

THE CONTINUUM OF DESIGN AND ENGINEERING EDUCATION: COMPETENCIES IN FINAL PROJECTS

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ABSTRACT

The different professions within design and engineering, represent a continuum of competencies with some, not always clearly defined, overlap. The paper looks at final year degree projects from three different majors from the same university: Industrial Design, Product Development and Mechatronics Engineering. The results indicate significant parallels between Industrial Design and Product Development, both aiming at new products, while Mechatronics Engineering is more science based.

Keywords: Project competencies, education, industrial design, product development, mechatronics.

1 INTRODUCTION

Most manufacturing industries depend on highly competent efforts from various disciplines, like Product Development, Industrial Design, Mechanical Engineering and Mechatronics Engineering. The disciplines must work in collaboration to ensure business success. In academic education, the disciplines are more distinct, although experience shows that these and related disciplines represent a continuum of competencies with some, not always clearly defined, overlap. A recent study of the professionalization of product design in Finland concludes with the following. 'Designers compete with other professions: 1. to span the outermost boundaries of their profession ever outwards 2. to bring barriers to entry ever closer to the most inward core'[1]. Design thinker and educator Nigel Cross sees successful design practice converging towards 'the "industrial design engineer", a designer (or design team) with knowledge and skills from both engineering and industrial design' [2].

Engineering design programs are increasingly aware, 'that the project based approach being accompanied by workshops concerning soft skills results in development of competencies being expected by employers'[3]. New design-engineering programs emerge and many see this as the necessary response to the need for engineers to demonstrate designerly thinking in addressing product design problems[3]. One of the leading universities in education of Industrial Design Engineers, TU Delft in The Netherlands, has recently reorganized the curriculum towards the professional competencies being the building blocks instead of traditional scientific or engineering subjects. The objective is to overcome the persistent problem of many (IDE) programs: the gap between theory and practice[4]. The new curriculum for IDE at TU-Delft deviates from the traditional discipline-based model by being built up from large thematic multi-disciplinary courses in which the ability to perform in an authentic product development context is central[4].

Massey University in Wellington, New Zealand has a renowned School of Design, and a School of Engineering and Advanced Technology. They have expertise in Industrial Design (ID), Mechatronics and Product Design Engineering[5], with Product Development (PD) also offered at Massey's other campuses. The two schools have made attempts to collaborate in the last few years, but success has been limited. Much of the failure can be attributed to the distinctly different cultures in the Schools. There is an upcoming redevelopment of the Massey majors with the aim of creating a program in Design Engineering at Wellington, which will include core elements of Industrial Design and Product Development within engineering education. To establish such a program, without creating a new school, requires careful preparation. One of the tasks is to determine the competence profile of the candidates. The existing disciplines of ID, PD and Mechatronics aim to produce graduates with distinctly different competencies. Design Engineering (DE) aims to combine elements of these courses

with further abilities in engineering design and manufacturing. The question is which elements of the ID, PD and Mechatronics courses are relevant, and is it possible to create a Design Engineering graduate with unique competencies? As a contribution to this discussion we have chosen to analyze a number of final year degree projects from three different majors: Industrial Design, Product Development and Mechatronics Engineering. With this we hope to identify the similarities and differences between the three programs directly from the student projects.

2 COURSE REQUIREMENTS

The final projects serve two different goals. Firstly the projects have unique learning goals, such as project management and communication skills and, secondly, the projects should demonstrate the general competencies profile of each major. The engineering majors have been developed with program competencies consistent with those prescribed by IPENZ for accreditation as a professional engineer[7]. The industrial design curriculum does not have a similar external accreditation. The three majors are four years, with a final project as a part of the fourth year. There is a considerable difference in size of the projects between ID and engineering. The ID project amount to 75 credits of the 120 credits required to complete one year while for both engineering majors the final year project is specified as 30 credits, but all span both first and second semester. A short presentation of the expected learning outcomes follows.

2.1 Mechatronics Project (ME)

Students apply their skills and knowledge gathered during their previous study, along with creative and thinking skills, to a specific problem. Most projects involve either industrial problems or are related to research and development activities and students are expected to gain experience through exposure to the conditions imposed by the commercial or professional research environment. Specifically, upon successful completion a student should be able to:

- Identify problems and define projects leading to technically & commercially viable solutions through critical analysis, focused discussion and interaction with both industrial clients and academic or research scientists and the application of innovation and thinking techniques.
- Plan and execute a detailed, individual project through self-imposed milestones developed by an analysis of relative workload and task complexity within the scope of each project.
- Exercise professional judgment, self-monitoring and peer assessment
- Communicate effectively by oral, visual and written means, project plans and results through progress meetings, project presentations and the final project report.
- Contribute to a project in a commercial or professional research enterprise.

2.2 Product Development Project (PD)

This provides the industrial vehicle for the student to undertake, within a supervised environment, a complete product development project from initial need identification through to prototype development, manufacturing and market planning, and overall feasibility assessment. Projects are sponsored by a commercial client in most cases. Specifically, the project should give a clear demonstration of the student's ability to:

- Manage project resources
- Communicate effectively to all stakeholders
- Integrate and apply multidisciplinary knowledge and solve problems creatively
- Provide pragmatic solutions and recommendations in a commercial context.

2.3 Industrial Design Project (ID)

The final year project is developed from two papers. In the first semester, Industrial Design Research and Development provides the research basis for their product design concept. In second semester Industrial Design Research Project builds and develops the design from the initial concept stage to a developed product concept (including looks-like prototype).

From Semester 1, the student should be able to:

- Critically evaluate and contextualise the chosen design research topic within an existing field of industrial design knowledge and practice.
- Identify an area of focus for research, and formulate a design research proposal to define product

and systems performance and experience parameters.

- Demonstrate an understanding of industrial design research methods, processes and practices.
- Synthesise research outcomes into appropriate design specifications.
- Critically and innovatively conceptualise and generate design concepts and evaluate these against research outcomes and design specifications.
- Demonstrate an advanced ability to present design processes and proposals.

From Semester 2, the student should be able to:

- Demonstrate an ability to complete comprehensive design projects to an advanced level
- Exhibit an advanced ability to synthesise research outcomes into design proposals
- Critically evaluate design concepts against research outcomes and design specifications
- Present written, graphic information and models in support of design proposals

2.4 Areas of commonality and difference between project learning outcomes

In all disciplines, it is expected that the students will apply technical skills obtained throughout their course of study, and demonstrate an element of multi-disciplinary knowledge. Students in all disciplines are also expected to display creativity in their problem solving and to be able to communicate effectively on multiple levels. All disciplines require the student to demonstrate an understanding of the core process of design, engineering or product development. This extends to an ability to define, plan and manage the project effectively. The learning outcomes for ID are much more structured than in either PD or Mechatronics, probably due to the increased length of the project, but possibly a reflection of the depth of process understanding required. Mechatronics and PD projects both state a requirement for a commercial or professional research context to the project, and in PD the projects are usually sourced from industry. This is not a requirement of an ID project. There is also less explicit emphasis on technical abilities in PD, and there are more requirements for the student to demonstrate effective management of the project resources.

3 METHODS AND SELECTION OF PROJECTS

Regardless of the origin of the project, ID, PD or ME, projects will have a different focus and display different individual qualities and skills. Firstly, each project calls for a specific set of skills to accomplish the project. This is equally important if the assignment is developed by the student, the supervisor, or posed directly by an industrial partner. Secondly, students within a course have varying interests and skills and, thirdly, supervisors do not always have a common model of supervising major projects. To compensate statistically for all these variations, it would be necessary to work through a considerable number of projects. The approach chosen here was to ask each of the course leaders to provide three of the best reports from the year 2009. An additional wish was that the projects should have a relation to manufacturing industry. Selecting the top students should guarantee that most of the required competencies for that major will be present in the projects. The analysis of the projects initially used an approach similar to grounded theory: the projects were analyzed for elements of knowledge and skills, letting the actual elements found define the structuring. A table was created by first reading through all the projects noting factors and keywords. These were then collected in the table and grouped. Redundant entries were removed, and the projects were checked once more. No attempt was made to evaluate how well the projects fulfil the requirements of their program. The work with the assessment of the projects was completed before looking at the specifications for each of the programs. By this we ensure that the students own accounts of their projects are taken at face value. What the students do not mention in their reports is not counted. Analysis was carried out by a researcher from the product design engineering discipline with no links to any of the courses, to provide an independent and unbiased approach. Titles of the projects are as follows:

ID: Product innovation for fire fighting personnel, Farm Data Management System, and Defensive penalty - Face Mask

PD: Live Feed Cam, Performance Stand, and Hollow Wooden Surfboard

ME: Expanding the functionality of a VTEQ brake test lane for ABS system testing, Intuitive motor control for an electric-assist utility bicycle, and Mobile Robot Navigation via Olfaction

4 FINDINGS

Table 1 shows the average results for each of the groups. Note that marking was done on scale 0-4,

indicating if a factor is presented in the project documentation or not. Low numbers indicate that one or two of the candidates presented the actual factor as a part of their work.

Factors	ID	PD	ME	Factors	ID	PD	ME
Project and planning				Knowledge of Technologies			
Project background	4	4	4	Strength calculations		1	
Project context	4	4	3	Electro motors			4
Project plan	2	1	3	Microcontrollers			4
Project aims	4	4	3	Materials	3	3	
Background and research				Production methods	3	3	
Problem understanding	4	4	3	Communication technology	1	1	4
Background technology	3	2	4	Electrical classification	1	1	4
Competitors	2	4	1	Skills and Methods			
Patents			1	Laboratory experiments	1		4
Scenarios of use	4	3	2	Simulation Math Lab			1
Ergonomics	4	1		Programming			3
Market research	2	3		Prototyping	4	4	1
Development process				Sketching	4	2	
Specification	4	3		3D modelling	4	3	
Concept development	3	3	1	Finite Elements		2	
Alternative solutions	3	2	1	System Design	2	1	1
Concept evaluation	4	3	3	2D Drawings	1	3	
Product life considerations	3	1		Cost calculations	3	4	
Presentation and evaluation				References/Bibliography			
Conclusions	4	3	2	Number of references	35	11	23
Related to initial goals	4	4	3	Books and Journals	25	2	12
Report communication	4	3	3				
Model/ Prototype	4	4	3				

Table 1. Factors observed. Comparison of the three majors.

The table shows a number of significant differences and some clear similarities:

- Project planning was evident across all disciplines, though not all contained a formal project plan.
- Strength in background reviewing and research was evident in all disciplines.
- Mechatronics projects do not contain ergonomics or market research, whereas these areas are similarly demonstrated in PD and ID.
- There is little evidence of the development process in Mechatronics, possibly due to the projects being more defined at the start. This area is strongest in the ID projects.
- All disciplines place similar emphasis on presentation and evaluation.
- Knowledge of technologies is evident in all disciplines, but the actual technologies differ.
- The skills are methods used in ID and PD are similar, focussed mainly on design development for proof of concept or manufacture. Mechatronics, by contrast, shows little design development and the skills are more laboratory-based.

Two important factors from the study are not included in Table 1 as these need more explanation. Firstly we tried to look at the origin of the projects, and secondly we looked at the main type of innovation in each of the projects. The initial project assignment is apparently formulated in different ways. For industrial design, the students spend considerable time on background research aimed at clarifying the design task. Often this is in cooperation with lead users or based on user surveys. But the student is clearly responsible for formulating the assignment and concluding the first part of the project with a design specification. Product Development projects seem to be defined either by the student or a cooperating company. In both cases the initial project brief clearly defines the final goal for the development process. In the case where the student has the initiative, it can either be related to own business concept or an observed need. In the one PD case where the assignment comes from industry, a performance specification seems to be the starting point. Mechatronics students also get

similar problem solving tasks from industry, but here projects are also defined by the supervisor and integrated into current research activities of the faculty. Assessing the type of innovation is not based on any standard classification, rather on our own judgment. The results indicate that innovations from ID are product oriented in a system context. The results from PD also focus on new products but more towards production and management, while the ME students engage in more technical or scientific tasks. For one of the ME students no innovation was observed.

ID	Product/system	Product	User interface/system.
PD	Product function	Product	Production methods
ME	Technical principle	--	Algorithm

Table 2. Different results in terms of innovation.

5 DISCUSSION

The low number of projects involved in the evaluation excludes any statistical comparison. However, looking at Table 1, there are clear parallels between the ID and PD majors. Looking at the specifications of learning outcomes for the two projects the differences are seemingly much bigger. This could be explained by different language conventions. In particular in the ID part (2.3), the word ‘research’ is extensively used while the word is not used in the PD part (2.2). Another explanation would be to look at the different ways of presenting the results of the projects with ID focussing on the development of the form and physical manifestation of the product and its use. One could expect that ME and PD would have more factors in common than ME and ID, but judging from Table 1 the profile of ME is equally different from PD as it is from ID. This is intriguing, given that both PD and ME programs are accredited to the same standard by the Institute of Professional Engineers New Zealand (IPENZ). The Mechatronics outcomes allow for an emphasis on research and development, which may explain the lack of specific design development towards concept or manufacture. This is supported by the types of innovation observed and shown in Table 2. Generally, the students say little about issues related to project management and planning. This is reflected in Table 1, where a limited number of factors address managerial issues. All three programs are at undergraduate level, which may indicate that the ambition is primarily to finish the project and get the work done and less to reflect on the process and methods. For the engineering majors this final project is the first real challenge in undertaking an own project. The Industrial design students surely have more training in project work, but then with primary focus on the designed result.

5.1 Industrial Design

The Industrial Design students develop their projects from observed challenges in real life situations, rather than starting with a technology or an idea. This can be rooted in a personal experience as with the ‘Penalty Face Mask’, where the project is initiated from the students own injuries. Another student starts with a broad study of the working conditions of fire fighters and then narrows down to a problematic area. This partly explains why the ID projects are more than twice the size of the engineering projects. Actually the ID students spend most of the first semester studying the problem area, which involves considerable amount of research either related to understanding the design challenge or searching for available technologies for new design concepts. All three reports include a declaration of originality signed by the students.

5.2 Product Development

The three projects assessed seem to fall in two different categories, defined primarily by the type of assignment. Two of the projects were be initiated by the students and related to their own interests: A wooden surfboard and a performance stand for musicians. These projects have the initial focus on the situation of use, similar to ID, but then the development work aims to solve the practical problems related to material and production, rather than develop a product concept into the situation of use. The third project is initiated by a company and the student seems to have little influence on formulation of the assignment, which requires knowledge of electronics and communication technology. The student does well to work through seemingly unknown technology, and manages to develop working solutions by coupling various standard components. The process followed is clearly goal and solution oriented, but references to product development methods are rather sparse. It is surprising that only one of three

students mentions a project plan in his report, but on the other hand all three reports follow a similar structure that reflects an underlying development process.

5.3 Mechatronics

Judging from the projects assessed, this major is clearly the most research or science based. The projects are to some extent related to situations of use, and the development work done is characterized by formulation of a hypothesis and testing. This sometimes results with a great effort in the laboratory which only leads to a negative conclusion. Example is 'The motor control for an electric-assist utility bicycle' project, where the initial hypothesis is to measure the tension of the chain from the chain vibration. After time consuming building of a prototype and lab testing this is proven to be too expensive and unreliable way of measuring.

5.4 Academic Ways of Working

The number of references used is not always a measure of the academic quality of a project. It is, however, an indication of the student's ability to search for relevant information and to link to current developments in science and technology. In this assessment it has been chosen to group books and journals together, which leaves internet references, legislation and technical references in a remaining group. The high number of internet and technical documentation references is not surprising, as these serve several different purposes. General information is collected from sources like "Wikipedia.com", standards and statistics from official sites of governments or branch organizations and technical information from suppliers or even competitors. A higher number of scientific references to books and journal articles indicates a more scientific way of working. It is interesting to note that the ID students generally use more academic references than the engineering students. These are primarily related to the background research in the first half of the project. In the design phase, references are sparse.

6 CONCLUSION

This simple approach of comparing competence profiles by looking at a limited number of final year projects indicates significant parallels between Industrial Design and Product Development, both concerned with the development of new products. Collaborative student projects involving students from other programmes could be the next step to improve the understanding between the disciplines. The development of the DE course at Massey must consider the position of the existing PD course. It is expected that DE will contain more technical ability (some common to Mechatronics and ID, and some unique to DE), and less management and process focus than PD. To clearly differentiate the courses it is recommended that the focus of PD is reviewed to ensure that the process and management aspects of the course are strongly evident. Furthermore, the results show that all courses lack any focus on systems design or engineering. This approach is core to a multidisciplinary course such as DE, and it would be a strong point of difference if this was emphasized throughout.

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