

ENHANCING TECHNICAL ENGINEERING EDUCATION WITH INDUSTRIAL DESIGN: CONSIDERATION OF PROFESSIONAL ENGINEERING REQUIREMENTS

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ABSTRACT

Very few engineered products are judged purely on function, the primary focus of engineering, and industrial design contributes significantly to perceived product quality. The two disciplines must work concurrently and in collaboration to produce successful products and, in industry, this is common practice. However, many academic engineering courses in New Zealand focus on technical engineering content and have few links with industrial design. Massey University is unique within New Zealand as its School of Engineering and Advanced Technology provides an academic course in Product Design Engineering, which is co-taught with the School of Design. In 2009, the course was reviewed for accreditation by the Institute of Professional Engineers New Zealand (IPENZ). While provisional accreditation was granted, the review highlighted a number of potential concerns around the reduction of technical engineering content required to accommodate increased industrial design content. This paper discusses the results and impact of the 2009 IPENZ review of Product Design Engineering at Massey University in the context of current academic engineering courses in New Zealand. The function of accreditation for professional engineering status for such courses is explored. A case study based review of international academic Industrial Design Engineering and Product Design Engineering courses is conducted to develop solutions to the issues raised. The insights are applied to a redesign of academic engineering courses at Massey University, which will establish a core Design Engineering course.

Keywords: Professional engineering, Product Design Engineering, Engineering education

1 INTRODUCTION

1.1 Engineering Education in New Zealand

Professional engineers in New Zealand must complete a four year university degree, followed by additional years of practical engineering experience. The engineering discipline is primarily analytical and applies scientific principles to solve *complex engineering problems*, defined by the Institute of Professional Engineers New Zealand (IPENZ) as “having no obvious solution, requiring originality in analysis and involving wide-ranging or conflicting engineering, technical and other issues” [1].

In reality, very few products are judged purely on their engineering content, the primary focus of which being function, and the design of the product must also include aspects of user experience and interaction, aesthetics etc. Together with the function of the product, these create a perception of product quality [2]. The discipline of industrial design contributes significantly to this perception in consumer and industrial products. The two disciplines must work concurrently and in collaboration to produce successful products and, in industry, this is common practice. Design educator Nigel Cross goes further and predicts a convergence towards “the industrial design engineer”, a designer or team with knowledge and skills from both engineering and design [3].

Of the eight Universities in New Zealand, six offer the professionally recognized Bachelor of Engineering (BE) programme. In 2008, no university directly offered a major in design or product engineering, or manufacturing disciplines. However, five universities offered a major in mechanical or mechatronic engineering, which contain a significant focus on engineering design. The courses are

similar in format and structure. Enrolling students require mathematics and physics in addition to the general university entrance standards. The first year of study forms an intermediate year, and in all cases consists of modules in mathematics, engineering sciences and a basic introduction to engineering. This is followed by three ‘professional years’ of study where the depth of engineering increases and students are able to specialize in a particular discipline related to their major of study. None of the courses contain industrial design content or have established links to design schools, an observation that is not confined to engineering education in New Zealand [4].

Engineering programmes in New Zealand, including those described above, are accredited to the Washington Accord by IPENZ. This international agreement governs the mutual recognition of engineering qualifications and professional competence. It was signed in 1989 by six national accrediting bodies in Australia, Canada, Ireland, United Kingdom, United States and New Zealand, and has since expanded to 13 signatories with a further four pending [5]. The benefits of accreditation for graduates of these courses are the national and international recognition of their engineering skills for further study or employment. For the course provider, it is a marketing tool to attract students and to ensure the course is aligned with the needs of the engineering profession.

1.2 Product Design Engineering at Massey University

A BE course majoring in Product Design Engineering (PDE) was established at Massey University in 2009 at the Wellington campus. The major aligned with a strong national and regional focus on industrial innovation and creativity. It aimed to produce graduates with robust engineering abilities complemented by strong creative design influence, who are equipped for careers in design and manufacturing engineering, industrial design or product development. The major was informed by established and successful courses overseas in Australia, Europe and the USA, but was a first for New Zealand. The development was the first significant collaboration between the Institute of Design for Industry and the Environment (IDIE) and the School of Engineering and Advanced Technology (SEAT) at Massey.

In order to create a viable business plan for PDE, development aligned with the existing, IPENZ accredited, BE programme offered at Massey University. The vast majority of the modules used were already taught within the BE programme, and formed the engineering and product development content. A number of other modules, comprising approximately a quarter of the major, were also offered in the Bachelor of Design (BDes) programme at Massey. The inclusion of the design content made PDE significantly different to other Massey BE majors. The structure is shown in *Table 1*.

Table 1. Structure of BE(Hons) Product Design Engineering at Massey University, showing the design stream (white text), product development modules (grey shaded), and engineering modules (black text).

Year 4-2	Quality Systems Design	Sustainable Product Development Practices	Project 2	<i>Elective</i>
Year 4-1	Mechatronics	Product Development Process 2	Project 1	Product Design Studio 2
Year 3-2	Mechanical and Manufacturing Engineering	Consumer Research and Innovation	Project Engineering	Industrial Design Interaction and Interfaces
Year 3-1	Engineering Materials and Analysis	Product Development Process 1	Agile Manufacturing	Industrial Design Modelling
Year 2-2	CAD / CAM	Digital Systems Design	Industrial Innovation	Product Design Studio 1
Year 2-1	Technological Mathematics A	Analogue Systems Design	Mechanics of Materials	Industrial Design Studio
Year 1-2	Principles of Statistics	Physics 1b	Programming	Materials: Design and Making
Year 1-1	Calculus	Physics 1a	Engineering & Media Fundamentals	Drawing

In 2009 SEAT submitted the PDE major for professional engineering accreditation with IPENZ. As a new programme, it could only be granted provisional accreditation. However, this would be an endorsement of the engineering content and aims of the major and would provide feedback regarding accreditation of such an innovative professional engineering qualification within New Zealand.

2 2009 IPENZ REVIEW OF PDE AT MASSEY UNIVERSITY

For accreditation of professional engineering courses to the Washington Accord, IPENZ use the criteria shown in *Figure 1*.

4. OVERVIEW OF ACCREDITATION CRITERIA

IPENZ has adopted three fundamental parts to the accreditation criteria:

Part 1: The programme and programme outcomes

- (i) Graduate outcomes
- (ii) The curriculum
- (iii) Admission standards
- (iv) Assessment

Part 2: Institutional Infrastructure, Staffing and Culture

- (v) Academic staff
- (vi) Technical staff
- (vii) Laboratories
- (viii) Independent study facilities
- (ix) Educational and professional culture

Part 3: Management structures and quality systems to sustain and enhance the programme and its delivery

- (x) Management structure
- (xi) Institutional support
- (xii) Advice from Industry
- (xiii) Quality processes

Figure 1. IPENZ Accreditation Criteria [6]

The criteria most likely to be discussed regarding accreditation of the PDE major at Massey were the graduate outcomes and curriculum (Parts 1i and 1ii) and the academic staff and educational and professional culture (Part 2v and 2ix). These aspects were where PDE was significantly different to the other accredited BE majors at Massey, and where the impact of the design curriculum, staff and culture on engineering education would be considered.

The review of PDE, alongside all other BE majors at Massey University, was conducted by a panel formed by IPENZ. This consisted of academic and industrial engineering professionals from New Zealand and overseas. The panel was supplied with programme documents prior to a three day site visit to Massey, where they were able to interview staff and students and experience facilities and the academic culture first-hand.

During the review, and as expected, the panel raised concerns regarding the balance of engineering and design content and the overall graduate outcomes of the PDE major. These were addressed through discussion with both engineering and design staff and the presentation of benchmarking studies (summarized in section 3). Further questions were also raised regarding the mix of academic staff contributing to the PDE major, and the overall educational and professional culture within the major.

The outcome of the accreditation review was to grant provisional accreditation for the PDE major, with a condition applied: Massey was required to supply annual assurance that projects in the major maintained focus on demonstrating engineering competence. In particular, the panel noted concerns about the inclusion of design modules and their integration with engineering, noting that:

- PDE contains less engineering science than other Massey BE majors, due to the need to teach industrial design concurrently with engineering.
- Staff from the IDIE may or may not share common objectives regarding the extent to which engineering principles are explicit in integrating design.
- In this major, students need to learn design in a wider context and are likely to have fewer opportunities within design papers to apply their engineering knowledge.

3 BENCHMARK COURSES

During development of PDE at Massey, and for accreditation, a benchmarking exercise of similar courses was conducted. The BE Product Design Engineering at Swinburne University of Technology

in Australia [7, 8], and the MEng Product Design and Manufacture at Nottingham University, UK [9] were chosen for detailed comparison. These were both established and successful majors, and both accredited to the Washington Accord by Engineers Australia and the IET respectively.

Swinburne view Product Design Engineering as a combination of two traditionally separate fields: engineering and industrial design. The subjects studied are equally shared between the Faculty of Engineering and the Faculty of Design, and focus on creative design, engineering science, material and manufacturing process selection, project management and innovation. The aim of the course is to provide students with an integrated study of engineering and science at the Faculty of Engineering, with human-centred design at the Faculty of Design, to enable them to conceive, conceptualise, design, develop and successfully prototype market-competitive products.

The University of Nottingham course intends to equip graduates “for a career in product design, industrial design or the product development sector and is aligned to the way the design process is conducted in industry today” [9]. All modules in the course are taught by the Department of Mechanical, Materials and Manufacturing Engineering and include engineering modules shared with other engineering majors, and design modules specific to the Product Design and Manufacture major. As at Swinburne, the course uses extensive projects in years two to four to integrate the streams of design and engineering learning.

3.1 Comparison of Massey, Swinburne and Nottingham Design Engineering majors

The three majors state similar aims, and it is reasonable to expect that graduating students will have similar profiles. It is also reasonable to suggest that there will be some common learning strategies, but that there may be significant differences that might affect the overall success of the majors. Comparing the structure and content results in the following observations:

- All require additional mathematics proficiency, above standard university entry. Massey also requires additional physics qualifications.
- Massey offers more product development and management modules, Nottingham more manufacturing and Swinburne more mechanical design.
- Nottingham and Swinburne offer significantly more elective options in years three and four than Massey, giving the opportunity to specialise.
- The first and second years at Massey include significantly more mathematics and science papers.
- Technical engineering content is slightly higher at Nottingham and Swinburne.
- All offer creative and industrial design from year one onwards with comparable content.

The content of the three courses is broadly comparable. The PDE major at Massey contains fewer technical engineering modules than the Swinburne and Nottingham courses. On examination, this is not due to increased design content, as this is in line with the other courses. Rather, the focus of the Massey major reflects the academic strength of Massey in the field of product development. There is also a higher fundamental mathematics and science content in the Massey major. This is a result of the BE structure, and is apparent in other Massey BE majors at Massey as well as those offered by other New Zealand universities and accredited by IPENZ.

It is notable that there is less formalized integrating project work throughout the Massey PDE major. This, again, was a constraint imposed by the Massey BE structure and the requirement to develop the major by using existing modules from the BDes or BE programmes. It can also be partially attributed to the poor history of design and engineering collaboration at Massey resulting in little opportunity to develop joint projects for the PDE major.

Nottingham and Swinburne take two different approaches to include design learning and integrating projects. The Nottingham major is taught solely by staff in the Department of Mechanical, Materials and Manufacturing Engineering. The department has developed courses in creative and industrial design methods and techniques for engineering students. Integrating projects are included from the second year and, as for the rest of the course, all are offered through the engineering department. The Swinburne approach is to mix creative design modules from the Faculty of Design with technical engineering modules from the Faculty of Engineering. In later years, this content is integrated through project-based product design engineering modules, based at the Faculty of Engineering, that form the core of the major.

Despite the noted differences, the study demonstrated that the Massey PDE major is significantly similar to the benchmarked majors, which have been accredited as delivering professional engineering education to the Washington Accord.

4 DISCUSSION

4.1 Impact of accreditation on PDE at Massey University

The award of provisional accreditation for the PDE major at Massey, albeit with conditions, was a successful outcome. Accreditation aligns the major with other Massey BE majors, and students graduating from PDE will be internationally recognized professional engineers. The award could be viewed as evidence of a shift away from ‘traditional’ areas, such as mechanical, in New Zealand engineering. At least, it is reasonable to suggest that it demonstrates recognition by IPENZ of the changing nature of engineering in New Zealand; a move towards engineering as a broader multi-contextual profession.

Some aspects of the accreditation report demonstrate, however, that IPENZ may not be totally accepting of Design Engineering as a valid engineering discipline, and do not fully understand the need for the industrial design content. This is evidenced in their concerns over the engineering content of the design modules, which is aligned with their role as the governing body for professional engineering in New Zealand, but somewhat overlooked the reason for including industrial design courses in major. IPENZ state that “...accreditation criteria are not intended to restrict degrees to the traditional disciplines of engineering. Other disciplines and technologies may be recognized by IPENZ as meeting the initial academic education requirements for professional engineers...” [6]. The application of accreditation criteria to the PDE major suggests that the IPENZ recognition of diversity is contained *within* engineering education, and does not extend much beyond engineering. This conclusion is at odds with wider observations that engineers must understand human-centred design and develop an ability to work in multidisciplinary contexts [10] and that engineering must include an understanding of wider social science context [11].

The IPENZ panel did, however, recognize the importance of integrating project work, and raised valid concerns over the limited extent of this project work within the major. While the aims of IPENZ (which can be summarized as: demonstrating integration of engineering abilities by solving complex engineering problems) differ from those of the PDE program (summarized as: demonstrating integration of engineering and broader design skills to realize solutions to complex problems), the importance of project work is clear for both.

IPENZ accreditation directly or indirectly imposed a constraint on the structure and content of the PDE major. By adopting the core BE structure at Massey, the PDE major needed to include a significant number of fundamental mathematics and science modules in the first two years. This structure is evident in all accredited New Zealand BE programmes. It is unclear whether this originated as an accreditation requirement, or developed into an accreditation requirement through inclusion in BE programmes. For PDE it resulted in taught design and engineering modules first appearing in year two, and being concentrated in year three. This limited the extent of the integrating project work in the major, and possibly the depth of design and engineering science learning.

4.2 Future development of Design Engineering at Massey University

The existing BE programme at Massey University is currently undergoing a significant redesign, with the revised majors due to be launched in 2012. An evolution of the PDE major will be delivered at the Wellington campus. An important question for the development team is whether professional accreditation should be an aim of the revised design engineering major? Successful accreditation implies that the major reflects the existing engineering profession in New Zealand and, to a lesser extent, overseas. This has to be a significant aim of the redeveloped design engineering major, but this must be balanced by the desire to appeal to the wider design and engineering industry. Benchmarking of similar courses in Australia and the UK has shown that it is possible to achieve the wider appeal while satisfying professional engineering accreditation conditions. Does the question then become: do IPENZ and the accreditation process recognize the wider multi-disciplinary design engineering field? We might also consider the predicted focus of the engineering profession in New Zealand five years hence (when the revised Design Engineering BE major will be producing its first graduates), rather than the existing professional focus?

A significant lesson learnt from the PDE development and accreditation exercise was the requirement for extensive and carefully planned project work. This needs to demonstrate the students’ ability to solve complex engineering problems and to integrate the disparate streams of design and engineering. There seems to be no reason why both goals can’t be satisfied with the inclusion of the right type of

project work from the first year of study. It is also apparent from the PDE experience that aligning with the accredited BE structure and obtaining IPENZ accreditation will impose constraints on the major. These include minimum standards for enrolment, requirements for fundamental mathematics and sciences that may not be appropriate, and a limit on the extent of non-engineering content that can be included. Removing the accreditation requirement will potentially remove some or all of these criteria. However, the question is not about accreditation, but whether SEAT at Massey are comfortable in offering a major that is significantly different to its other BE majors.

Perhaps the real focus of development should look beyond the immediate question of accreditation, and consider the wider goals of accreditation. The benefits to graduating students and the course provider rely on the accreditation process reflecting the needs of the profession and industry. As it is essential that the design engineering major reflects the wider, multi-disciplinary design and engineering industry and must be relevant to this industry five or more years hence, it seems logical to approach the development by focusing on these areas, rather than directly on accreditation. This leads to the following core themes of development:

- Significant and early engagement with design engineering industry (in New Zealand and overseas).
- Involvement of academic advisors linked with successfully implemented design engineering courses overseas (ideally with professional engineering accreditation).
- Development of course structure and content based on industry and professional requirements, within SEAT constraints, but with freedom to challenge these constraints when necessary.
- Significant and early communication with IPENZ and other professional engineering bodies (in New Zealand and overseas).

If the design engineering major is developed to include these themes, then it follows that it must be acceptable for accreditation. In this way it should be possible to ensure that the essential design content is included whilst still satisfying professional engineering requirements. Furthermore, it is suggested that establishing an open dialogue with IPENZ and other professional engineering bodies would encourage discussion of accreditation criteria as they relate to qualifications such as this, and potentially lead to joint development of the design engineering discipline within New Zealand.

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