Product design engineering: interdisciplinary pedagogy integrating engineering science with ‘designerly ways’

Ian de Vere, Gavin Melles, Ajay Kapoor

Swinburne University of Technology, Melbourne, Australia

KEYWORDS:
Product design engineering, product design and development, multidisciplinary curricula, engineering curricula, creativity

ABSTRACT

Product design and development teams are now multidisciplinary environments which require designers and engineers to collaborate harmoniously. This integrated approach enables new synergies and an extension of service provision, which leads engineering into fresh areas of professional activity but challenges traditional engineering education. The characteristics of product design and development have also changed. There is greater focus on sustainable design, socially responsible design and design for need; opportunities exist for designers to make a positive contribution to the welfare of global communities whilst advancing technologies that support sustainable development. In this changing environment, design engineers must assume new responsibilities and a greater role to achieve successful product realisation. However to be effective, they require new skills including creative design ability and a human-centred approach. These are not attributes commonly addressed by engineering curricula, but are evident in an emerging paradigm; Product Design Engineering (PDE) which integrates industrial design and mechanical engineering curricula. These interdisciplinary engineers are proficient in both design and engineering roles and make valuable contributions to more integrated product design and development environments. This paper investigates the emergence of this paradigm and the innovative curricula developed through collaboration between the design and engineering faculties at Swinburne University of Technology, Melbourne, Australia.

INTRODUCTION

Traditional engineering curricula does not address the new roles or responsibilities of engineers, nor does it necessarily reflect the values of the age; cultural sensitivity, socially responsibility and sustainable practice. Societal expectation requires engineering designers to contribute positively to global societies in a responsible and innovative manner. Instead engineering curricula continues to address the ‘science’ of engineering, (Dym et al., 2005) neglecting the practice of engineering and the contexts into which engineering graduates emerge.

Product development teams require an integrated and multidisciplinary approach. Engineers must operate effectively within global multidisciplinary teams as adaptable and creative designers who are culturally sensitive and user centred.

“In this evolving world, a new kind of engineer is needed, one who can think broadly across disciplines and consider the human dimensions that are at the heart of every design challenge.” (Grasso and Martinelli, 2007).

The Product Design Engineering curriculum develops interdisciplinary, industry-relevant professionals who utilise intuitive creativity with sound engineering design methods; responsible and reflective engineering designers with a strong understanding of social context, user and environment, “New paradigms such as product design engineering are catalysts for significant change and directly respond to industry needs and societal demands” (de Vere and Melles, 2010).

I. THE NEED FOR CHANGE

“Increasing competition for consumer markets and the growing awareness of the importance of design for the market has led to reinforcement of the view that successful design can only be accomplished by an integration of the skills of both engineering and industrial designers” (Cross, 2000). It is apparent the boundaries between these disparate disciplines are eroding, especially in the product design and development (PDD) arena where designers and design engineers collaborate in new areas of activity to extend the range of service provision. Design consultancies and manufactures now require flexible and adaptable engineers who can operate effectively in global multidisciplinary environments. A human centred and creative approach is essential for engineering design to contribute to rapidly changing environments and cultural and societal requirements (Akay, 2003).

“Engineering appears to be at a turning point. It is evolving from an occupation that provides clients with competent technical advice to a profession that serves the community in a socially responsible manner….a new
educational approach is needed to meet these changing requirements. It is no longer sufficient, nor even practical, to attempt to cram students full of technical knowledge in the hope that it will enable them to do whatever engineering task is required of them throughout their careers” (Beder, 1999).

Engineering regulatory bodies support the need for a new identity and educational direction for the engineering profession. The ‘Educating Engineers for a Changing Australia’ report (Institution of Engineers Australia, 1996) identified the need for “a high level of understanding of the broad human, economic and environmental consequences of the professional tasks engineers have to face today.” The SARTOR (Standards and Routes to Registration) accreditation document by the Engineering Council UK requires universities to show how graduates could achieve “the ability to be creative and innovative”. “It is now up to the educational institutions to discover ways of fostering creativity in students” (Baillie and Walker, 1998). However, more than a decade later, it is difficult to see many instances of new or innovative engineering curricula, or indeed that engineering education is adapting to address the needs of a rapidly changing world. Even engineering course accreditation reveals a deep suspicion within the engineering community of curricula that focuses on design and creativity, or seeks to move beyond the science-based theory model.

II. ENGINEERING DESIGN AND CREATIVITY

It is implicit that creativity is integral to design innovation, and that design and the fostering of creativity should be the cornerstone of engineering pedagogy.

However, despite the dissatisfaction with traditional engineering pedagogy (expressed by Dym, Beder, Akay, Pappas etc), many engineering faculties continue to focus on engineering science, without providing opportunities for students to develop design aptitude or creativity. “Engineering is, by nature, a creative endeavour, but many engineering colleges fail to address this, and end up training engineers for technological task completion” (Pappas, 2002).

Engineers Australia confirms that, “design is a primary function of the engineering profession. Professional engineering education should encourage an applications-oriented framework to the teaching of engineering science material and a greater emphasis on project work of a design nature” (Institution of Engineers Australia, 2008).

An interdisciplinary engineering program at Swinburne University of Technology responds with a new approach to engineering design through integration of “designerly ways” into the engineering curriculum. It addresses the key concerns; “The purpose of engineering education is to graduate engineers who can design” (Dym et al., 2005) and “Creativity is of paramount importance in engineering for it endows one with insight and discipline to seek out and address problems from the boundaries of different engineering disciplines” (Ghosh, 1993).

The ‘product design engineer’ is the new engineer; interdisciplinary, adaptable and human centred, critically aware of their societal responsibilities in regard to environment and user: a creative and sensitive designer rather than a technical practitioner. Graduates are capable of operating with distinction in both professional arenas as creative, fully accredited engineers with methods enhanced by the flexible, solution-focussed and human centred approach of the industrial designer.

III. DEVELOPING A NEW PEDAGOGY

Product Design Engineering emerged as a new engineering discipline in Scotland in the late 1980s responding to changing manufacturing environments that demanded fluency in both engineering and design. Originating from collaboration between Glasgow School of Art, (Industrial Design) and the University of Glasgow, Department of Mechanical Engineering it was soon followed by similar pedagogy at the University of Strathclyde. PDE proposed to alleviate the educational and professional void between design and engineering and to introduce many of the educational topics raised by Donald Schön in ‘Educating the Reflective Practitioner’ including reflection-in-action and joint experimentation on open-ended problems. This new engineering curriculum integrated the design and engineering disciplines to create one model of reflective practicum (Green & Kennedy, 2001) with “design a continuous thread running through the teaching”, an attribute favoured by the Grant Report, The Formation of Mechanical Engineers: Present and Future Needs (IME, 1985).

In 1997 Swinburne University of Technology established its own PDE curriculum with inter–faculty collaboration between the School of Design and School of Mechanical and Manufacturing Engineering (now the Faculty of Design and Faculty of Engineering and Industrial Science). Graduating its tenth student cohort in 2010, PDE has firmly established itself in the Melbourne employment sector with 100% graduate employment (prior to the global financial crisis) and enviable career pathways established in the design, automotive and manufacturing industries.

In 2008 the Swinburne Product Design Engineering course was commended by Engineers Australia during reaccreditation for its “innovative” educational model. This may in part be due to the curricula meeting the published aims of IEAust in “Engineering Design: A National Asset” which asserts that “synergistic attitudes and relationships must be developed and fostered between engineering designers and industrial designers, who are natural professional companions.”

The success of this new discipline is evidenced by the enthusiastic reception by industry and the proliferation of similar courses worldwide. There are now at least 28 accredited engineering courses that have integrated industrial design teaching into the curricula, albeit in many differing models. Whilst PDE is mostly concentrated in the manufacturing regions of the UK, the geographic spread includes Western Europe, North America, South America,
India and Israel. These curricula are in addition to the Industrial Design Engineering courses in the UK and Europe which similarly integrate design and engineering, albeit by integrating engineering into design programs.

IV. THE PDE CURRICULUM

The product design engineering curriculum comprises 32 undergraduate subjects over four years; 16 engineering subjects, 12 design subjects plus four elective subjects (a minor stream of study). The course “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” (de Vere et al., 2009).

The design projects develop creative skills, and support and apply engineering theory to product outcomes. Engagement with industry and community is frequent and includes externally-led projects from the manufacturing and design sectors or humanitarian scenarios provided by World Vision. After the industry-based-learning internship year, the self-initiated final year project expects students to collaborate closely with industry partners on unprecedented social need projects.

V. THE INTEGRATED LEARNING PROCESS

Integrated learning is an ideal pedagogical model as students make cross-curricula connections and unite skills and knowledge from numerous sources and experiences. They learn to utilise diverse and contradictory positions, understand issues contextually and apply their abilities to practical outcomes in multiple environments. In the product design engineering curricula, the design and engineering subjects are delivered in a parallel manner with varying degree of cross-fertilisation or integration occurring both formally and naturally. Design subjects utilise the in-class support of experienced engineering practitioners.

These practitioners offer engineering support, technical expertise and ensure that design units have sufficient engineering content to meet accreditation requirements. Project outcomes require the application of engineering science in the context of a design problem. The product development ‘approach’ is unique and differs from industrial design in that products are often designed from the “inside out” – the product architecture is engineered before the product is designed, ensuring that engineering expertise is fully integrated into the design process.

VI. PROJECT BASED LEARNING

Traditional engineering pedagogy is often criticised for not preparing students for the ‘practice of engineering’. By contrast design pedagogy utilises experiential learning processes which foster creativity and develop real-world problem solving ability. Project-based learning is integral to design learning as it instils the tools of design practice early in the curricula, then allows significant opportunities for development of skills, knowledge and confidence.

Engineering students require opportunities to apply their science through project-based learning, rather than through problem solving activities that do not provide a tangible outcome for evaluation. The PDE curriculum reflects the understanding that project based learning is constructive, participatory and the most effective way to educate creative engineers for product design and development.

VII. FOSTERING CREATIVITY THROUGH ‘DESIGNERLY WAYS’

‘Designerly ways’ represents the universal thinking approach of designers, which differs significantly from a techno-scientific approach, as used by engineers. Cross observed that scientists problem-solve by analysis, whereas designers problem-solve by synthesis (Cross, 2001). The designers approach is user and solution-focussed, frequently intuitive and divergent; whereas convergence is at the core of the engineering process. Engineering education must learn from design pedagogy if engineering students are to develop creative problem solving skills.

The Swinburne PDE course fosters creativity through an emphasis on design, open-ended problem framing and solving and sketching. “Creativity is of paramount importance in engineering for it endows one with insight and discipline to seek out and address problems from the
boundaries of different engineering disciplines” (Ghosh, 1993).

Sketching whilst integral to the design process, develops creativity as it allows “the reflective conversation with the situation” (Schon and Wiggins, 1992) and contextual citing of the design intent that enables “designers to handle different levels of abstraction simultaneously” (Cross, 2000). It is imperative that students are fluent at creative exploration and critical reflection, and are effective communicators of design intent. This is reflected throughout the PDE curriculum with the expectation that students achieve a high level of proficiency in perspective sketching and rendering.

Many of the problems facing the 21st century design engineer will be ill-defined design problems not amenable to the techniques of science and engineering (Cross, 2006). These ‘wicked’ problems will require co-evolution of problem framing and solving, a creative, divergent and adaptable approach, and less fixation on prior solutions.

To facilitate opportunities for student exploration, experimentation (and failure) as part of the learning process, outcomes should not be predefined by the project brief, but challenge students with open-ended problems that develop abilities in problem framing and divergent thinking and foster creativity.

VIII. SOCIAL RESPONSIBILITY AND SUSTAINABILITY

Engineering curricula must address ethical behaviour, social responsibility and sustainability. Our graduates will be required to drive the inevitable changes in product design and manufacturing environments as companies deal with diminishing natural resources, restricted consumption of energy and materials, regulatory carbon taxes and emission controls, the introduction of more sustainable processes and changes in consumer behaviour. Engineers will need not only awareness, but an embedded ethical philosophy through curricula that responds to the mandatory generic attributes specified by Engineers Australia including:

- understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
- understanding of the principles of sustainable design and development
- understanding of and commitment to professional and ethical responsibilities

We are now halfway through the United Nations ‘Decade of Education in Sustainable Development’ (2005-2014). This is a global initiative that aims to “encourage changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability and a just society for present and future generations.”

Unfortunately there little evidence of sustainable or socially responsible design agendas in engineering curricula. However, in the Product Design Engineering program, we have developed a sustainable design program that teaches skills and awareness, plus the tools to affect behavioural change and to lead reform in design practice and manufacturing. Equally importantly, students are taught to consider the needs and aspirations of those at the base of the pyramid (the other 90%); those who lack the basic elements that constitute a safe, healthy and equitable existence. It is here that design can make the greatest contribution to the societal improvement. “Design needs to serve not just the needs of business, but to also treat society and the environment as clients too” (Fuad-Luke, 2007).

IX. STUDENT DEMOGRAPHIC

Product design engineering has proved appealing to student demographics typically not well represented in engineering faculties, particularly young women and the creative. Whereas females represent less than 10% of students in most engineering faculties, at Swinburne the PDE course has significantly more female students, averaging 25% for the last six graduating years, compared to 2% for mechanical engineering (from which half its subjects are derived). It appears that the human-centred pedagogy appeals to female students and the focus on creative design and engineering innovation attracts divergent thinkers who have a natural instinct for creativity, and who would normally gravitate towards industrial design or the arts. Retention rates are high, and after the first year are close to 100%.

X. CAREER PATHWAYS

Product design engineering graduates continue to forge new and unexpected career pathways. Already well established in the engineering and manufacturing sectors, these ‘new’ engineers are now making an impact in traditional industrial design fields, particularly product design consultancies. Product design and development environments are often hampered by inflexibility, lack of understanding and professional rivalries, but are enhanced by innovative engineers such as the product design engineers whose interdisciplinary approach connects disparate disciplines and develops new relationships based on trust and respect.

Of interest is the categorisation of this new discipline by industry; PDE graduates are employed in differing environments and with diverse roles and responsibilities, even within the same organisation. It is common to find a PDE graduate in a manufacturing engineering position liaising with a former classmate who is engaged in front-end product design. Whilst this can be partly attributed to individual skills, it is apparent that their cross disciplinary knowledge, creativity and adaptability are highly valued, increasing employment opportunities and resulting in rapid progression into positions of responsibility.

CONCLUSION

The Product Design Engineering program at Swinburne University of Technology represents innovative engineering pedagogy, unique in Australia.
Through integration of industrial design and mechanical engineering it develops creative and adaptive engineering designers, who understand and can resolve the complex needs of societies and environments with innovative and appropriate solutions.

Contrary to some expectations, the integrity of the engineering science has not been compromised; in fact the PDE students have proven more adept at regular engineering tasks, due to their ‘designerly ways’, open-ended problem framing/solving abilities and skill in the application of science to real world problems. They are experienced and technically competent designers who display a reflective and creative approach.

However, as product design engineering occupies a unique position, juxtaposed between the ‘adaptive’ design space of the engineer and the ‘new’ design space of the industrial designer, it is not without its cultural and pedagogical issues.

Initially some students struggle to deal with the multidisciplinary approach and cross cultural teaching. Yet once the foundations of both disciplines are established, students settle into an interdisciplinary methodology which is flexible and adaptable and become strong advocates for the discipline, with many graduates returning to contribute to the teaching program.

Engineering curricula could benefit from re-evaluation of its teaching approach to foster creativity and improve graduate employability and critical thinking. Potential exists for design pedagogy to contribute significantly to new engineering curricula, as has occurred within the product design engineering paradigm.

REFERENCES


IME (1985) The formation of mechanical engineers: Present and future needs (the grant report). Institution of Mechanical Engineers

Institution of Engineers Australia (1996) Educating engineers for a changing australia. IEAust report.

