, scale, breadth, creativity and all such factors that contribute to emphasizing and building real professional practices. We cannot address every item listed in Figure 3 in every project course. But the repeated and cumulative exposure to team projects means we can ensure that on completion of the programme all are an integral part of the core curriculum. As an example, consider the requirement for engineers to be able to communicate with people without a technical background. One of the ways in which we address this is in another project role play, of technical advisors to a public relations group. This is in the second semester of the second year. Students prepare and present material suitable for a company bill board or public relations brochure.
that informs the general public on a process, its constituent units and structure, and its impact on the economy, environment and society. In later years students undertake further role plays representing special interest and lobby groups at community information meetings and debates.

What Do Our Graduates Say About PCC?

Since implementation was completed in 2001, there has been extensive assessment of PCC to assess its teaching and learning qualities and in particular issues associated with developing graduate attributes.

Team project courses consistently rate higher in terms of overall student satisfaction compared with conventional engineering science courses. Standardized university administered course evaluations indicate a high degree of student satisfaction with project courses. For example both second year project courses have scored an overall (Hi) level of student satisfaction since 2002, meaning they are considered to be in the top quartile.

Chemical Engineering also conducts its own annual graduate exit survey. Results from this in-house survey show high levels of overall satisfaction with the PCC undergraduate experience. In the survey, students are asked to respond to a series of questions asking for their level of agreement with statements on their satisfaction with their undergraduate experience and on their perceptions of acquisition of skills. Responses are scored on a 5 point Likert scale where 1 means strongly disagree, 2 means disagree, 3 is neutral, 4 is agree and 5 is strongly agree. Return rates of this survey are in excess of 80%. Response rates to individual questions are generally greater than 55% and therefore are a strong measure of the total cohort experience. The overall satisfaction indicator from this survey is shown in Figure 4 along with a cluster of individual indicators relating to the development of particular generic graduate attributes. These include the student’s confidence in their ability to use knowledge and skills acquired to tackle new and unfamiliar work (confidence in transferability), their team working capabilities, problem solving skills, communication skills and their ability to explore new ideas with other people (collegiate inquiry). Inspection of these scores indicates much higher levels of confidence and satisfaction than pre-PCC assessments (Smith and Watt, 2000). All chemical engineering students were surveyed during 1999 on their 1998 student experience.
experience and courses. Individual courses were assessed in terms of 15 themes and additional survey items included inquiry into the student experience in cohort and discipline engagement, coordination and clarity of links between courses, workload, acquisition of graduate attributes and availability of elective choice. Pre-PCC:

- Fifty percent of final year students found previous courses were not coordinated to articulate clear links between them,
- Sixty percent of courses did not encourage students to practice using knowledge and skills acquired in the course,
- Sixty percent of courses did not result in students believing they were acquiring an understanding of the subject areas,
- In 55% of courses, students were not confident that they would be able to use skills and knowledge to tackle new, previously unseen situations,
- Fifty-five percent of courses were rated as not intellectually stimulating,
- Only 38% of third year and no second courses, respectively, were rated as satisfactory overall by 70% or more of students.

When compared with 2004 graduate exit survey results which found that:

- 94% of final year students believed the programme had developed their problem solving skills;
- 83% were confident in their ability use skills and knowledge to tackle new, previously unseen situations;
- 83% found the courses intellectually challenging;
- 4% of students were not satisfied overall with the programme quality;

this represents a significant improvement in the cohort experience.

Nationally benchmarked indicators of graduate perceptions corroborate the improvements in quality arising from the introduction of PCC. The Course Experience Questionnaire (CEQ) is Australia’s nationally administered annual graduate survey. CEQ indicators of good teaching, overall satisfaction and generic skills indices (Graduate Careers Council of Australia (GCCA, 1999–2004) are shown in Figure 5. From being below or on a par with the national average as seen in the 1999 data, indicators have risen to well above the national average after PCC implementation was completed in 2001. Results are scaled from $-100$ expressing extreme dissatisfaction to $+100$ for strong satisfaction. The UQ chemical engineering response rates to the national CEQ survey are low (up to an approximate maximum of 50%) and caution is needed in interpreting these results. Results for 2000 are not shown as there were only six responses (7%) from UQ graduates completing their degrees in this year. However, the trend is increasing on the absolute scale and relative to the national average.

Graduate testimonials enlarging anecdotally on the preceding quantitative measures are reproduced below and show that in the early career stages, around 2–3 years post-graduation, the learning engendered in the project courses particularly in relation to the generic skills is valued greatly by our graduates.

As a student in the chemical engineering department I have valued my experience … and I feel that I have been prepared more than adequately for my future career … because the Department teaches life skills as well as technical ones [Ms A, BE (UQ) 2003].

As the course has many project and team based activities it allowed me to develop time management and communication skills, which have proved invaluable since joining the workforce … Also a major benefit to the students, was the department’s and student society’s strong links with industry and the various professional institutions who were available to give valuable insight [Mr B, BE (UQ) 2003].

I know a more traditional topic based curriculum would not have prepared me to work in the environment I am now in [Ms C, BE (UQ) 2001].

The project engineering subjects … taught by Chemical Engineering, were the most valuable subjects that I studied during my two degrees at the University of Queensland …

Trans IChemE, Part D, Education for Chemical Engineers, 2006, 1(D0): 1–10
they have given me an edge in this profession [Mr D, BE, BA (UQ) 2002].

Studying chemical engineering at UQ has prepared me well for the workforce. Chemical engineering at UQ is largely project and team-based, which is what it is like in the real world. The focus the course places on problem-solving and analytical thinking has also been very beneficial, as such skills are highly valued in the workplace [Ms E, BE (UQ) 2003].

International benchmarking also indicates PCC success in motivating significant student interest in developing generic skills as part of their professional education. Shallcross conducted an international survey of student perceptions of chemical engineering in 15 chemical engineering schools including three in Australia (Shallcross, 2002). UQ students ranked second highest in agreeing with the statement that ‘Chemical engineers need communication skills of a high standard’. And UQ students expressed strongest overall satisfaction nationally with the quality of their student experience through agreement with ‘Chemical engineering offers scope to express my creativity’ and ‘I would recommend others to study chemical engineering’.

What the Profession Says About PCC

Graduate employment rates continue at very high levels, and a broad range of industry continues to employ UQ chemical engineering graduates, including some companies who actively seek out our graduates as desirable prospective employees.

The chemical engineering graduates that X has recruited over recent years have been outstanding. We... rotate them into different roles working on projects for different industries. In addition to a foundation in our design office, many have been working in responsible roles (in) our clients offices and have performed well with good feedback from these clients. We particularly value their technical skills and attention to detail, their ability to be flexible in work assignments, and their communications & time/project management skills. The project centred curriculum is an excellent preparation for our multidisciplinary project teams (Manager Z, Brisbane office of company X and employer of seven UQ graduates since 2002).

We are sometimes asked in what ways and where our inclusion of generic skills in the curriculum has diminished our graduates’ technical skills. We believe the question should really be in what ways are technical skills enhanced? Generic skills enable successful professional practices—they are essential, integral and do not detract from or replace technical expertise. There is no simple measure of the nature of the interdependence or relationship, but we offer the following as anecdotal evidence. Before PCC implementation UQ chemical engineering students had never in the history of the prestigious nationally competitive Kvaerner Student Design Competition won an award. This competition is conducted under the auspices of IChemE and attracts entries from all chemical engineering departments in Australia and New Zealand. UQ students won their first award in 2001 and then repeated the win again in 2002. A curriculum in which we emphasise the importance of generic skills saw our students performing professionally, technically at a level comparable with the best in Australasia.

Industry support and engagement via campus based project work is strong and continues to grow with commitments to activities such as industry mentor schemes, industrial site learning opportunities and learning partnerships between industry and academia that are now opening up more opportunities for industrial and site based projects. Both the industry engagement and project framework were commended in a recent accreditation visit (Engineers Australia, 2002).

There is growing local, national and international interest in and recognition of the improved teaching and learning quality deriving from the PCC model of engineering education. UQ chemical engineering staff won UQ and national teaching and enhancement of student learning awards in 2002 and 2003. In 2004 the PCC initiative was awarded the Australasian Association for Engineering Education’s Award for Excellence in Curriculum Innovation and in the year 2005 it won the Australian Award for University Teaching in the category of Enhancing the Quality of Teaching and Learning.

DISCUSSION

In reviewing the 10-year pursuit of graduate attributes undertaken by the PCC team at UQ the following are considered central to the achievements of the new curriculum.

1. A ‘top down’ approach using graduate attributes as the output requirements and driver for curriculum development provides vital connections between course content, and instructional processes.

   a. The attributes and learning objectives should not be considered to be independent of the processes that can effectively deliver, assess and demonstrate the ‘content’ or learning objectives engendered in the attributes.

   b. A ‘systems approach’ provides programme coherence and a framework of understanding and development that helps prepare students for professional practice.

2. A ‘bottom up’ approach to ownership and sustainability of the curriculum development, delivery and quality control is essential.

   a. The introduction of PCC took place after extensive consultation by the curriculum team with academics, students, employers, the profession and educational developers. In all, a total of 4 years was needed from inception of the vision to the first stages of implementation. Time to consult widely and develop an inclusive culture is time well spent.

   b. Champions initiate change, but ownership by the wider academic community of the instructional processes as an integral part of the overall curriculum design is needed to effect cultural change in teaching and learning. Project centred teaching is not the domain of just the few committed enthusiasts. It now involves an academic community in which these approaches are an accepted and integral part of the discipline’s teaching and learning culture. For many individuals, such change brings them into unknown territory well outside their personal comfort zone. Establishing an environment that supports, encourages and directs such teaching and learning innovation is essential. Team teaching...
into projects generates networks and communities of practice and is a useful mechanism for communication, networking, management and quality control at course, semester and programme level. Teaching teams also create a shared ‘corporate memory’ as well as opportunities for collaborative staff development that effectively manages a changing educational environment.

Future Prospects

Projects are a potential vehicle for engaging more widely with other engineering disciplines such as civil, electrical, mechanical engineering. They also enable exposure to and engagement with broad socio-technical issues through areas such as risk assessment/management, ethics, legal and regulatory requirements, resource and environmental management factors. We see exciting prospects for PCC’s future in areas of:

1. Future truly multi-disciplinary engagement through possible connections with; psychology in the area of human factors in design and operations; law including ethics and professional responsibility; and social, geographical and environmental sciences and management disciplines educating community and planning professionals.

2. Promoting systemic change through wider dissemination of PCC within chemical engineering and other engineering disciplines.

3. Ensuring alignment with professional practice in industry is maintained through continuing collaboration with industry on projects, site learning and learning partnerships.

CONCLUSION

The experience with PCC at UQ over the last 10 years demonstrates that graduate attributes can be used to successfully establish a coherent teaching and learning framework for updating engineering education. The PCC framework accounts for and balances both educational processes and content as essential and interdependent components of the engineering curriculum. It enables curriculum innovation by harnessing the advantages of problem based learning through limited strategic use of project centred learning without effecting a whole of programme shift to problem-based learning. It specifies when and where these instructional processes are used and how they are integrated into an overall programme design. We have documented student and graduate perceptions of enhanced learning in the area of generic skills and overall satisfaction with their undergraduate experience for the 4 years since full implementation of PCC in 2001. Along with endorsements from industry, professional bodies and the higher education sector they support the effectiveness of this approach to curriculum design as more effectively aligning educational practice with professional practice.


Vigild, M., 2005, Kemiteknik, Danish Technical University, Lyngby, Denmark, personal communication, 17 October, 2005.


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No queries