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## Product design engineering – a global education trend in multidisciplinary training for creative product design

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Product design is the convergence point for engineering and design thinking and practices. Until recently, product design has been taught either as a component of mechanical engineering or as a subject within design schools but increasingly there is global recognition of the need for greater synergies between industrial design and engineering training. Product design engineering (PDE) is a new interdisciplinary programme combining the strengths of the industrial design and engineering. This paper examines the emergence of PDE in an environment of critique of conventional engineering education and exemplifies the current spread of programmes endorsing a hybrid programme of design and engineering skills. The paper exemplifies PDE with the analysis of the programme offered at Swinburne University of Technology (Australia), showing how the teaching of ‘designerly’ thinking to engineers produces a new graduate particularly suited to the current and future environment of product design practice. The paper concludes with reflections on the significance of this innovative curriculum model for the field of product design and for engineering design in general.

**Keywords:** engineering education; product design; industrial design; engineering design

### 1. Limitations to engineering design education

Two decades ago Qarante (1988) observed that the engineer designer concerned with an enlarged systems approach to product design would need to adapt to working in an interdisciplinary and human-centred context of project (not product) management. In the current climate, engineers must be flexible, creative and solution-focussed with a strong understanding of human-centred design and an ability to work in multidisciplinary contexts (Grasso and Martinelli 2007). Since Qarante (1988) there have been some responses to the need for ‘designerly thinking’ (e.g. Cross 2006) in engineering design. In a recent review, Dym *et al.* (2005), however, suggest that engineering design courses have yet to create an appropriate engineering and design balance.

Engineering educators and practitioners are aware of the limitations of traditional teaching methods, which can focus excessively on technical knowledge to the exclusion of other dimensions of engineering design problems (Beder 1999). This limitation is echoed by engineering regulatory bodies worldwide, calling for broader programmes. Thus, in the UK, the SARTOR (Standards and Routes to Registration) accreditation document by the Engineering Council UK requires universities to show how graduates can be creative and innovative (Baillie and Walker 1998). Product design engineering (PDE) offers an appropriate interdisciplinary response to this call for change.

### 2. Combining design and engineering thinking and practice

Product design is ‘a generic term for the creation of an object that originates from design ideas – in the form of drawings, sketches, prototypes or models – through a process of design that can extend into the objects production, logistics, and marketing’ (Slack 2006, p. 6). The product design process involves stages of product planning, concept design, product development, product styling and detail design (Baxter 1995). Owen (1998) has suggested that product design is more concerned with ‘making’ and aesthetic and cultural judgements than is typical for (mechanical) engineering.

Unfortunately, many texts treat industrial design’s input into product design as a single stage in a multistage product design process. Ulrich and Eppinger (2000), for example, claim that ‘the ID [industrial design] process is a sub-process of the product development process’ and that ‘the technical nature of the problems that confront engineers in their design activities typically demands more development effort than do the issues considered by ID’ (p. 202). As a consequence, product design is often taught as a component of the mechanical engineering curriculum or taught in design schools as a specific incarnation of industrial design. However, industrial design can have a larger purchase on the product design process, a shift that would, nonetheless require educational innovation and change.

Cross (2008) claims that the frequent conflicts between industrial designers and engineers can be overcome by ‘the “industrial design engineer”, a designer (or design team) with knowledge and skills from both engineering and industrial design’ (p. 204). One response to the need for greater synergies between engineering and industrial design has been the development of industrial design engineering programmes, particularly in the UK and Europe (e.g. Delft University). Another more engineering response has been the development of PDE, building ‘designerly’ thinking into accredited engineering courses.

### 3. Product design engineering

PDE consists of an integration of two traditionally disparate fields – (mechanical) engineering and industrial design – and its intention is to develop ‘integralists’ (Eekels 1987) who are fluent in all areas of the product development process. This new discipline has its roots in Glasgow, Scotland in the late 1980s, where the demands of a changing manufacturing industry inspired a new style of engineering practitioner; one with

fluency in both engineering and design. The first PDE course was conceived through collaboration between the Department of Mechanical Engineering at the University of Glasgow and The School of Design at Glasgow School of Art in late 1987; the course aimed to integrate the two disciplines with a view to emphasising critical reflection on the PD process (Green and Kennedy 2001).

Such students learn to work in teams through international student project exchanges (e.g. Andersen 2001), are taught through problem-based learning (e.g. Denayer *et al.* 2003) and develop sensitivity for the language of design and mathematics (e.g. Dym 1998). They also have a greater appreciation for the aesthetic qualities of materials selection in the product design process (e.g. Ashby and Johnson 2005).

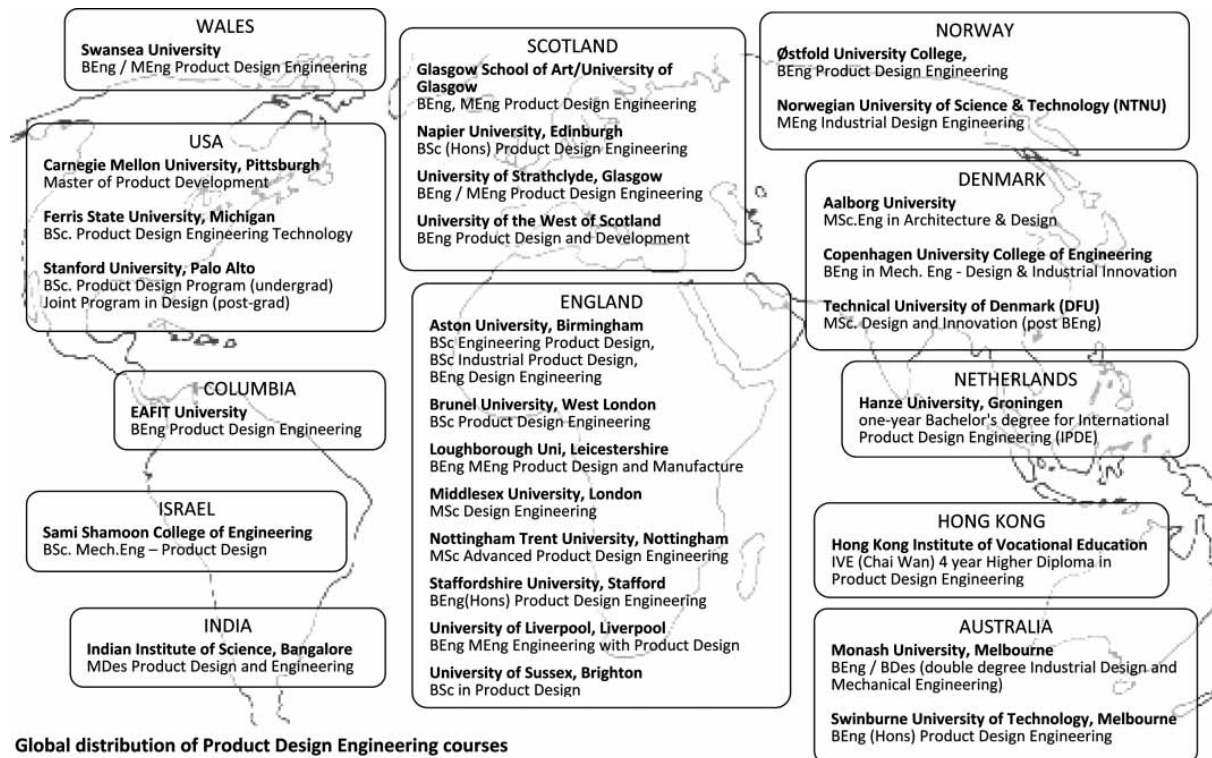


Figure 1. PDE global landscape.

Having been enthusiastically received by industry, PDE programmes are now spreading internationally with similar programmes in many universities as outlined in Figure 1. While there is still a concentration of schools offering PDE in the UK, the geographic spread is now wider, including Europe, North America, Australia and South America (Figure 1).

In addition to complementing accredited engineering courses, the PDE mission statements from a selection of institutions show a similarity of programme themes commonly occurring: creativity and innovation combined with technical strength; interdisciplinary education; user focused/humanistic; social responsibility/focus on societal benefits; and sustainability. This similarity in purpose is reflected in curriculum statements attached to courses such as those below:

The Product Design major concerns itself with the conception and design of products, services and experiences for the benefit of society. The programme teaches a design process that encourages creativity, craftsmanship and personal expression and emphasises brainstorming and need finding to discover latent or un-served human need. (Stanford University Website, USA 2009)

This profession is consolidated from the research and the analysis of man's needs, the generation of innovating ideas, the creative design of products as solutions for said problems, and all of this, with the contribution of the engineering sciences, the selection of manufacturing materials and processes for the effective management of business projects. (Universidad EAFIT, Columbia)

The study combines humanistic, esthetical (aesthetical) and technological sciences with practical skills in creating functional, user-satisfying products. (Østfold University College Website, Norway 2009)

#### 4. Developing a new pedagogy

In 1997, Swinburne University of Technology, with assistance from Glasgow PDE staff, established its course through faculty collaboration between the then School of Design, and School of Mechanical and Manufacturing Engineering (now respectively the Faculty of Design, and Faculty of Engineering and Industrial Science). This course, which graduated its eighth student cohort in 2008, has firmly established itself in the Melbourne employment sector with 100% graduate employment and enviable career pathways into automotive, manufacturing and design industries.

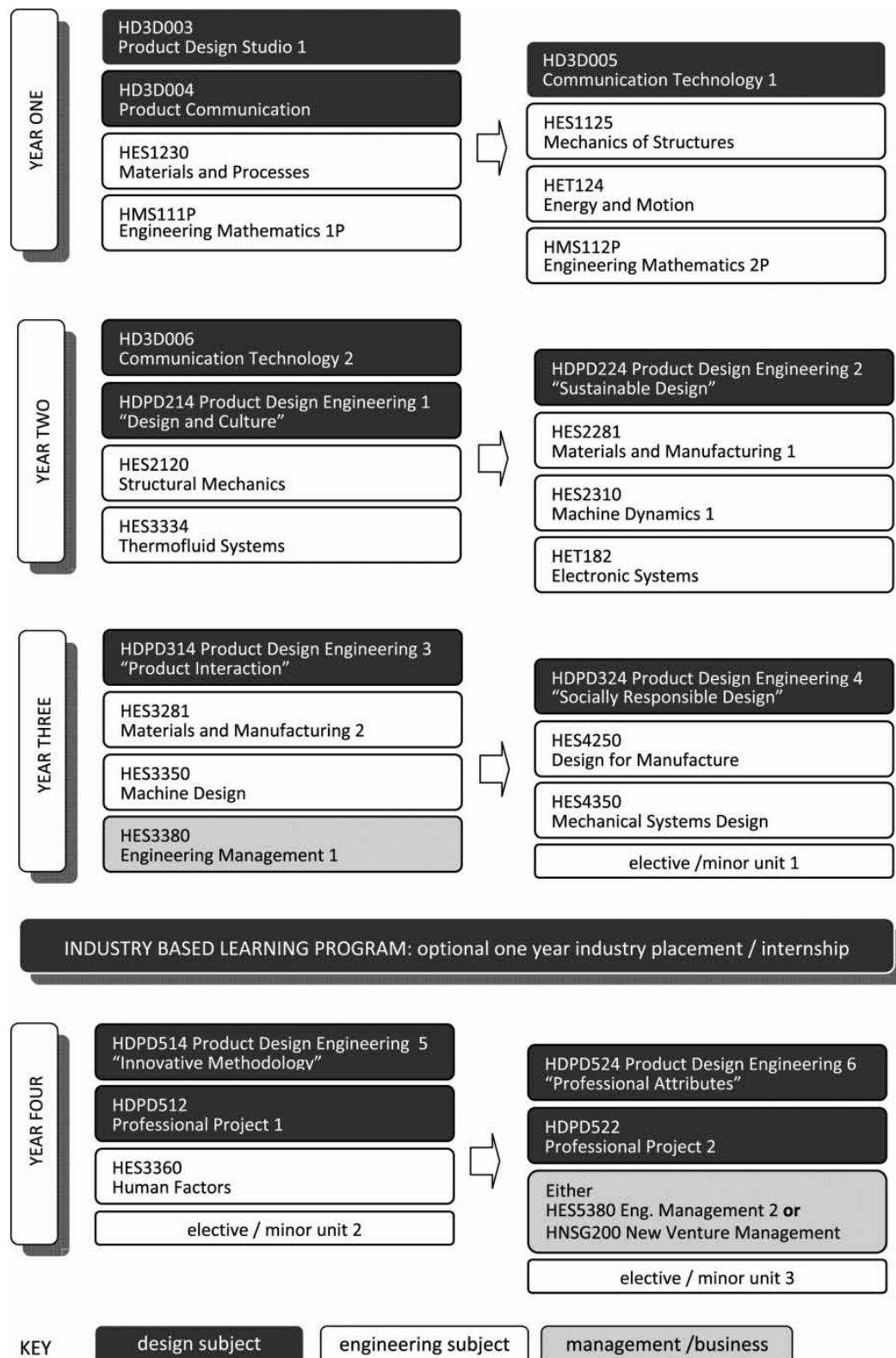


Figure 2. PDE curriculum.

The 4 year (32 subject) course has 16 specific engineering subjects, 12 subjects led by the design faculty and 3 (recommended to become 4 in 2010) elective subjects (as outlined in Figure 2). Through electives, the programme offers students a possibility of specialising in manufacturing engineering, manufacturing management or biomedical engineering. Students can also broaden their skills by choosing three (elective) subjects in design, including enterprising marketing and sustainability (Figure 2).

The Swinburne PDE course was commended as innovative by the Institute of Engineers Australia, a regulatory body, during the 2008 reaccreditation process. Early in the programme, design projects are created by lecturers to meet specific learning criteria and to support the engineering theory. As the course progresses, engagement with industry and community partners develops, leading to industry-led projects in the third year either industry-based such as tamper evident closures for plastics packaging or humanitarian projects based on scenarios provided by WorldVision. After the industry-based-learning internship year, the final year project expects the students to collaborate closely with the industry partners, who have a pro-active role in defining the project, then evaluating and assessing the outcomes to real-world projects.

At Swinburne, the PDE students benefit from access to the full teaching, workshop and laboratory resources of both the design and engineering faculties in addition to student facilities available across the two campuses. Students have dedicated design studio spaces and rapid prototyping facilities, which have facilitated the development of a 'studio culture' and the sense of community. Students have access to a range of 3D-CAD and digital visualisation software and 3D visualisation facilities.

Although the programme includes only a general grounding in electronic systems as part of the mechanical engineering syllabus, students are encouraged to seek the input of electronic engineering academics and to engage closely with electronic industry partners in the development of their products. The PDE programme realises the importance of digital systems to the success of many products, and while not teaching electronic system design in any great depth, concentrates on the design integration of these systems, including interface design and product interaction.

#### **4.1. Social responsibility and sustainability**

With social responsibility and sustainability as key themes, in the final year design projects, the students are required to develop projects that address social need, alternative technologies, energy consumption, waste minimisation and improving the lives of those at the base of the pyramid.

With this agenda, in 2008 PDE initiated collaboration with World Vision Australia to provide students with the opportunity to develop solutions for real-world humanitarian projects. From the four scenarios provided by World Vision Australia – low birth outcomes in Nepal, Kala Azar disease prevention in Somalia, healthcare services reconstruction in Banda Aceh and child survival in India – the students developed 11 innovative project solutions – bicycle or yak powered ambulance, portable minimal, low-cost solar-powered baby isolette, ceramic sterilisation unit, portable greenhouse that uses transpiration to generate clean water, system for transporting vaccinations and syringes, hand-powered electronic audio device that plays educational audio files, re-nutrition, healthcare, birthing, portable aerobic toilet, solar-powered portable insect zapper. These projects have been influential in determining an attitudinal shift among the student cohort and an emergent understanding of the need for socially responsible design.

#### **4.2. Creativity and the role of sketching**

Fostering creativity in engineering education may not be occurring or is currently ineffective. Employers surveyed by Cropley and Cropley (2000) indicated that three quarters of new graduates were 'unsuitable' for employment because of 'skill deficiencies' in creativity, problem-solving, and independent and critical thinking.

The need for visual 'artistic' skills in engineering as part of designerly capability has been acknowledged in various ways (e.g. Stewart 1999). Sketching is an activity that is not only integral to the design process, but is closely related to developing a creative process as it allows 'the reflective conversation with the situation' (Schön and Wiggins 1992). Goel (1995) goes further with the 'dialectics of sketching' in which he describes the analogical reasoning and reinterpretation of the sketch that provokes creativity.

Sketching enables the abstract development of a solution to an 'ill-defined problem' through the visualisation of mental imagery. This articulation of the concept facilitates a discussion not only with the designer's peers and clients, but more importantly with oneself as a recording and reflection process. In the context of engineering practice, sketching serves multiple social and cognitive functions, which may be hampered by the introduction of CAD (Henderson 1991). In the PDE curriculum perspective, sketching and rendering are integrated into the learning experience from the first semester through to the final year, with a shift to CAD only at the stage of product definition and documentation.

#### 4.3. Problem-based project work

Engineers are typically engaged in pragmatic problem-solving, where cost-effective and ‘known’ solutions are developed through sequential convergence on solution. Thus, ‘off-the-shelf’ components and products are preferred as they do not require new manufacturing plants and machinery, and provide a low-cost and time-tested component. However, many of the problems facing the twenty-first-century design engineer will be ill-defined problems; design problems that are not amenable to the techniques of science and engineering (Cross 2006). Thus, for engineering students, experience of open-ended problems develops divergent and flexible dichotomies, problem-framing abilities, a reflective approach and the skills to successfully resolve poorly defined problems (Wulf 2000). These ‘wicked’ problems require a co-evolution of problem framing and problem-solving, divergent and flexible dichotomies, creativity and a lack of fixation on prior solutions.

Conventional design pedagogy fosters problem-framing, divergent thinking, open-ended (or wicked) problem-solving, creativity and user-centred design in a more open way than typical of engineering education. While creative designing may be discussed in (engineering) product design texts, these considerations are subordinate to product specification and documentation processes (e.g. Ullman 1992). In contrast, Cropley and Cropley (2000) define ‘creative’ engineers as those who are driven to seek uniqueness, have unusual ideas, tolerate the unconventional and seek unexpected implications. These are also distinguishing traits of designers and are apparent throughout design education, but rarely in engineering curricula. The PDE programme aims to encourage this capacity for open problem-solving and attracts divergent thinkers who have a natural instinct for creativity (Lewis 2004) and who would normally gravitate towards design or the arts. The dual consideration of engineering and design is illustrated in Figures 3–5.



Figure 3. Landmine detection vehicle. A remote controlled self-levelling vehicle for use in rugged terrain that uses gamma and metal detection systems to detect landmines without risk to personnel.

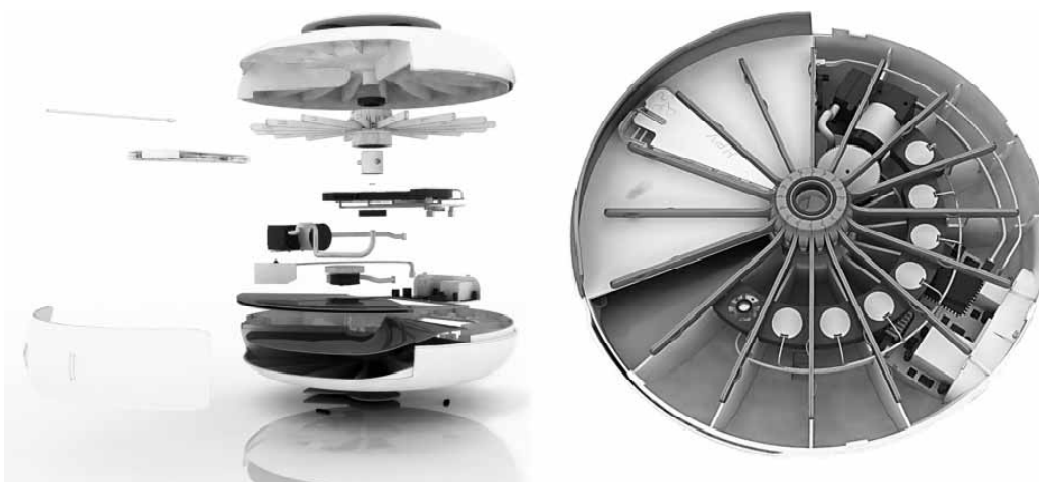


Figure 4. Molecular diagnostics device for HPV detection. Pathology laboratory equipment utilising advanced microfluidics technology. Designed to detect cervical cancer strands of the human papillomavirus (HPV) using a highly automated process minimising user labour and reducing the possibility for human error and cross-contamination.



Figure 5. Mobix hybrid mobility shopping aid. Designed primarily for elderly users, this innovative product combines the benefits of a walking frame with a user-sensitive shopping cart. Foldable, lightweight with integrated seating and improved access to storage compartments.

#### 4.4. Student demographic

The PDE course has proved appealing to a student demographic that is not usually enticed into engineering education, including young women. Noting a female predilection for certain subfields, such as environmental engineering, Engineers Australia (2008) notes that, 'At university, females studying engineering are significantly under-represented. . . In 2006, 6026 domestic students graduated from university courses in engineering at the bachelor level, while only 964 of these were female'. The PDE programme has a significantly higher proportion of graduating and enrolling female students compared with other engineering disciplines. Female enrollments are 2% for Swinburne Mechanical Engineering and a 10% average for all Swinburne undergraduate engineering courses, figures which are comparable to the national average. Over the last six graduating years, female graduates have stabilised at close to 25% of each cohort – 2003 (19%), 2004 (25%), 2005 (29%), 2006 (28%), 2007 (27%), and 2008 (17%). Among the traditional engineering disciplines, female student numbers are typically well below 10% (Swinburne RQF Report 2007). International Students from Norway, Columbia, Japan, Scotland, the Netherlands and France have travelled significant distances to Australia to study PDE. Retention rates are universally high, particularly among female students, suggesting that students are enjoying the project-based learning process, with its open-ended creative solutions.

#### 4.5. Professional project and IP

Students work on a professional project during the final year of their degree. The project work spans both semesters and is generally an industry-related product that students design. They also organise an end of year event called 'Inside Out', where the products are displayed to the general public and industry. These events have proved highly successful in generating awareness of the programme and in imparting organisational skills in students. The programme organisation including fund raising is done by the students themselves. Several of the projects are sponsored by industry and the students regularly win local and national prizes, including the VACC Target2020 competition for concept car design, ALSTON Light Rail 2020 competition for tram design, 2006 Dyson Student Design Award, and 2006 and 2008 Reece Bathroom Innovation Awards.

At Swinburne, undergraduate students have unconditional ownership of their designs. During the latter part of the course, when students engage with industry partners, intellectual property (IP) issues are discussed and the students have access to an independent Patent Attorney who provides instruction regarding non-disclosure agreements, patents and design registrations. Students are encouraged to utilise the Design Institute of Australia standard Confidentiality Agreement and to seek professional advice where appropriate to protect their IP. This works in both directions as often industry partners provide students with access to their own technology and students and the university become bound by commercial IP restraints when exhibiting or publishing student outcomes. There is always the chance of a breach of a student's or company's IP; this has not occurred due mainly to the establishment of close partnerships with industry partners and close monitoring of these relationships by teaching staff.

#### **4.6. Career pathways**

Career pathways for PDE graduates continue to be both encouraging and perplexing. It is difficult to define the exact nature of PDE graduates, as individual employers utilise them in different roles and environments, even within the same organisation. This could, in part, be due to the strengths of individuals, but equally could be attributed to the graduate's adaptability and flexibility, and their multidisciplinary skill sets. It is refreshing to find PDE graduates working in all areas of the design, engineering and manufacturing sectors and to see their rapid progression into decision-making roles.

Students have established new roles in industrial design consultancies with product engineering and front-end design roles, in manufacturing as production engineers, as part of research and development teams in design and engineering design roles. Several early graduates (now experienced practitioners) have formed their own product development consultancies, specialising in engineering design and analysis, product design, development and manufacturing management.

Employers in the transportation sector include Ford Australia, General Motors Holden, Toyota, Bombardier Transport, Paccar/Kenworth and Alstom Trams. In the design industry, many leading consultancies benefit from the unique and diverse skills of the product design engineer. Graduates have been enthusiastically received by industry with the course maintaining 100% graduate employment statistics for the 5 years preceding the global financial collapse of 2008.

The ability of graduates to work across disciplines has led to far greater employment opportunities than for either industrial design or mechanical engineers in the same workplaces. They are also helped in planning their career during the third year through a university-wide unit on Careers in the Curriculum. This is a non-credit bearing unit and has 1 h per week of contact time with special university resource providing help and support to students for finding employment, CV writing and interview techniques.

#### **4.7. Cross-faculty collaboration**

While the programme results from collaboration by two faculties, it is rare that staff from both faculties teach together in a common subject. This is due mostly to administration reasons rather than any lack of synergy between design and engineering staff; the faculties are located on different campuses. However, while the accrediting body (Engineers Australia) would like to see more engineering faculty staff teaching design subjects, there are few engineering academics on staff who have the necessary industry experience in product development to contribute significantly to the programme.

Instead, the design subjects utilise the in-class services of an experienced engineering practitioner for technical support and to ensure industry relevance. These practitioners offer 'engineering support' and ensure that design units have sufficient engineering content and that project outcomes apply engineering science in the context of a design problem. These sessional staff are usually PDE graduates (with a minimum of 5 years industry experience) who are well versed in the product design process.

### **5. Discussion**

PDE with its design-enhanced accredited engineering structure offers a unique and increasingly global response to the need for engineers to demonstrate designerly thinking in addressing product design problems. Current challenges lecturers face include managing student expectations and workloads across two faculties and ensuring students are supported and cognisant of the connection between the science of engineering and its articulation through the design projects. In this regard, all the design subjects that the PDE students attempt are written exclusively for the PDE course, which ensures that the course meets the Institute of Engineers Australia accreditation requirements, and provides far greater synergy between the disciplines, than is typically found in double degree courses.

It is perhaps regrettable that the curriculum comprises design subjects that are unique to the PDE programme, but that most of the engineering content is shared from a common pool of subjects undertaken by all mechanical engineering students. This is a restraint placed upon the curriculum as a result of the engineering accreditation process. Accrediting panels not familiar with the PDE discipline (Swinburne is the only course of its type in Australia) tend to be suspicious of subjects that differ from conventional engineering curricula and which may not appear to be sufficiently rigorous in engineering science. However, the curriculum and its delivery results from intensive collaboration between programme coordinators from both faculties, and the design subjects offer sufficient flexibility to ensure that innovative educational processes are achieved across the programme.

The challenge for engineering staff has been to develop a greater appreciation of product design and development. Similarly, design staff have needed to work to better understand the engineering discourse and approach to product design. Course development is currently focussed on improvements in the teaching of engineering science to ensure that the integration of the design and engineering disciplines works in both directions.



While students initially struggle with the cross-cultural, cross-campus course delivery (with subjects being offered equally by both engineering and design faculties), an interdisciplinary rhythm is quickly established. It is a measure of the course's success that so many of the sessional staff contributing to the teaching programme are graduates of the course. These engineering design professionals, with 5–8 years industry experience, are keen to maintain their connection with the course and help develop awareness of PDE as a profession within industry and the wider community.

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