

AC 2007-1573: A MULTIDISCIPLINARY DESIGN EDUCATION APPROACH FOR SUPPORTING ENGINEERING PRODUCT INNOVATION

Rainer Seidel, The University of Auckland

Rainer Seidel (Dipl.-Wirtsch.-Ing., Ind.Eng., PhD) works in the Department of Mechanical Engineering at the University of Auckland, New Zealand. His main research, teaching and consulting activities are in the areas of technology management and strategic business innovation in SMEs, productivity improvement in manufacturing, new product development, and engineering education. He is currently the Project Director of the multi-disciplinary R&D project 'High Technology Design for Engineering Product Innovation' funded by the New Zealand Government.

Linda Haemmerle, Plume Ltd.

Linda Haemmerle graduated in 2002 with a Bachelor of Design, major in Product Design from UNITEC Institute of Technology, Auckland, New Zealand. She has designed furniture, lighting and consumer products (Bob Pen: 'Highly Commended' – Best Design Awards 2000, New Zealand, 1st place award IDRA 2001, USA) and is a director of design company Plume Ltd. in Auckland, New Zealand. Linda is currently the Project Manager of the New Zealand Government funded project 'High Technology Design for Engineering Product Innovation'.

Chris Chambers, CPC Consulting Ltd.

Chris Chambers (BEng(Hons)) runs his own consulting engineering design and development business. New Zealand and US clients use him for special projects that solve long standing problems or that establish new platform products. His expertise focuses on modularity, simplification and innovation that deliver key commercial benefits protected by patent. Chris' interest in cross-functional design management has propelled him to become a contributor to the 'High Technology Design for Engineering Product Innovation' project funded by the New Zealand Government.

A Multi-disciplinary Design Education Approach for Supporting Engineering Product Innovation

Abstract

Manufacturing success in today's global business environment depends on a manufacturer's ability to design and produce innovative products which are technologically sound and satisfy the customers' functional requirements, but at the same time possess those attributes that create excitement and capture the imagination. Generating and maintaining a creative and synergistic design environment and culture to achieve this is challenging for Small and Medium manufacturing Enterprises (SMEs). Therefore it is particularly important for them that their engineering and design staff have sound backgrounds in engineering science and design, possess multidisciplinary skills and experience and are capable of playing an integrative role in a creative design-driven business environment. However, many manufacturing SMEs that produce technologically complex products have insufficient human resources and skills to cover the breadth of competencies needed. Opportunities for improvement are often limited or seen to be too expensive, such as enhancement of their in-house design capacity through external resources in the form of design services, tertiary institutions, or by cross-industry knowledge sharing.

This paper describes an innovative educational program, which is aimed at the development of talent pathways for engineering students that reflect the skill requirements of design driven manufacturers. Concurrently, a professional development framework for design practitioners from the industry is being established that caters to their specific training needs, reflects the requirements of professional bodies and industry training organizations, and is closely integrated with the academic curriculum. Based on this educational framework, a comprehensive design-training program is currently being developed and implemented: consisting of specific design courses, teaching modules, short courses on particular design related topics and industry-based training activities such as design internships, practice-based case studies and collaborative project work.

The first activities in the new program have been successfully introduced in the 2006 academic year. Amongst them are two teamwork and project-based design courses involving real industrial product development tasks. The courses were organized and delivered in cooperation with staff from business and creative arts faculties, local manufacturers, and external engineering and design professionals. Many positive comments were received from students coming from engineering, business and the creative arts faculties. As knowledge from the different areas was gained, students were able to appreciate different viewpoints from fellow students of different academic backgrounds. Plans for the 2007 academic year cover a multi-disciplinary, inter-faculty design course in each semester. Additionally, design internships for senior students have been organized to foster industry/academic collaboration, to expose students directly to design in a business environment, and to enhance the appreciation of academic design teachers of practical business requirements.

Introduction

To compete in today's competitive international marketplace, Small and Medium sized manufacturing Enterprises (SMEs) must have the capability to design and produce innovative products that both function and capture the imagination. For products involving significant technology or engineering development, design engineers and product designers must be

competent in engineering design and science fundamentals, and also possess the creative and managerial skills required to drive product development. However, many manufacturing SMEs that produce technologically complex products have insufficient human resources and skills to cover the breadth of competencies needed.

Recognizing the importance of these issues, the New Zealand Government undertook a major study in 2003 into the role of design for the economy¹. The study reported that two thirds of successful exporters identified design as a key factor for their international market penetration, and concluded that design is a 'key enabler' of international business success, especially when enterprises use it as a strategic discipline. However, it also recognized that design was under-used in the vast majority of local SMEs.

Design is a key element of the Growth and Innovation Framework (GIF) that was established by the New Zealand Government in 2002². The Growth & Innovation Framework has sought, amongst other goals, to provide additional support for enhancing the use of innovative design, because of its ability to enhance the growth of existing sectors such as the manufacturing industry. One result from this is the Growth and Innovation Pilot Initiative (GIPI) funding scheme of the New Zealand Tertiary Education Commission, which supports pilot projects between New Zealand Tertiary Education Organisations (TEOs) and businesses. GIPI funding is aimed at building TEOs' capability to engage with industry and enterprise in the GIF focus sectors such as design³.

The goal of this tertiary sector/business engagement is to:

- Enhance the relevance to business teaching, learning and research
- Nurture entrepreneurship in both TEOs and the respective GIF sector
- Promote two-way sharing of knowledge and expertise between the tertiary sector and industry.

The GIPI programme 'High Technology Design for Engineering Product Innovation' introduced in this paper is aimed at enhancing tertiary design education in all areas of engineering, as well as in business and the creative faculties at the University of Auckland. Its overall goal is to achieve a closer match between human resource requirements in the areas of engineering design and new product development of New Zealand's manufacturing SMEs, and the skill profiles of future engineering and other University graduates. The three-year program is an initiative of the Department of Mechanical Engineering at the University of Auckland, and its funding started in 2006.

The program's focus is on the establishment of appropriate curriculum structures and on the development of talent pathways into product development for students from engineering, and also from business, science and the creative arts, that reflect the skill requirements of design-driven manufacturers. At the same time a professional development framework for professional design engineers and other design practitioners from the industry sector is being established that caters to their specific training needs, reflects the requirements of professional bodies and industry training organisations, and is closely integrated with the academic curriculum.

Based on this educational framework, a comprehensive design training program consisting of specific design courses, teaching modules, short courses on particular design related topics and industry-based training activities such as design internships, practice-based case studies and collaborative project work, is currently being established. For the development,

implementation and delivery of the new course program additional internal and external staff resources are being created. They will have appropriate academic qualifications as well as practical design experience, and whose suitability needs to be endorsed by the GIPI program's Industry Advisory Board.

Emphasis is on a holistic and multidisciplinary approach that integrates academic and educational perspectives with the practical requirements of the target industry, as well as the strategic human capital development objectives of the industry. The necessary integration and concurrent consideration of aspects and disciplines from outside the traditional engineering design domain, such as industrial design, marketing and branding, is a significant departure within the new curriculum from the traditional, discipline-based teaching system, and therefore requires considerable developmental efforts and resources. To ensure the quality, consistency and relevance of the framework and its individual elements, the Advisory Board oversees all phases of the development and monitors its outcomes.

Throughout the duration of the program close collaboration between the industry sector, the University of Auckland and key external stakeholders is emphasised, for example through seminars, newsletters, focus group meetings, site visits, a program website, and a broad range of team and momentum building activities. This is to develop an extensive network of relationships and a 'critical mass' of design related activities that ensure the long-term survival and success of this initiative. The resulting networking infrastructure will provide a broad range of resources and opportunities for sharing of design knowledge, design education and training, research and networking for stakeholders.

As innovative design depends on a broad perspective and a multidisciplinary and integrated approach, a critical aspect of this GIPI program is the alignment of its objectives and activities with complementary initiatives. Of particular importance is the integration of industrial, product and graphic design, and combining aspects like ergonomics, aesthetics, etc. with engineering design, which so far has been the main focus of the targeted industry sector. Other important areas included are business innovation, technology management, marketing, branding and entrepreneurship, which are covered in a range of departments and faculties at the University.

A range of educational activities in the new program has been successfully introduced in the 2006 academic year. Amongst them are two teamwork and project-based design courses involving real industrial product development tasks, which were organized and delivered in cooperation with staff from the business and creative arts faculties, local manufacturers, and external engineering and design professionals.

Industry-sponsored design project: 'Design for Competitive Advantage'

The first project 'Design for Competitive Advantage', comprising half of the compulsory final year mechanical engineering design course, involved 13 teams of mechanical engineering students being directly involved with a manufacturer of automatic door openers for garages. The main focus of this project, as its title suggests, was the development of design solutions for a consumer product, which create a clearly definable competitive advantage in a business context. Two project alternatives were offered to the students: the first to improve product performance of a particular product, and the second to find innovative design solutions for another product. The tasks were structured in such a way that students were able to acquire a good understanding of the range, variety and complexity of

the different design and manufacturing considerations involved in everyday consumer products through the systematic analysis of the existing product and the creative development of improved design alternatives. They were required to perform their development work using the host company's business tools and stage-gate based design approach, for example Design Failure Mode and Effects Analysis (DFMEA) and target costing. In this way they familiarized themselves with concepts such as user-oriented values, as well as design concepts such as Design for Assembly (DfA), Design for Manufacture (DfM) and Design for the Environment (DfE), and were exposed to various techniques and systems used for new product development in business practice. Final product concepts were visually presented to the client at the end of the course, using CAD modelling and various other means.

The organization of the design project was based on best practice principles of project based learning⁴, which have been practised and refined in the Department's various design classes for a number of years^{5,6,7,8}. Educational and practical outcomes of this project were closely monitored and evaluated based on student feedback, on academic performance with respect to pre-defined learning outcomes, and on feedback from the industry partner in terms of practical value and business relevance of the design concepts developed by the project teams⁹. The results of all of these evaluations were overwhelmingly positive, as illustrated by a typical student comment: *"The course offered me so much more than (sic) I was expecting. The skills for and importance of working in a multidisciplinary team were invaluable insight into the scenario I will shortly be working in. As a mechanical engineer my opinions on the course are biased accordingly."*

Interfaculty design course: 'Innovation and New Product Development'

The second course in the following semester 'Innovation and New Product Development' was initiated and organised by the Department of Mechanical Engineering as a new interfaculty design elective. The course was offered to final year undergraduate students of all faculties and academic disciplines within the University of Auckland. It involved the collaboration with a local industry partner, to foster industry/academia relationships and to practice 'real-life' new product development in a business context.

The following learning outcomes for the students were defined:

- Acquire a good understanding of the range, variety and complexity of the different design and business considerations involved in the development of new products.
- Apply creative processes and a structured, well-managed team approach for solving a complex product development task.
- Use practical and theoretical methodologies to communicate and evaluate product ideas.
- Be able to effectively identify and prioritise key areas for design development to achieve the best commercial outcome.
- Present the proposed product concept in a professional fashion to a business client.

In order to facilitate deep and experiential learning and to create a sound understanding of the concepts, tools and techniques covered, the course was also designed as a project based learning experience. Students were grouped into cross-functional and cross-disciplinary project teams, each comprising engineering, business and arts students. Each team was provided with an initial product brief by the business client, which it had to develop through a range of stages into a professionally presented product proposal and business case.

Learning was supported through group work and discussions, lectures and presentations from industry professionals, independent study, assignments, and written and oral presentations. All course content was delivered in the context of the different stages of the team based product development process. A broad range of electronic resources was provided on a specifically prepared course website and in the lecture material. Tutors with industry experience, who brought a range of technical and business expertise into the team discussions and the learning process mentored project teams. As teamwork experience is seen as an important skill of modern business professionals, teamwork and project management issues were carefully moderated and monitored throughout the duration of the course.

As mentioned above, teams comprised students from different faculties, resulting in multi-disciplinary teamwork and exposure to different ideas and approaches to problems, providing a more 'holistic' perspective to the design problem. Apart from presentations on the design process from an engineering perspective, lectures included presentations from creative arts faculty staff on visual communication through sketching, creative considerations such as design history, styling, human perceptions and critiquing past and current designs for incorporation into a body of work. Presentations by business school staff and management consultants covered basic marketing principles and strategies, strategic aspects of design, selling strategies, and the evaluation of customer requirements and market expectations. Industry experts were also involved with presentations by intellectual property consultants as well as manufacturers' perspectives on new product development.

All coursework was related to the project task and structured into 'iterations', to enable closer and closer refinements towards a final, commercially viable product concept. This mirrored industrial reality of problem solving: 'a problem is not solved until it is solved'. To help them achieve their target and come up with a professional solution, project teams were provided with one-on-one industrial mentoring on a weekly basis, given support, positive feedback and kept on track with the process. Final product concepts were presented to the client at the end of the course in the form of a business case, and also as a poster and PowerPoint presentation.

As mentioned earlier, the ability to work in a multi-disciplinary (design) team is one of the most important attributes that students are expected to develop during their undergraduate engineering degree course¹⁰. Some of the main benefits of team based projects include the honing of good interpersonal communication skills, experience in dealing with conflicting views and dissent, practice in the division of work tasks and labour, and enhancement of the creative potential of team members¹¹. These skills and experiences are very relevant to professional engineering work in industrial practice, in particular in the multi-disciplinary domain of new product development⁴. Therefore the importance of a teamwork approach was particularly emphasised and practised in this course. However, potential downsides of teamwork in an academic environment are that some students attempt to take advantage of team arrangements in order to get a 'free ride', or to avoid certain types of tasks such as CAD modelling or report writing^{7,8}. To eliminate these problems as much as possible, a range of tools such as confidential peer assessment, oral interviews and specific work and submission instructions for students were used in the course. A confidential peer review process was applied as a tool to discourage students from freeloading and cheating. Another important tool used to facilitate the teamwork was the 'Team Contract'. At the start of the project students received a sheet with team contract guidelines, which covered the main issues that have proven to cause problems during teamwork. Students were asked to discuss the guidelines during their first team meeting. They then had to define and record in writing their

own rules for the work in their team, and submit a copy of their contract to the course organiser soon after start of the project.

Course outcomes

Overall, the outcomes of the course were very encouraging. The majority of the 11 project teams developed design concepts that were of high standard, and were very favourably received by the sponsoring industry partner. From an academic perspective, the vast majority of the 41 students enrolled in the course also achieved the learning outcomes mentioned above. This is reflected in typical comments received on the course benefits through the formative feedback process as summarised below:

- Working in a multi-disciplinary team gave rise to different ideas and approaches to problems from people with different backgrounds
- Realising and appreciating diverse skills from other team members
- Gaining passion and motivation and developing new thought processes
- Real work examples of working on actual problems for an actual company
- Gaining insight into other areas of no previous knowledge
- Appreciating how necessary a design feature was in context to profitability
- Gaining knowledge of different types of product development (incremental versus radical) and their different marketing strategies
- Creative design considerations such as the importance of aesthetics for marketing/sales
- Realising the emotional qualities of products
- Going through design iterations with deadlines

Discussion and conclusions

Valuable experiences were gained from this first interfaculty, industry-sponsored design course, and opportunities for further refinements and improvements were discussed with the participating parties. As with any introduction of new teaching materials or methods, there will be a progression of refinements and improvements towards reaching the overall goal of matching industry requirements of New Zealand's manufacturing SMEs with the skill profiles of future graduates. To ensure that graduates from the University of Auckland become multi-skilled professionals means not only a closer dialogue and collaboration between different departments and faculties within the University, but also between academia and industry. Therefore one of the main objectives in the GIPI programme is to involve increased numbers of quality industrial partners and business professionals in our teaching and networking activities.

Apart from the introduction of a broader range of multidisciplinary design courses and teaching modules in the University's undergraduate and postgraduate teaching programmes, concrete steps have been taken to develop short courses on particular design related topics, and industry-based training activities. At the time of writing this paper, six final year engineering students (mechanical, mechatronics and electrical) perform design internships with local manufacturing companies. The internships involve on-site learning and problem-solving directly with an industrial partner, and are jointly supervised by academic staff and engineering managers from their host companies. The project topics and objectives of the internships have been carefully formulated to include tangible business outcomes as well as a contribution to the better understanding of business requirements in the area of new product development.

Experience gained will form the basis of further industry case studies at postgraduate level, and simultaneously inform the development of future design courses and collaborative project work. An educational framework for students of engineering, business and the creative faculties will be further developed within the three-year duration of the programme, and educational pathways will be provided for up-skilling and gaining complementary skills for practising professionals. Close alignment with industry is planned throughout all stages of the program, with the support of an information networking infrastructure to facilitate the sharing of information and design resources available to SMEs.

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