A Study of the Design Process and Methodologies Employed by Students in Final-year, Major Projects in Industrial Design

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A study of the design process and methodologies employed by students in final-year, major projects in industrial design

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ABSTRACT

An initial study surveyed academics involved in teaching industrial design in Australia, and overseas. The study sought to determine the approach of students, in various industrial design degree programs, to their final-year projects and the extent to which the design process and design methods were incorporated in their project reports and documentation. The findings revealed a number of operational needs associated with studio-based learning, particularly those associated with final-year, project-based activity. These findings, together with teachings from the literature concerning how students go about design in the studio and the needs associated with project activity, led to the proposal of a generic model, entitled the Major Project Development Model "MPD Model". The operational criteria in the MPD Model guided the development of a computer-integrated system of design methods allocated to the respective phases of the process. This system, called the "MPD System", was designed to support and enhance student design work in major projects. The results, obtained from the use of this model and process, are presented and the implications discussed.

I. INTRODUCTION

A major project development model, suitable for final-year, industrial design student projects, was proposed by the author. This model was based on the research of a number of authors, namely: Archer (1966); Cross (2000); Cross and Roozenburg (1992); Maffin (1998); Bonollo and Lewis (1996); Baxter (1995); Eder (1998); Green and Bonollo (2001); and more accurately reflects the steps and process carried out by students as they progress through year-long, final-year major projects in industrial design. The model was also informed by findings from an initial structured survey that revealed the approaches of students during major projects. The model and system were tested in use by a cohort of students during 2004. These results were contrasted against a cohort in 2003 that did not employ the model and process.

II. THE MAJOR PROJECT DEVELOPMENT MODEL

The model, termed the MPD Model, includes seven phases, their description and applicable design methods are listed as follows:

Product Planning (PP): A set of tasks that determine a new project or product idea and based upon a survey of a particular market using benchmarking or a study of competitive products. Applicable methods are: Literature search; Features analysis; Benchmarking; Patent Search; SWOT analysis; Project checklist; Peeves analysis; Project time plan.

Task Clarification (TC): A set of tasks including negotiating a brief with the client and/or manager; setting objectives; planning and scheduling tasks; information search; quoting time and cost estimates. Applicable methods are: Objectives tree method; Cost visibility; Pareto analysis; Function analysis; Cost-function analysis; Performance specification.

Concept Generation (CG): A set of creative tasks aimed at generating a wide range of design concepts as potential solutions to the design problem or brief. At this phase the implied assumption is that all ideas are equal in credit value. Methods: Brainstorming; Synectics; Bionics; Design-by-drawing; Concept selection; Design catalogues; patent search; Morphological analysis.

Evaluation and Refinement (ER): A set of analytical and creative tasks in which the concepts generated are evaluated (using weighting and ranking techniques) and reduced to a small number of refined candidate solutions. Methods: Interaction matrix; House of Quality; Design-by-drawing; CAD; Design review.

Detailed Design (DD): A set of tasks aimed at developing and validating the preferred concept, and its sub-problems, including calculations; selection of materials, finishes, indicative tolerances and components; layout drawings and dimensional specifications. CAD; Value engineering; Taguchi/robust design; Cost determination; FMEA; Component design specifications; Life-cycle analysis.

Communication of Results (CR): A set of tasks whereby the concept now detailed is communicated to the client and/or manager via appropriate two and three-dimensional media and written report. Methods: Design drawings; Renderings; Prototypes.

Preparation for Production (PP): A set of tasks that determine the needs of the product in terms of its production. These include design issues for manufacture, validation of the manufacturing method and estimation of manufactured cost. Methods: Revised cost visibility; Change proposal; Statistical process control; Fault tree analysis; CAD.

The purpose of the MPD Model is to establish a structure and methods that would enable the student to identify the nature of the project and to produce an appropriate project time plan and carry out research that includes a wide consideration of issues.

III. THE "MPD SYSTEM" (A SUITE OF COMPUTER-BASED DESIGN METHODS)

The design-teaching/learning instrument developed in the study is called the "MPD System" consisting of a computer-integrated suite of design methods based on the "MPD Model". The MPD System provides a resource to assist the student industrial designer in studio projects and in particular final-year, major projects in industrial design. The "MPD System" has resulted from research based on a survey of academics who have supervised students engaged in major studio projects. The MPD System consists of a suite of computer files, arranged around the phases of the MPD Model. Methods are aligned with a particular phase however these methods can be used in other phases. For example, brainstorming can be used in the *Product Planning*, *Task Clarification* and *Concept Generation* phases. Forty-three (43) design methods are assigned to the various phases of the system.

The Product Planning phase includes the following design methods, namely *Literature Search*, *Features Analysis*, *Benchmarking*, *Patent Search*, *SWOT Analysis*, *Project Checklist*, *Peeves Analysis*, and *Project Time Plan*.

The *Features Analysis* section presents a design method that employs an Excel spreadsheet that assists to determine the features of a product, the weighting of those features and a comparison of features across a number of products. An example of application is included to guide the student when they select a blank worksheet.

An alternative design method in the Product Planning phase is *Benchmarking* which describes the application of benchmarking to a group of mobile phones. Again in this section an example is provided that compares a range of mobile phones and presents a clear example of the application of benchmarking.

This *System* represents a significant development that enables application in the studio and provides a means by which systematic thinking can be accommodated and by which a more dual-brained approach can be achieved.

IV. APPLICATION OF THE MPD MODEL AND SYSTEM TO PROJECT-BASED LEARNING

There is difficulty in introducing a higher level of systematic thinking and procedures in the design studio without compromising the creative, solution-focused approach. And there are problems in more effectively integrating teachings from associated disciplines. The model shown below in Figure 2 includes the elements of the prior-discussed MPD Model and System. In addition, it includes aspects described by Tovey (1986), wherein he proposed a dual-processing model, where left-brain thinking needed some foundation to facilitate its relevance in the studio environment. The MPD Model and System is superimposed over the left and right brain domains in the studio and the Model is intended to act a connecting bridge or instrument to facilitate dual-brain processing in the studio.

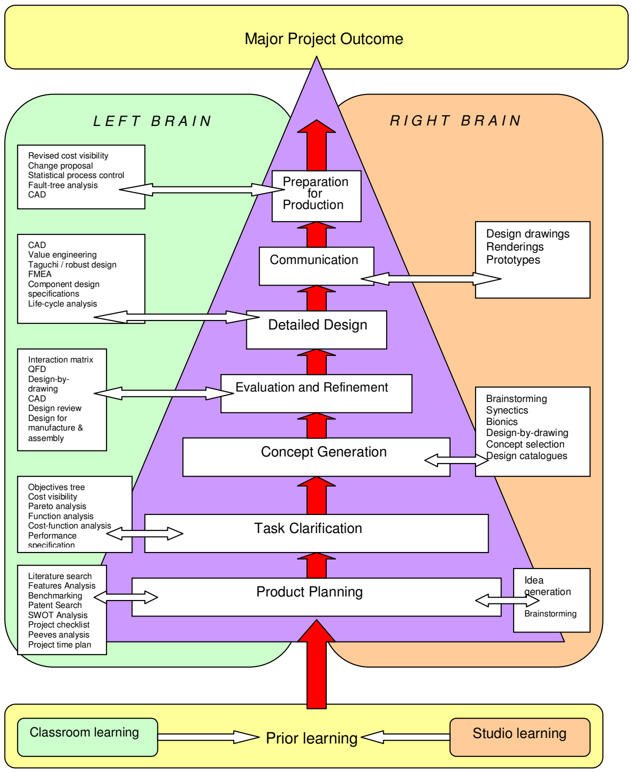

Figure 2 Author's application of the MPD Model superimposed over left and right brain activities within the context of a major project

The MPD Model above provides a structure and methods supportive of the final-year studio project. This model includes a statement of outcomes and tasks, which may be applied in the studio by the student to clarify and structure project work. The MPD System has been developed to provide a practical instrument that facilitates application and adoption of the MPD Model.

The studio process depends on the prior learning of the student and after completing three years of the programme the student enters the final year with prior knowledge resulting from both classroom and studio learning. This is shown at the bottom of Figure 2.

Figure 2 shows seven stages commencing with *Project Planning* wherein the student would understand the outcomes required and may conceptualise in a right-brain mode using methods such as, idea generation or brainstorming. However a significant, if not dominant, aspect of the first phase is left-brain thinking where the market is identified, patents consulted and identification of a project opportunity is determined.

The next phase of the project is *Task Clarification* which is largely a left-brained activity. In this situation, the student may use a variety of methods to reinforce the specifications of the project and to determine a brief. Tools available in this stage are *objectives trees*, to clarify design objectives, *pareto analysis*, to understand the costs associated with a product and *function analysis* to clarify the functions. The MPD System is applied in the studio, firstly to provide a means of carrying out tasks within the framework of the MPD Model and secondly, to support the design process by providing methods and tools to assist design decision-making.

The proposed MPD Model and the MPD System represent a significant development in industrial design education and potential application in professional practice. The MPD Model has resulted from an exhaustive study of design process models and methods and a structured survey of design academics.

V. METHOD

A suite of tasks associated with the MPD Model was proposed. These tasks reflect the sequence of actions that a student might address over the course of the major project and are related to the respective outputs from each phase.
This model has provided an aligned pedagogical methodology (phases → tasks → methods) for teaching and learning associated with major projects. It represents an important finding of this research and a considerable pedagogical breakthrough. The normal assessment of projects is not usually based on rigorous analysis of tasks carried out in the project reports; the assessments are carried out by lecturers and casual staff and there is no existing structure or instrument available that enables assessment based on anticipated outcomes and tasks.

A proposed instrument for analysis of tasks is shown in Figure 1. This instrument and methodology avoids the chaos of assessment of projects by providing a rationale for assessment with evaluation criteria that reduces the subjectivity and confusion. The relative importance of a task is allocated a *weighting,* for example, the *strategic review of the market* is allocated a weighting of 5 whereas *patent searching* a weighting of 4. The basis of the allocation is that tasks directly associated with the industrial design process are given a weighting of 5 and a task, such as, *dimensional specifications,* which is a detailed engineering activity is given weighting of 3. These weightings have been derived from discussion within the industrial design programme at UNSW over a period of 5-6 years.

The score associated with a particular task is assessed over a range 0 to 10 and assessment as to the extent to which the task is executed is dependent on the experience and skill of the examiner.

Student.. Student number...

Project..

Major Project Development Process Worksheet

Student name:
Project:

Phase	#	Tasks	Weighting factor	Score 0	1	2	3	4	5	6	7	8	9	10	Total score	Total possible
Product planning	1	Strategic review of the market	5													50
	2	Competitor analysis	5													50
	3	Patent searching	4													40
	4	Identify opportunities for a project	5													50
	5	Planning and scheduling project	4													40
Task clarification	1	Setting design objectives	4													40
	2	Materials research	3													30
	3	Technology research	3													30
	4	Human factors research	4													40
	5	Development of a brief	5													50
Concept generation	1	Solution conjecture	5													50
	2	Generation of ideas	5													50
	3	Folio of concept sketches	5													50
	4	Simple models (mock ups)	5													50
Evaluation and refinement	1	Evaluation of concepts	5													50
	2	Refinement of candidate solutions	5													50
	3	Relevant technical information	4													40
	4	Determination of preferred concept	5													50
Detailed design	1	Development of preferred concept	5													50
	2	Specification of materials	4													40
	3	Layout drawings	4													40
	4	Dimensional specifications	3													30
Communication of results	1	Folio of presentation drawings	5													50
	2	Technical drawings	4													40
	3	Refined three-dimensional model	5													50
	4	Manufacturing information	3													30
	5	Financial information (ROI)	3													30
Prepare for production	1	Analysis of costs	3													30
	2	Consideration of tooling	2													20
	3	Estimate production investment	3													30
	4	Consider DFA	2													20

Totals.................. | | 1270

Figure 1 Proposed instrument for assessing the tasks executed within the stages of the MPD Model

A specific project report is compared across a range of reports in order to understand the relative degree to which the task has been accomplished. In addition, the opinion of the examiner with respect to how the task could have been carried out, compared to the actual outcome was part of the assessment process. Therefore the score of a particular, task multiplied by its weighting produces a definitive score.

VI. RESULTS

Figure 3 contrasts the respective scores for the tasks and structure included in the 2003 and 2004 cohort project reports. The results show a considerable difference between the scores achieved by the respective cohorts.

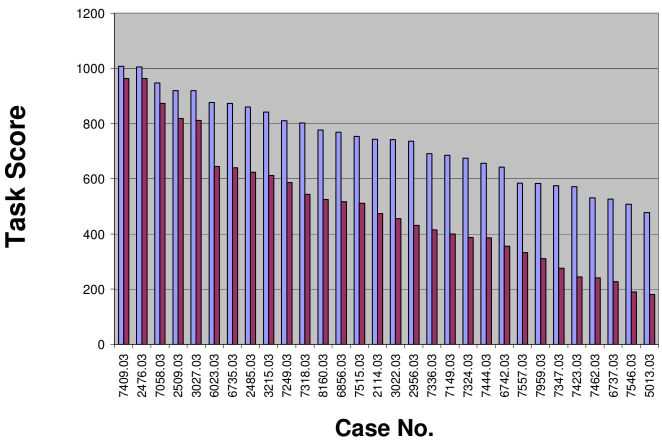

Figure 3 Bar chart contrasting the scores associated with the assessment of tasks included in the 2003 and 2004 cohort reports

The 2003 cohort achieved an average score of 498 and the 2004 cohort 736. The 2004 cohort clearly demonstrated a greater awareness of the use of design methods and knowledge of the major project development process. These findings were tested by comparison of the scores obtained by the two cohorts. It was found that the difference between the cohorts was significant and not a chance event. The two columns of data were tested using EXCEL function analysis software firstly by TTEST resulting in the determination of p= 0.000006 and similarly Chi-square = 0. These results confirm a significant difference between the two cohorts.

VII. CONCLUSION

Because the two cohorts are similar academically, each group has similar education in design methods and since one external assessor assessed all the reports it can be concluded that the better performance by the 2004 cohort has been achieved by the reinforcing effect of the MPD System because many of the tables and charts included in the reports came from the MPD System. A single very experienced assessor was thought to offer greater consistency and impartiality in contrast to an assessment panel. The 2003 cohort, although educated in design methods and the product development process, have not consolidated these into their design process. The methods have been perceived as optional and because they did not have access to standardised spreadsheets and information to support their progress through the major project their extent of application of methods was not significant. In contrast, the 2004 cohort had access to software to support their use of design methods and as a result the categorising of information, the breadth of consideration of issues and the use of design methods was greater.

The most notable conclusions concerning industrial design teaching and learning were that:

• students engaged in final-year, major projects in industrial design did not use a model of the design process and use of design methods was not significant. In addition, skills and capabilities, in relation to planning and management, particularly time management, were poor;

• the overall performance of students improved when they deliberately employed the MPD Model of the design process described in this paper;

• student performance also improved when a computer-integrated a suite of design methods was provided;

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Phase	Proposed Macrostructure	Design Method
Product Planning (PP)	A set of tasks that determine a new project or product idea and based upon a survey of a particular market using benchmarking or a study of competitive products.	Literature Search Features Analysis Benchmarking Patent Search SWOT Analysis Project checklist Peeves Analysis Project time plan
Task Clarification (TC)	A set of tasks including negotiating a brief with the client and/or manager; setting objectives; planning and scheduling tasks; information search; quoting time and cost estimates.	Objectives tree method Cost visibility Pareto Analysis Function analysis Cost-function analysis Performance Specification
Concept Generation (CG)	A set of creative tasks aimed at generating a wide range of design concepts as potential solutions to the design problem or brief. At this phase the implied assumption is that all ideas are equal in credit value.	Brainstorming Synectics Bionics Design-by-drawing Concept selection Design catalogues Patent search Morphological analysis
Evaluation and Refinement (ER)	A set of analytical and creative tasks in which the concepts in (3) are evaluated (using weighting and ranking techniques) and reduced to a small number of refined candidate solutions.	Interaction matrix House of quality (QFD) Design-by-drawing Computer Aided Design Design Review
Detailed Design (DD)	A set of tasks aimed at developing and validating the preferred concept, and its sub-problems, including calculations; selection of materials, finishes, indicative tolerances and components; layout drawings and dimensional specifications.	Computer Aided Design Value engineering Taguchi/robust design Cost determination Failure mode and effects analysis Component design specifications Life-cycle analysis
Communication of Results (CR)	A set of tasks whereby the concept detailed in (5) is communicated to the client and/or manager via appropriate two and three-dimensional media and written report.	Design drawings Renderings Prototypes
Preparation for Production (PP)	A set of tasks that determine the needs of the product in terms of its production. These include design issues for manufacture, validation of the manufacturing method and estimation of manufactured cost.	Revised cost visibility Change proposal Statistical process control Fault tree analysis CAD