A STUDY OF THE DESIGN STUDIO IN RELATION TO THE TEACHING OF INDUSTRIAL & PRODUCT DESIGN

by

Lance Noel GREEN
BE *(NSWIT),* MDes *(UTS),* MHEd *(UNSW)*

A THESIS SUBMITTED TO THE UNIVERSITY OF CANBERRA
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN THE FIELD OF INDUSTRIAL DESIGN

November 5, 2005

SCHOOL OF DESIGN AND ARCHITECTURE
DIVISION OF HEALTH, DESIGN AND SCIENCE
THE UNIVERSITY OF CANBERRA

ABSTRACT

In this thesis the industrial design studio has been investigated with particular reference to studio thinking and learning and project-based activity. This investigation has been set in the context of a final-year, degree program in industrial design that includes a substantial research and development project. From a critical review of the relevant literature the characteristics of studio culture have been identified, together with its role in the teaching of both creative and systematic endeavour. In addition, the history and context of the role of the industrial/product designer is reviewed in order to understand the nature and the required skills of the discipline.

In this thesis, 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 design process and design methods were incorporated in their project reports. 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", is designed to support and enhance student design work in major projects.

A second study was conducted that analysed: student performance in their project reports; the extent to which their design research conformed to the MPD Model; and the extent to which design methods were used in their final-year projects. Criteria and guidelines for the successful conduct and evaluation of such projects have been proposed and set up as part of the experimental programme. The experimental work, reported in this thesis, is based on an in-depth, comparative investigation of a range of major project reports, firstly those produced in the year 2003 during which final-year students did not have access to or knowledge of the MPD System and secondly, those produced in 2004 where students were provided with the MPD System, hence providing two cohorts for comparative purposes.

The theoretical and experimental work have been related, with appropriate results and conclusions, to the following issues: *Design theory* – an MPD Model has been proposed and applied in keeping with a set of operational criteria; *design methods* - a model reflecting a range of methods aligned to phases of the MPD Model have been established in keeping with needs of designers in their execution of phases of the process; *brain-based learning theory* – a model of the integration of the MPD System as a means of linking systematic and creative thinking in the studio process is proposed; *academic performance* – the academic performance of students has been studied and data have been derived which provide valuable information for the design educational process.

The results of this research will encourage use of a more structured teaching and learning approach and the employment of design methods in major projects. This comprehensive research thesis provides a framework for further research and recommendations for further research.

Acknowledgments

Firstly, I wish to thank Professor Elivio Bonollo, Emeritus Professor of the University of Canberra, for his tireless efforts on my behalf, his very fine example and his encouragement, initially to commence and then during the period of my study. Professor Bonollo opened many doors to interesting topics for me and our good working relationship and effective communication has produced a number of well-regarded papers published as part of this research. Thank you Elivio.

I also wish to thank: David Baskind, a graduate of the industrial design programme at UNSW, for his help with regard to the MPD System, a suite of computer files of design methods; Darren Holloway for his advice and assistance in statistical issues associated with my research; Oya Demirbilek for her encouragement and assistance with many aspects of computer expertise and her advice with respect to the nature of PhD study; Aida Morden of UNSW for her valuable help in both statistics and the interpretation of demographic issues; Bob White for his tireless assistance in the examination of the major projects; and the University of Canberra for providing a scholarship and facilities that were essential for the successful completion of my studies.

Finally, I wish to thank my wife, Rosemary for her encouragement, patience and support over the five years of my study.

Table of Contents

List of Tables

List of Figures

Abbreviations and Symbols

ANOVA	Analysis of Variance
CAD	Computer-aided design or Computer-aided drafting
CAE	Computer-aided design
CAM	Computer-aided manufacture
CIM	Computer-integrated manufacturing
CNC	Computer numerical control
DFA	Design for assembly
DFM	Design for manufacture
DFDA	Design for assembly and disassembly
FMEA	Failure mode and effects analysis
MPD Model	Major Project Development Model
MPD System	Major Project development System
QFD	Quality function deployment
PDP	Product development process
VA	Value Analysis
UNSW	The University of New South Wales
TQM	Total quality management
PDC	Product development cycle
DR	Design research
PR	Product research
SPC	Statistical process control

Chapter 1

Introduction

This chapter provides a background to the research thesis and establishes aims and research questions associated with the project. The layout of the thesis is explained and the content of each chapter clarified. A flow diagram indicating the major steps in the research process is included to assist in understanding the overall research plan.

1.0 INTRODUCTION

1.1 Background

In most 4-year industrial design programs in Australia a final-year project is included to enable students to demonstrate their skills and capabilities in the research, design and development of a major project. The project also enables students to showcase their professional capacities, which may be of interest to potential employers. Such projects are usually of one-year duration and often include two stages, namely design research and design execution. The major project draws upon the prior learning of students over the period of their study, from courses in engineering, manufacturing, ergonomics and design.

Central to the teaching of industrial designers is the design studio, a place of teaching that has evolved from studio-based teaching of fine arts and architecture and a place where students learn to visualise and represent aspects of a problem graphically and to *think as a designer*. The studio context celebrates *learning-by-doing,* via projects of increasing complexity, as the most appropriate theory upon which to base the teaching of design. Emphasis is placed on creativity, drawing, problem solving and communication. Knowledge of technologies such as manufacturing and marketing is taught in supporting courses that compliment projects assigned in the design studio and provide understanding appropriate to the studio level.

Industrial design programs vary in focus. Some emphasise art and creativity whilst others, more technical in focus, include significant content in engineering, management and manufacturing. Typical content in these more technical programmes might include courses in physics, engineering mechanics, manufacturing materials and processes, CAD, workshop, ergonomics, design methodologies, management, marketing, history, statistics and design. The task of making the connections between these disparate disciplines is difficult for students. And when these have to be made within a major, year-long project, the student, in many instances, experiences difficulty in making these connections.

The solution-focused approach, where an idea is proffered, explored and either accepted or rejected is central to studio thinking and teaching, and which facilitates a creative emphasis that can produce unique outcomes. Right-brain thinking is encouraged by a studio culture that prioritises visual outcomes and inadvertently discourages analysis. However the emphasis on creativity may not sufficiently provide a platform for design research, project planning, design brief development, and evaluation and refinement associated with an extensive complex project. In addition, the studio may not provide a platform that effectively integrates coursework teaching of other disciplines such as marketing, engineering and manufacturing.

Whilst the teaching and learning benefits of the studio, to creative and visual thinking, are well understood it is not clear how designers are taught to deal with the complex networks of information and disciplinary interactions that are associated with significant design projects.

More research into the nature of the final-year projects is needed in order to better understand the circumstances affecting the student, to inform the educational process and improve the attitudes, knowledge and industrial design skills of graduates.

1.2 Context and Scope of Research

In this thesis, the industrial design studio is investigated with particular reference to final-year industrial design major projects. The theoretical and experimental work is set in the context of final-year undergraduate degree programme in industrial design, in the School of the Built Environment, The University of New South Wales. In scope, this investigation includes a study of the characteristics of the industrial design studio together with a brief historical background in order to identify requirements of skills and knowledge that are the desired outcomes of educational objectives in the studio. From a review of the literature concerning the history of the studio, the nature of industrial design, models of teaching applicable in the industrial design studio and findings from a structured survey of academics, an understanding of the role of the studio in major projects is established and fundamental problems identified.

A theoretical framework has been developed that led to the specification of a model that defines the phases and tasks associated with final-year, major projects from inception to completion. The model was enhanced by the addition of selected design methods aligned with the phases of the model. This enhanced model is entitled the Major Project Development Model or "MPD Model". An additional aspect of the research focused on the relative complexity of projects. The research sought to create a model that could be used to assess the complexity of student projects. The application of the model formed a part of the experimental work and analysis in this project.

The operational phases, associated tasks and methods in the MPD Model guided the development of a suite of computer-based methods designed and developed as part of this investigation. The computer-based system of methods is called the "MPD System", which is intended to serve as an instrument that encourages systematic activities within the creative culture of the studio.

The experimental work and analyses reported in this thesis have utilised the MPD Model applicable to final-year major projects. The experimental data available for analysis includes qualitative and quantitative information on tasks executed in major project reports, as well as the extent of use of design methods. The author has developed questionnaires that enabled the collection of data associated with the project reports for successive cohorts of students in years 2003 and 2004. The study had the following aims:

1.3 Aims

1.3.1 Based upon investigation of the literature associated with product design, studio-based teaching and teaching and learning in general, this work will determine problems associated with student engagement in final-year design projects conducted in the industrial design studio.

1.3.2 To confirm the determinations of 1.3.1 above a survey of academics in industrial design programs in Australia and overseas will analyse the performance of students in their final-year major projects with respect to project management, conceptual development and design resolution and the extent to which design methods are included in their project work to structure and guide their determinations.

1.3.3 To construct a theoretical framework that includes a range of methodologies to support student work in final-year major projects.

1.3.4 Based upon the theoretical framework developed in 1.3.3 above, to construct a computer-based, expert system of design methods that will provide a resource to support student work in final year major projects.

1.3.5 To investigate student major projects in successive years of a program where:
a) students have no access to the expert system; and where
b) students are provided with the expert system referred to in 1.34 above.

1.3.6 To draw appropriate conclusions and make recommendations for the function of the studio process and the incorporation of structure and methodologies that may enhance major project outcomes.

In working towards these aims, the experimental investigation and the analyses of the experimental data have been related, with appropriate conclusions, to the following issues:

Design Theory: Validity of a process model that links creative and systematic tasks associated with major project execution in the industrial design studio.

Design Management: Examination of tasks associated with major project execution; comparison with student perception of project tasks; and assessment of design methods used in project work.

Complexity of Projects: Investigation of the relative complexity of projects by application and validation of the author's model that defines complexity.

Academic Performance – Investigation of designer performance in the context of the academic environment with reference to assessment criteria based on a model of the major project execution process.

1.4 Research questions

In relation to the above aims and issues a number of research questions have resulted. These are used to guide the research and in the establishment of a number of research propositions which are shown in Chapter 4.1.1.

1. What design methods are taught in the UNSW program?

2. Do students who are trained in design methods apply these methods within final-year, major projects?

3. What design methods are found in students' final-year, major project reports?

4. Are existing design processes and methodologies used by students?
   Are they available and to what extent?
   Are they in a form that is convenient in use?

5. Will availability of these methodologies assist students in the conceptualisation and development of their final year project? How?

6. To what extent can the provision of a model, consisting of a development structure and design methodologies appropriate to final-year major projects, encourage students to adopt a more systematic approach in their project reports.

7. To what extent can the provision of a computer-integrated system, consisting of a range of design methods, encourage students to incorporate such methods in their project reports.

8. To what extent do complex projects use design methods?

9. Are the current teaching-learning processes and methodologies, applied in the design studio, sufficient to achieve students' objectives in the conceptualisation and development of final-year projects?

10. Is there a relationship between higher-performing students and use of design methods?

1.5 Layout of the thesis

The layout of the thesis is straightforward. **Chapter 1**, **Introduction** provides background to the topic and clarifies the nature and scope of the research. **Chapter 2, The Industrial Design Studio** describes, the historical development of the design studio, the context of the industrial designer and industrial design, design teaching and learning, and clarification of the design process as it occurs in the studio. The results of a structured survey of academics into student approaches and competencies displayed in their major project work, at a number of universities, are discussed. In addition, reflections by the author, on the supervision of student major-project work, over a twelve-year period, are included. The conclusions associated with the structured survey and the reflections by the author, lead to the statement of possible strategies for introducing a higher level of systematic thinking and procedure in the design studio without compromising the creative emphasis. **Chapter 3, Theoretical Development and Constructs** discusses educational theories of learning together with descriptions of the design process as it applies to industrial design and engineering. Typical methods that are used in the stages of the product design and development process are clarified. A model of the major project development process that includes stages and design methods that provide a framework for student work is introduced. The model guided the development of a computer-based system, which is described. **Chapter 4, Research Methodology and Experimental Programme** provides an explanation of the context and aims of the research together with a description of the subjects, the questionnaires employed, the instruments of analysis used in deciphering information and the mathematical analyses and statistical tests used in processing empirical data. **Chapter 5, Results and Discussion**, presents the results of the experimental investigation. **Chapter 6, Findings and Conclusions**, summarises the results and describes opportunities for further research. A **Bibliography** is included together with a comprehensive **Glossary of Terms**.

The diagram on the following page, Section 1.5.1, clarifies the principal stages in the research programme. These commence with statements of the research questions, outlined in section 1.4 and lead to three strands of enquiry, namely: a literature search; a structured survey of industrial design academics; and reflections by the author on twelve years supervising student major projects. These teachings lead to possible strategies, which establish a direction for the research. Further research, conducted into theories of learning and design process and methods, guide the development of a Major Project Development System (MPD) model. This model is applied to student projects and tested as the central part of this investigation.

1.5.1 Diagram of the research plan

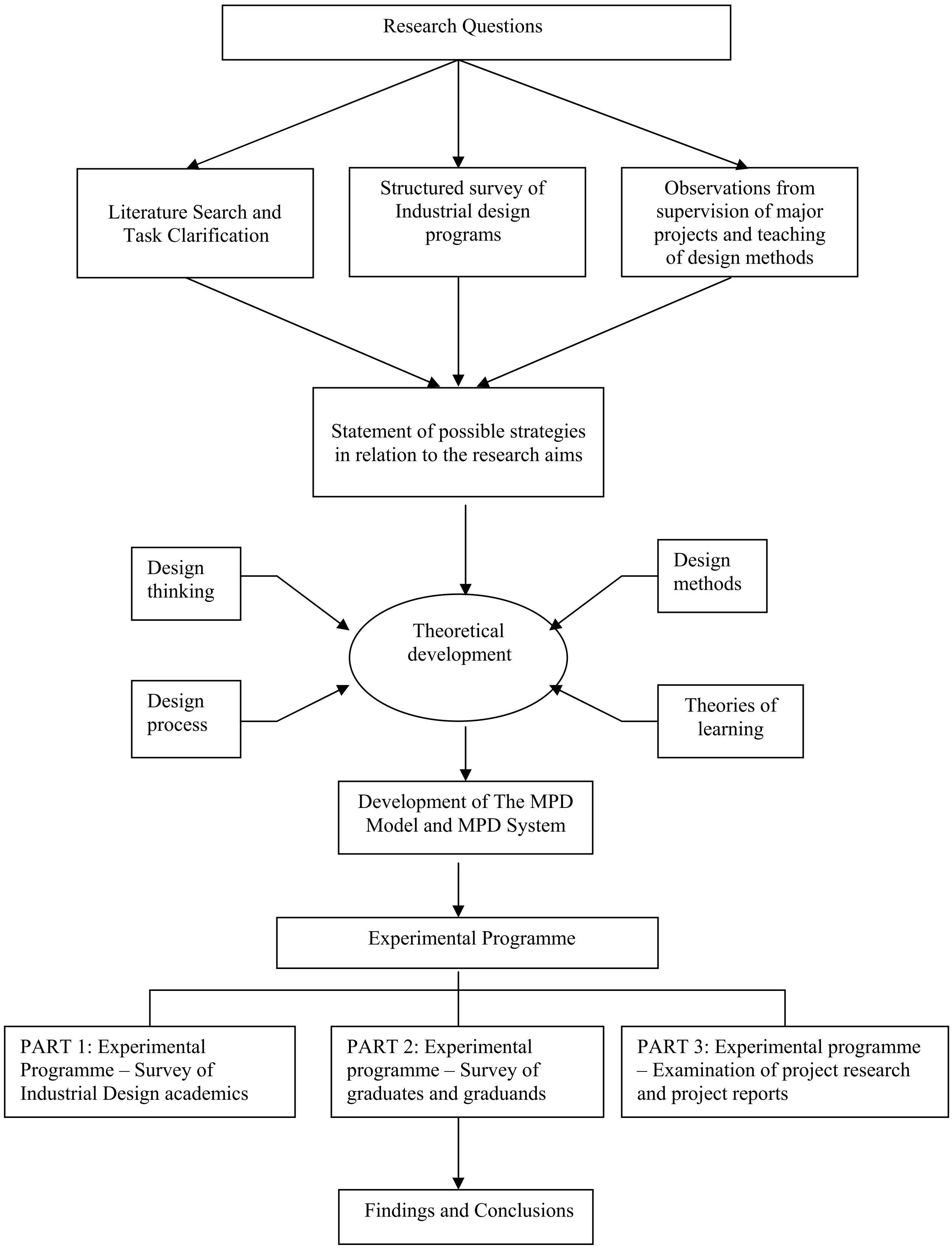


Figure 1.1 Diagram of the research plan

Chapter 2

The Industrial Design Studio

This chapter researches the historical background of the architectural studio and how the studio evolved to be a fundamental part of industrial design thinking and learning. The educational advantages and disadvantages of the studio, the nature of the studio and the type of problems encountered are clarified as background to the research problem.

The history of industrial design is considered in order to understand: the origins of the separation of designing and making; the rapid developments in industry in the 19th Century; the era of mass-production; the massive rise in consumerism; and how these contributed to the role of the industrial designer. In addition, the context of the current designer, the nature of the problems faced in professional activity, together with definitions of associated design activity, such as product and engineering design, are also included. Design teaching is clarified particularly as applied to problem and project-based learning in the design studio and the difficulties that students have in gaining confidence in design decision-making.

A study was undertaken in the form of a survey distributed to a number of industrial design academics experienced in the supervision of students engaged in final-year major projects in industrial design. The survey sought to establish the general approach of students to their major projects and the process and methodologies they employ. Finally, a statement of possible strategies associated with the studio established the rationale for this research.

2.0 THE INDUSTRIAL DESIGN STUDIO

The studio is usually a large room equipped with drawing tables and chairs to enable students to work independently on projects. Good natural lighting is essential for effective drawing work and wall areas are provided to enable students to "pin up" their work for review. The design of the room contrasts the traditional teaching classroom and whilst lectures occur within the studio their nature is more in the form of presentations and discussions. These presentations usually seek to explain the nature of a project, the associated milestones and submission requirements. The studio teaching process is supervised by a studio director and a number of tutors assist in coaching students as the

Figure 2.1 A typical design studio environment[1]

project progresses. The studio has evolved from an earlier system, described in Chapter 2.1.1, which was based on the "master"/ "apprentice" method of conveying skills and values. This system prevails today, where the apprenticeship system is maintained, in the relationship between the studio director and student.

Many studios incorporate facilities such as workshop equipment that enable the student to experiment with the form or function of a product, and shaping tools and foam materials may be provided. This encourages learning by "doing" and frees the student to experiment and consolidate intangible aspects such as shape and feel. External to the

[1] http://www.cia.edu/academic/undergraduate/industrialdesign/default.asp

studio are facilities that are essential to the execution of the studio project. These include the workshop where woodworking and metalworking machine tools enable the creation of models and the computer laboratory, which facilitates the production of rendered drawings, engineering drawings and the development of computer-based models. In the modern setting these models can be transferred to privately-operated bureaus which facilitate the rapid-prototyping of product models. The workshop enables students to construct models of products made from plastic, wood or foam and its importance to teaching and learning, as a means of resolving student projects, cannot be overstated. The significance of the use of a model is the answer or answers that are provided as a result of the modelling process. Models, of themselves, signify the object; modelling signifies the process. And in the end it is the process that provides the answers (Giard[1], 1999).

The importance of the design studio in the present-day industrial design curriculum can be gleaned from the fact that it is considered the heart of design teaching and learning; a place where students learn to visualise and represent aspects of a problem graphically. It is where students learn to “think as a designer”; the studio environment representing a place where skills and values can be brought to bear within a spirit of open inquiry. In the studio, emphasis is placed on creativity, drawing, problem solving and communication. Industrial and product designers are coached to think widely and deeply, formulating the problem using the right side of the brain. Discussion, conjecture, imagining, stretching the boundaries of issues, are tenants of design thinking. Maitland (1991) writing of studio teaching comments that: *the studio, however, is not just a space marked "studio". It is a way of thinking and learning*.

The manner of thinking encouraged in the studio is described as random, intuitive, holistic, synthesising, and subjective; all belonging to the fields of art, creativity and the skills associated with imagination and synthesis. Patterning, metaphors, analogies, role-playing, visualisation and movement are encouraged; all consistent with right-brain thinking. This is in contrast with the left-brain approaches of disciplines such as engineering and science where thought processes draw upon established principles and methodologies and where the approach is logical, sequential, rational, analytical, objective and concerned with parts. The left side of the brain deals with a problem or situation by collecting data, making analyses, employing a rational thinking process to arrive at a conclusion.

The design-studio course is complimented by disciplines, such as marketing, engineering, manufacturing and science, which are usually taught external to the studio and in many instances in other faculties. Teaching and learning in these disciplines is in conflict with the manner of teaching and thinking applied in the studio and thus there is some tension experienced by the student. In many instances students struggle to engage with such courses and subsequently the connections between these complimentary disciples, that are essential to effective project execution, are never quite made by many students. The studio-teaching process generally does not embrace the content of these external courses and the marriage between industrial design creative and intuitive thinking and logical, rational and analytical thinking, essential in marketing and engineering disciplines, is not harmonious.

The execution of a studio project involving design and product development processes requires both logic and creativity; namely a whole-brained approach. However, design studio activities emphasise right-brain thinking, that is, emphasis is given to art, creativity, and the skills of imagination and synthesis. Left-brain activities, such as the collection of data, analysis and rational thinking, occurs outside, for example, in the library or at the computer, but not in the studio. Hence the left-brain requirements associated with a studio project are executed elsewhere and are largely unsupervised and unstructured. This is not necessarily an issue in the earlier years of an industrial design degree where the studio approach is solution focused, that is, an initial solution is provided and then subjected to analysis, evaluation, refinement and development. But in the final year particularly, major projects can span a whole academic year and require a blend of logical and intuitive approaches and many students struggle within a studio culture that does not readily accommodate logical and analytical thinking. Many students are unable to plan, organise and manage a substantial project that includes significant elements of market analysis, consumer research, project planning, detail clarification and financial justification.

The above issues and characteristics of the studio in the preceding paragraph constitute many of the premises upon which this research project is based and the research will now describe the history and nature of industrial design, the industrial design studio and the current approach by students to major projects conducted in the studio.

2.1 EVOLUTION AND DEVELOPMENT OF THE DESIGN STUDIO

2.1.1. Origins of the studio

Plato (428-327bc) encouraged a free, unfettered exchange of knowledge. He brought disparate thinking into a forum of discussion much like that experienced in a modern-day studio. His model of teaching became known as Platonism and his community of scholars referred to as Academy, which he founded in 386 BC and where he taught and wrote for most of his life (Pevsner, 1940, p.1).

Figure 2.2 Plato's School of Athens [2]

The philosophy, associated with Platonism, expressed the view that the phenomenon of the world is an imperfect and transitory copy of a transcendent world of archetypal forms. His discussions with his pupils were intellectual in nature, but intuitive and free, allowing the intellectual and creative development of his students (Readers Digest, 1984, p.1303). The relationship between Plato and his students, although informal, was essentially the relationship between the "master" and "apprentice" where knowledge was conveyed, not as in a classroom, but informally, through discourse and critique and eventual agreement. A rebirth of Platonism occurred in Italy, during the latter part of the fifteenth century, where a large number of schools flourished based on humanistic discourse; a free, sociable and informal means of discussion, vastly different in nature to the scholastic pedantry of universities of that time. These schools later came to be known as

“Accademia Platonism” and although they facilitated an informal gathering of humanists they also included composing, reciting, and the criticism of poetry and writing. The development of academies proceeded to include two strands: one devoted to problems of language and philosophy and another concerned with physics, chemistry and natural history.

The literature refers to an Acadamia Leonardi Vinci and debate has occurred which suggests Leonardo Da Vinci (1452-1519) led an academia. Both Michelangelo (1475-1574) and Leonardo maintained studios where they instructed apprentices in art and sculpture. Their approach separated art from craft and they believed that painting was a spiritual expression and not a manual skill. At the time of these artists a new philosophy of art education was introduced where perspective was the first subject to be taught, then the theory and practice of proportion. The student would then be introduced to the techniques of illustration from his master’s drawings, drawings from relief’s, from nature and finally the practice of his art. Leonardo’s theoretical system required art to be sundered from handicraft and that the painter should be taught knowledge more than skill. (Pesner, 1940 p.35). In both the informal discourse of humanists in the Academia Platonism and the master-apprentice relationship of the renaissance art studio the culture of the modern studio was present and where emphasis was placed upon the creative imagination at the expense of the more logical, analytical approach.

2.1.2 The E’cole des Beaux-Arts

The Académie Royale d’Architecture in Paris was established in 1671 to standardise French architectural education. By the early part of the eighteenth century the Académie had become entrenched and unfashionable and as a result Blondels’s Ecole des Beaux-Arts emerged in 1743. Initially the Ecole was concerned with painting and sculpture however in 1793 it took over the function of the Académie Royale d’Architecture. In 1795 architecture was set apart from engineering and technical education and created the E’cole Speciale d’Architecture alongside schools of painting and sculpture. In the early 19th Century the three schools were united within the E’cole des Beaux Arts, although architecture retained its own faculty and curriculum. The primary function of the Ecole des Beaux-Arts was to provide drawing classes, theoretical lectures and an institutional framework for advancement through competitions. This school, together with many others across France, was a deliberate strategy to ensure a steady stream of skilled pattern designers who were responsible for the establishment of French design (Heskett, 1997, p183). The Ecole des Beaux-Arts, offered full-time studies, and was open six days a

[2] http://www.kfki.hu/~arthp/art/r/raphael/4stanze/1segnatu/1/athens.jpg

week, the mornings given over to discussions with the professors, while in the afternoon there were lectures on fortification, mathematics, geometry, mechanics, perspective, water supply and drainage.

Figure 2.3 The Ecole des Beaux Arts architectural studio in Paris[3]

The architectural studio emerged as a special form of education within the Ecole des Beaux Arts and concurrent with the program offered by the Ecole was part-time study of individual subjects, supplemented by employment, in the manner of the old *atelier* system of indentures and articles (Bingham, 1993). Many practitioners believed that this system of architectural training produced superior architects. The "masters" of the modern architectural movement, Frank Lloyd Wright and Le Corbusier, were both trained in this way (Proudfoot, 1989). The Ecole des Beaux Arts provided drawing classes, theoretical lectures and an institutional framework for advancement through competitions, however the practice of the arts continued to be taught in the artist's studio or the architect's drawing office. Increasingly, however, teaching studios were separate from an architect's office.

2.1.3 The emergence of industrial design

As a profession, Industrial Design is relatively young. It has arisen from developments in manufacturing that occurred over a two-hundred year period. The needs of the consumer

---

[3] http://web.centre.edu/french/fre470/belleepoque/page

together with the requirements of manufacturing have defined the profession. Moreover the explosion in consumerism in the 1930s and 40s delineated the profession from architecture and engineering.

The role of the industrial designer had its origins in the development of industrialisation and mechanisation that began with the industrial revolution in Britain in 1770. The separation of design from the processes of making became established in the latter part of the eighteenth century where the continuing expansion of trade, commercial opportunities and the growth in production led to a demand for innovation and distinguishing features in products (Heskett, 1997, p.15).

'Prior to the industrial revolution industrial design was not separately defined or recognized. Manufacturing was a handcraft industry where a product or craft item was not designed according to a cognitive thought process; rather it was adjusted over an extended period of time. This evolutionary process eventually defines a form for the object, which is well suited to its functional requirements' (Burch, 1993).

The phenomena of the establishment of the designer, separate from the maker, is best reflected in the pottery products and processes developed by Josiah Wedgwood. Wedgwood's intention to make a consistent, uniform product could not be achieved as long as his workmen were not constrained from making variations in the various pottery products. Pottery had been a craft industry, in the sense that a single individual was responsible for all the stages of making a pot, however this form of production had ceased in Staffordshire before the beginning of the eighteenth century. From the 1730s, if not earlier, potters had specialised in one of the branches of the trade, such as throwing or handling, or making glaze and slip. At Whieldon's pottery in the 1750s, the work was divided into at least seven different occupations, with each workman usually doing a single task. Breaking down the production process into more stages had the advantage that, for some of the tasks, he could make do with less skilled labour. However, when the manufacture of pots was broken down into processes carried out by different workers, an additional stage was required, the preparation of instructions for the various workmen to follow, namely, a design stage. The work of designing, or modelling became a distinct and separate stage in the production of pots.

By the 1750s, not only was modelling recognised as a separate activity, but also there were individuals described as modellers, whose sole task was to make prototypes as a basis for standardisation and uniformity. Good modellers became increasingly indispensable as the craftsmen's freedom to control the form of the pot was restricted.

Wedgwood had constant difficulty in finding modellers who could design in the antique style, whether for his ornamental or his useful wares. Ultimately Wedgwood solved the problem by employing artists from outside the pottery industry to do the modelling. Understanding the principles of neo-classicism, these artists gave modern products the character of the antique. Though the professional designer might have been able to conceive a very much more stylish and marketable product, the fact that there was work for him to do, was the result not of his invention, but of the division of labour in the factory (Young, 1995).

Prominent artists such as John Flaxman, George Stubbs and Joseph Wright were commissioned by Wedgwood to produce designs to be manufactured at his Etruria works which was conceived with the mechanical equipment to standardise high volume production. Catalogues were produced to advertise standard products and together with intense marketing the Wedgwood business grew considerably. These innovations had a profound effect on the process of design and established the role of the designer.

In the nineteenth century, because of a shortage of designers and the influence of manufacturers, designs lost much of their aesthetic quality and prominent designers such as William Morris and John Ruskin made sweeping condemnations of industry and its products. This led to a movement to improve art education and to provide museums and collections freely available to the public. However a number of individuals, the most prominent being, Henry Cole sought to raise design awareness in industry by being prominent in the plans for the Great Exhibition in 1851 and in establishing the Journal of Design in 1849. Many publications in the Journal sought to reconcile artistic values with utility and commercial production.

The poor execution of aesthetics in many products at this time was correctly attributed to the separation of designing from the processes of production. A later article stated:

'*the acme of beauty in design is only attained when the system of ornamentation is conducted in strict accordance with the scientific theory of production – when, in fact, the physical condition of materials, and the economic processes of manufacture, limit and dictate the boundaries within which the imagination of the designer may revel* (Heskett, 1997, p.21).'

The implications of this statement were that industrial production had expanded so quickly that an enormous shortage of designers resulted and in particular, designers who could relate to the massive pressure that industry exerted and who could retain design elegance in products in the face of the constraints of mechanisation.

In the later part of the nineteenth century new and significant industries developed. These included locomotive and rolling stock that required new expertise in design and fabrication. Engineering construction emerged as a technological discipline in its own right, although the consideration of the aesthetic was retained in the design of locomotives, shipping, and machinery of numerous types.

Ommitted for copyright reasons

Figure 2.4 Stephenson's Rocket

Concurrent with the dramatic gains in the construction of low-volume machines were developments in mass production emerging most notably in the United States. The innovation in the late eighteenth century with the work of Eli Whitney in the production of ten-thousand muskets established new standards in manufacturing. Developments in high-volume production continued into the mid-nineteenth century with the establishment of Samuel Colt's armory in Connecticut. The emphasis on mass production proceeded strongly in the United States due to the shortage of workers and due to the absence of an entrenched craft tradition. American inventiveness was applied to a range of completely different products differing from the European approach that focused upon decorative art. The best example of new American products was the sewing machine. Further innovations followed, such as the typewriter, the folding pocket camera and at the turn of the 20th century a wide variety of American mass-produced products were developed to cater for a rapidly developing consumer market (Heskett, 1997, p.56).

Design practice was carried out by artisans, mechanics, engineers and designers and applied over an extraordinary range of items, including objects, artifacts, machines and mass-produced products. Design, as a distinct activity, was not yet established, however a change towards a machine age, that included consideration of the aesthetic and production, was emerging out of the more ostentatious arts and craft period.

In the United States the low-priced, mass-produced car emerged. In parallel with this development were studies on the efficiency of work and production by Frederick Taylor and the scene was established where a huge advance in production was possible.

Engineering played a huge part in the mechanisation and industrialisation of Europe. Many famous engineers gained their first knowledge as millwrights or as colliery enginemen. For those that followed, the recognised routes into the profession became more regular, principally through an apprenticeship of three years in the office or workshop of an established engineer. However there was a strong movement towards a greater level of academic training in the discipline of engineering and as a result King's College London established its Department of Civil Engineering in 1838 and soon after widened its courses to include architecture. Glasgow University established a chair of engineering in 1840 and in 1841 a similar appointment was established at the University College, London (Thorne, 1993, p.23).

Ommitted for copyright reasons

Figure 2.5 Sewing machine, a typical example of mass production

Concern developed about Britain's slipping economic performance around the time of the Paris Exhibition in 1867 and as a response greater effort was applied to development of engineering teaching within academic institutions. Considerable tension existed between the philosophical approaches to the education of engineers, namely theory-based versus apprenticeship.

Meanwhile, the Royal Academy of Arts in England, which established courses in architecture in 1736, continued and reached the highlight of instruction by 1836. The classes were conducted on a part-time basis with students employed in an architect's office and who attended classes in the evening. However a major criticism was that the Schools did not encourage dialogue and the architecture courses were essentially lecture based. There was neither written work nor organised group discussion, which was different to the studio-based discussion that occurred at the Ecole des Beaux Arts in Paris.

Henry Cole in Britain, a civil servant, founded the *Journal of Design* in 1849. At that time *Design* was identified by ornament and did not necessarily include the process of imparting utility. Great errors in taste were occurring in Design and it was broadly identified that the separation of design from making had led to unsatisfactory outcomes. The teachings of the *Journal* served to demonstrate the way that design could be correctly applied to the development of products.

Design studios existed in a form appropriate to architects and artists. Artists were retained by industry to improve products, for example Alfred Stevens was retained to improve the aesthetic design of cast-iron ovens and fire grates. Elkington's of Birmingham released over 50 assistants for classes in Design at the Midland Institute. Henry Doulton, the pottery manufacturer, employed some students on an experimental basis and went on to establish a design studio that employed over two-hundred people. This studio served as a model for other companies' design studios (Heskett, 1997).

By 1914 British university institutions had reached a position where they provided an ample source of scientifically trained engineers for industry (Thorne, 1993, p.24). This emphasis on scientific rigour and its application in professional practice assisted England particularly to develop advanced products. The trend towards scientific emphasis inevitably set a future pattern for engineering education

2.1.4 The design studio in the 20th Century

The character of present-day architectural education was shaped during the period 1900 to 1914. Thereafter the alternative mode of education departed from the previous tradition of pupillage and endorsed universities as the sole provider of architectural training (Powers, 1993, p.34). Even though there was a strong culture associated with materials and construction architectural schools found that the attractiveness of the programmes to potential students depended on making design and drawing the core of the curriculum. This established historically the culture of communication by images rather than words and reinforced the nature of the studio

In the later part of the nineteenth Century and the early part of the 20th Century there was concern about the ugliness of the built environment and of artefacts. The achievements of the industrial revolution had outstripped the capacity to retain beauty in constructed and manufactured products. The founders of the Deutches Werkbund, under the authorship of Ernest Schumacher, published a manifesto in 1907, which described the situation that existed and called out for aesthetics to be accorded far greater emphasis (Giard, 1999). A new agenda in design followed which affected architecture, graphic design and industrial design for most of the 20th century: namely a total dedication to visual aesthetics as a means to address the visual ugliness of manufactured products. The architectural studio became a place where the obsession with the artefact was reinforced and self-expression within a product was legitimised. This set the agenda for the next fifty years and even though dramatic developments in mass production and awareness of human factors followed the nature and context of the studio was established as a place where creative self-expression was carried out.

The rapid rise of mass production in the early part of the 20^{th} century accentuated the separation of the tasks of designing and making. The role of the designer was thereby elevated and became more defined. To specify the nature of products so that they could be manufactured effectively became one of the major functions of the designer. Certain key designers created an awareness of industrial design and the profession was more readily accepted by many organisations. The major schools of design that arose out of this period were the Bauhaus in Germany and those in the United States.

The Bauhaus was a teaching institution founded at Weimer in Germany in 1919. It amalgamated the art and craft schools under the direction of Walter Gropius. The early years of the Bauhaus were focused on uniting art and craft and the objective was to train a new kind of collaborator for industry and the crafts who had an equal command of both technology and form (Heskett, 1999). Gropius (1983) maintained that:

Figure 2.6 The Bauhaus[4]

[4] http://departments.risd.edu/depts/arth/web/lecture16.html

'the school should be absorbed into the studio and that the manner of teaching should arise from its character, that is, the studio should not be an adjunct of the other teaching programs. On the contrary, all the teaching programs should exist only to support the studio and the design problems it is working on, reflecting the reality of professional practice, which is entirely driven by the needs of the project'.

He meant that the studio should be a place where theories are put into practice and that the unification of theory and practice produces the product. The execution of the unification between theory and practice could only occur within the controlled environment of a studio. The adjunct (studio supporting) courses such as mechanics, manufacturing and materials science should not be isolated from the project activity in the studio but complimentary to it.

The New Bauhaus, founded in Chicago, was the immediate successor to the Bauhaus, which was dissolved in 1933 under National Socialist pressure. Its ideology had a strong impact throughout America with the new former master Laszlo Moholo-Nagy as the director. The focus on natural and human sciences was increased and photography grew to play a more prominent role at the school in Chicago than it had done in Germany, with more sophisticated training in mechanical techniques.

Bauhaus style was characterised by economy of method, a severe geometry of form, and design that took into account the nature of the materials employed. It can be said that the Bauhaus firmly established industrial design. The school was built on the idea that design did not merely reflect society; it could actually help to improve it. The Bauhaus school of design adopted the principle of *function over form*, without totally neglecting the satisfactory design standards (aesthetic aspects). The philosophy of the Bauhaus school wanted to convey clean, functional, modern design. It also wanted to combine all the arts, craft and technology in the daily life, in order to pursue new forms and new solutions to humankind's basic needs.

International Style was applied to the American form of Bauhaus architecture, which became a symbolism of Capitalism. Bauhaus buildings have flat roofs, smooth facades and cubic shapes. Colours are white, gray, beige or black. Floor plans are open and furniture is functional. In the 1950s the New Bauhaus merged with the Illinois Institute of Technology, which remains an outstanding place of industrial design teaching and rates as a respected and professionally oriented school of design.

In the United States, industrial-design education formally started at Carnegie Technical College (later to become Carnegie-Mellon University) in 1935-36 under the direction of Don Dohner. This was followed by the Pratt Institute of Art in New York and these developments together with those occurring in industry served to establish the industrial design profession. Design education, in these years, grew from the demand for mass-produced products and the vision of design educators to delineate industrial design apart from architecture and engineering (Kaufman, 1999). Around this time in the United States designers came to prominence establishing studios to cater for a wide variety of products.

Meanwhile, the trend towards more logical and systematic methods of design became more defined during the 1950s. Contributory to this trend was the introduction of creative engineering and brainstorming as means to provide some bases for idea generation. Likewise, the subject, Design Methodology was introduced in the 1960s and 70s which drew attention to the need for design to be more transparent and more substantially based on a structure of analysis. However the idea failed to achieve wide acceptance as part of the normal process of designing and design methodology was not incorporated into studio teaching on a significant scale.

Ommitted for copyright reasons

Figure 2.7 The Pratt Institute, New York. Architectural design studio[5]

[5] http://www.rogersmarvel.com/...../higginsattic.jpg

The generation of design educators that experienced the ill-fated introduction of design methods failed to be convinced of the relevance of design methods in the process of design. As a consequence, there was a failure to integrate design methods into studio teaching.

Over the period 1980-1986 Donald Schon at MIT studied the manner of education of a range of professions and was intrigued by the apparent deviant nature of the architectural studio. He argued that the schools of other professions should learn from it. The movement towards revived studio functions led by Schon, suggested that subjects can be taught in an academically rigorous way without application in the studio having to take a similar approach. Schon rejected the established procedures in professional education of building application upon basic science and theory; he dismissed the notion that professional practice was based on the rigorous application of theoretical knowledge (Proudfoot, 1999).

The industrial design studio of the 80s did not differ significantly from the models exemplified by the Bauhaus and the American schools. They were essentially an amalgamation of art and craft. However during this period concern about the environment created a need to include considerations of sustainability in studio projects. Similarly the trend towards globalisation and world-competitive products demanded a greater emphasis on usability and cultural issues. The worldwide emphasis on Total Quality during the 80s identified that Design was central to product quality and issues of consideration developed, including design for manufacture (DFM), assembly (DFA) and disassembly (DFDA).

The studio of the 90s had to embrace much more than the blending of art and craft. In many schools the studio became a place where issues of art, design, culture, manufacture, sustainability and usability were integrated into a design process. However, whilst broader considerations did change the manner of many studio projects, the culture and nature of the studio, as it existed at the end of the 20^{th} Century, still primarily focuses upon visual attributes. Considerations of the environment and user needs are secondary. It is still a place where right-brain thinking and the emphasis on visual attributes is paramount. Its modern pedagogy and professional practice is still firmly rooted in the traditions of the arts and crafts, the fine and applied arts and architecture (Giard, 1999).

2.1.5 The design studio in the 21st Century

The modern industrial design studio is a place that coordinates studio projects. The studio may be complimented by other facilities namely:

- computer laboratory (including 2-D drawing and 3-D visual renderings and modelling);
- user-centred design laboratory;
- workshop (plastics, woodworking and metalworking);
- rapid prototyping;

A studio project, although coordinating sophisticated relationships with supporting facilities, is nonetheless still committed to a solution-focused approach.

Figure 2.8 A modern industrial design studio[6]

For most of the twentieth century industrial design practice and education has advocated one fundamental value: the overriding concern for and an accent on visual attributes. Various periods have emphasised other value sets and have conditioned the visual agenda but not to any great or lasting effect (Giard, 1999). Aesthetic considerations are embedded in the industrial design culture and dominate the focus of the studio. This is despite the fact that industrial design has moved closer to engineering and marketing and despite the fact that the breadth of considerations in the design process now include many

[6] http://www.artdes.monash.edu.au/design/studios/industrial/body/industrialdisplay.htm

value sets, namely user-centred issues, manufacturability, cultural, and emotional issues, among others. Industrial design is now a broadly-focused process, not just product focussed. It has a bottom-up approach, something quite different to the top-down model of the 20th Century and issues of user values are central to the design function.

Two fundamental issues will emerge and consolidate the culture of the 21st Century studio; the environment and the user. The importance of aesthetics will remain, however a much greater emphasis will apply to the experience of a product and user needs. Thus the earlier 20th century focus of industrial design upon *self-expression* and *artefact* will extrapolate to a much great emphasis on *experience* and *user needs*.

The implications for the 21st century studio are that projects will emphasise the *experience* associated with a product and *user needs* and will require the rapid development of product features and testing to verify suitability for such considerations as: environment of use; customisation; and issues of sustainability. User needs will be substantiated by focused research and the careful consideration of a host of issues including usability, emotion, universal considerations, and sustainability. The design methods potentially supporting the 21st Century studio such as rapid prototyping, 3-dimensional modelling, life-cycle analysis, quality-function deployment, user-centred testing, among many others will have a more legitimate place in the studio.

The historically-emphasised, right-brained approach to thinking has to give ground to accommodate a more whole-brained approach where the teachings of disciplines, supporting the studio, are more effectively integrated. For example, the teaching of manufacturing needs to be less lecture-based and more project-based. Projects set in manufacturing courses need to be complimentary to the studio project. This principle should also be applied to the teaching of marketing, management and design methods.

The studio then will become a place where a great number of considerations need to be considered and synthesised to arrive at design concepts. The means by which this can occur is not clear because the current studio remains a place of essentially solution conjecture.

In summary, the research has identified that very little is published in the area specific to the research questions that have been asked in this thesis. The following Chapter 2.1.6 focuses upon a specific industrial design studio and final-year project at the University of New South Wales.

2.1.6 The Industrial Design Studio at The UNSW

The University of New South Wales (UNSW) was one of the first tertiary institutions to be involved in industrial design in Australia. Initiatives date from the late 1950's. A Graduate Diploma in Industrial Design was offered in the 1960's and electives for industrial arts and architecture undergraduates were offered during the 1970's and 1980's. In the early 1980's, Master of Science (Industrial Design) and Master of Industrial Design courses were established within the Graduate School of the Built Environment. The Bachelor of Industrial Design degree was established in 1989 and at that time a Department was created.

Figure 2.9 UNSW industrial design studio

The current undergraduate course is an innovative 4-year, industry-cooperative program comprising approximately 60 percent industrial design and related subjects, 15 percent commerce and marketing courses, 20 percent engineering, science and manufacturing courses and 5 percent liberal arts. Student numbers are currently 260 over four years and six permanent teaching staff are employed. Additional teaching support is provided by a number of casual lecturers from industry and from the faculties of engineering, science, commerce and the built environment. Therefore teaching may be classified into two broad categories, internal, where teaching is conducted by staff lecturers, casual teachers, and external where teachers from other faculties conduct teaching programmes on behalf of the industrial design programme.

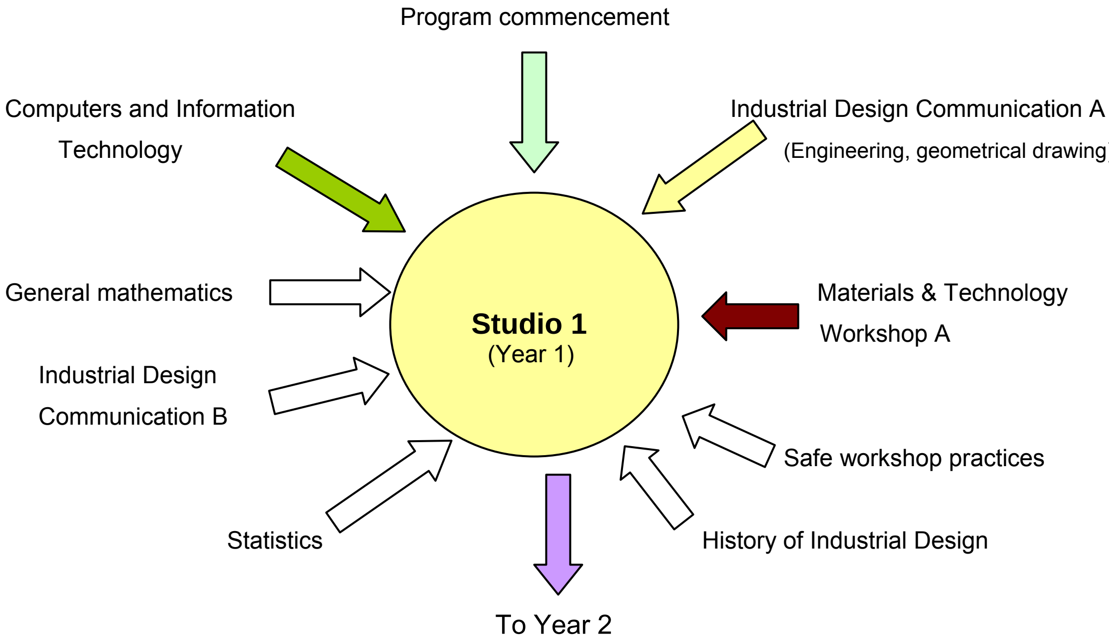


Figure 2.10 Diagrammatic representation of the Year 1 programme with courses arranged around the studio.

The design studio in each year of the course acts as a central hub and supporting courses are arranged around the hub and exist to compliment teaching and learning within the studio (refer Figure 2.10). In year 1, the overall objective is to achieve *visual awareness* in the student. Computer skills and technology, mathematics, and statistics provide a scientific foundation. Materials & technology A is a flexible course that integrates workshop skills, knowledge of engineering mechanics and electrical engineering.

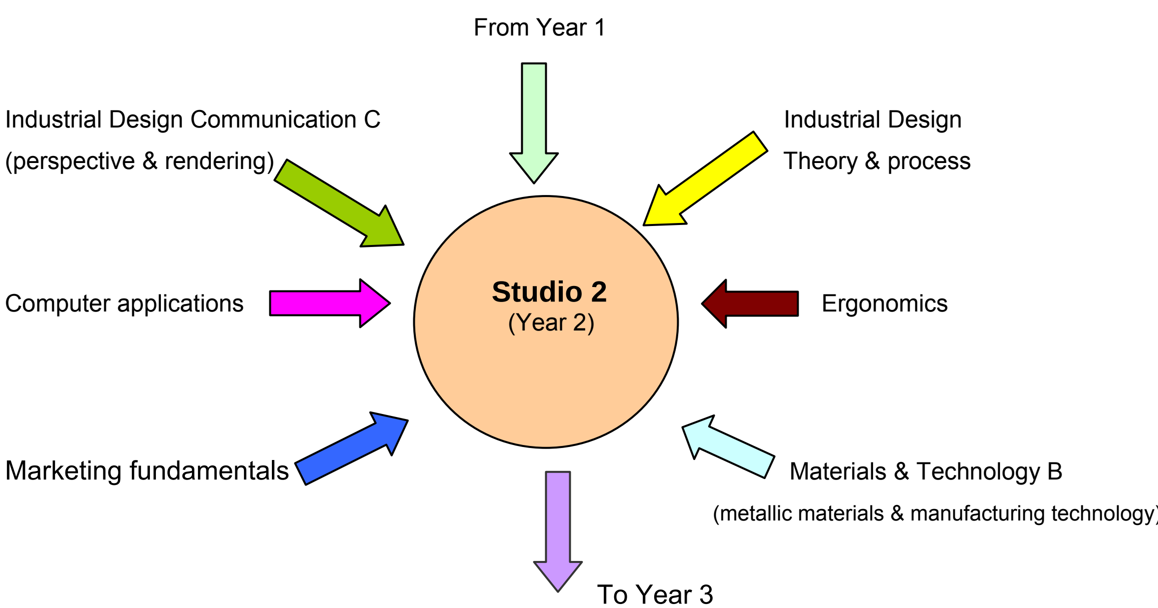


Figure 2.11 Diagrammatic representation of the Year 2 programme showing supporting courses related to the design studio.

Industrial design communication A & B intends to develop knowledge and skills in engineering and perspective drawing. *History of Design* describes design from the industrial revolution to the present day.

The objective of studio 2 is to achieve *visual literacy* in students. Studio projects are concerned with issues of usability and creative and visual thinking. Supporting courses in perspective and rendering and computer-aided drafting provide additional visual and drawing expertise (refer Figure 2.11). Industrial design theory and process provides an understanding of the design process and methods. A theoretical approach to ergonomics enables an understanding of human factors. Marketing is introduced and materials and technology clarifies design using metallic materials.

Year 3 introduces technology and seeks to make students *technologically aware*. Advanced courses in design methodology, manufacturing and computer modelling are

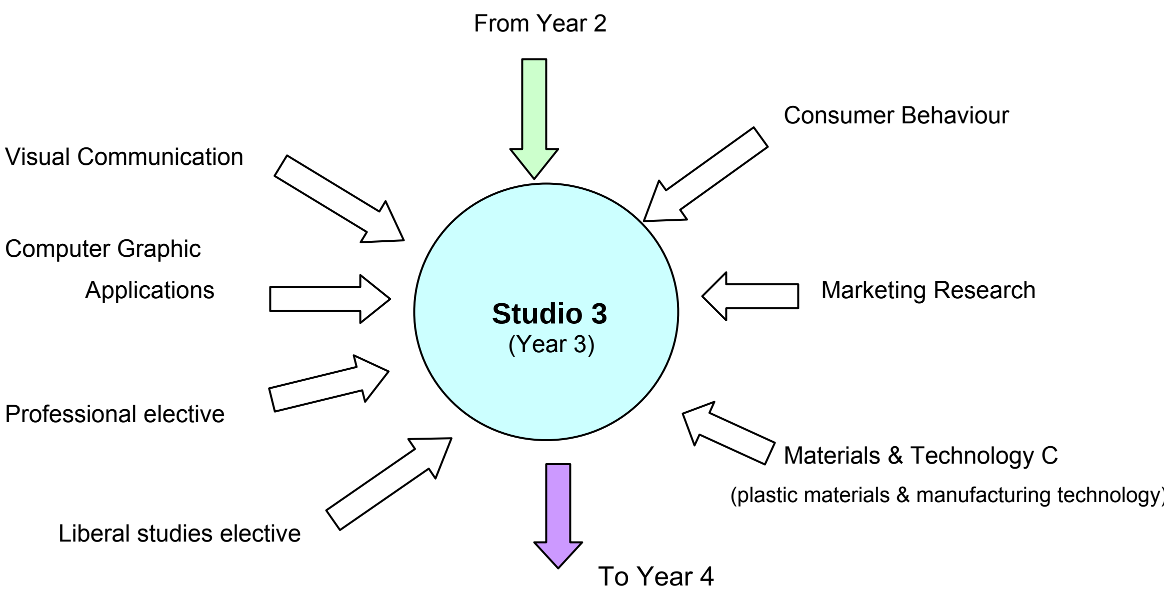


Figure 2.12 Diagrammatic representation of the Year 3 programme with courses arranged around the studio.

taught in supporting courses (refer Figure 2.12). At this stage the studio project integrates visual, human, functional and manufacturing issues. Projects require a higher level of technical and aesthetic resolution. At this stage students start to struggle and many are unable to make the connections with, and integrate into projects, the broad range of skills and knowledge. Many students are unable to confront the details of their projects and it is this lack of practice in detail decision making that impedes the development of their design capabilities.

The principal focus of this research is the final-year studio project and this will be discussed in Chapter 2.1.6.1 below.

2.1.6.1 The final-year and final-year Major Project at UNSW

Year 4 focuses upon *commercial awareness* and courses, such as industrial design management and practice, are taught in the supporting mode and these are integrated into the final-year major studio project, which is designed to link and demonstrate all the competencies acquired over the duration of the program.

The final-year, major project in industrial design is a significant undertaking of design research and product design. Other industrial design programs in Australia, namely: The University of Technology, Sydney; The University of Canberra; The University of Western Sydney; and the University of South Australia include a similar final-year project. This final-year project is also included in Universities in other parts of the world, namely: The National University of Singapore; The Seoul National University of Technology among others throughout Asia, Europe and the United States. The year-long, major project at UNSW culminates in an exhibition of student projects normally held in prestigious venues in Sydney, such as: the mezzanine level of Darling Park; Elizabeth Bay House; Technology Park at Redfern; and at the Exhibition Centre in Darling Harbour.

Figure 2.13 An Industrial Design final-year exhibition

The final-year project is an integral part of the course, an activity designed to put into practice the students' overall knowledge and application of the academic course. The project is carried out in two phases, namely:

1. Project Research
2. Project

- The *Project Research* phase spans a period from early March until the end of June, however the project actually starts in November of the prior year when students are guided towards the identification of an area of design research. The major aspects of the *Project Research* phase are the:

  - identification of an area of product research;
  - determination of the market together with commercial issues that are associated with the product or area of design research;
  - narrowing down of the research to identify a specific project;
  - investigation of the human factors associated with the project;
  - investigation of the materials and manufacturing processes that are applicable to the project; and the
  - specification of a product brief.
  - clarification of the brief and the requirements of the project;
  - generation of ideas;
  - further development of concepts;

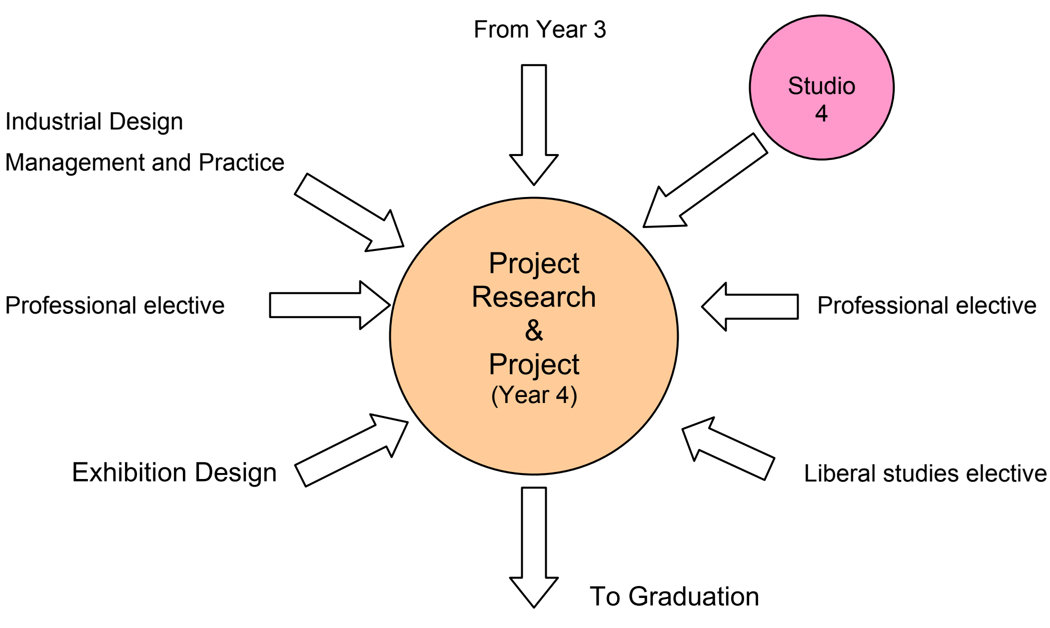


Figure 2.14 Diagrammatic representation of the Year 4 programme with courses arranged around the studio.

Project Research is intended to establish a carefully researched and clearly documented basis for the subsequent development of the *Project*. The outcome of

Project Research is a report of professional standard, which documents the research activities undertaken, and which specifies and justifies the relevant design criteria for *Project*. Project Research will also involve the development of design concepts. The *Project* phase spans a period from late July to late November following which the products are exhibited at a major exhibition.

- *Project* includes:
  - evaluation and refinement of concepts;
  - detailed design of a preferred concept;
  - communication of the project which includes computer modeling, renderings, assembly and detail drawings, a physical model and a business plan that includes a projection of the investment involved and the financial return.

The formal and informal hours appropriate to *Project Research* and *Project* are a substantial part of the programme and amount to 10 hours per week (face-to-face) and 20 hours per week of home study. Therefore careful planning over the two sessions is essential in order to manage the process. The time-plan associated with the final-year projects for the 2003 year is shown in Table 2-2. This includes a stage of assessment of *Project Research* in July and similarly *Project* is assessed in December.

		2002			2003											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	may	June	July	Aug	Sept	Oct	Nov	Dec
	Task Name															
	Project Research (IDES 4301)															
1	Introduction of *Project Research* and briefing concerning selection of topics of research	■														
2	Further briefing on topics and outlines for major projects.		■													
3	Informal development of projects by students			■	■	■										
4	*Project Research* course commences						■	■	■	■						
5	Stage assessments by overview panel							■		■						
6	Write up thesis and research results									■						
7	Quality assessment stage										■					
	Project (IDES 4351)															
1	Introduction of *Project* and explanation of the issues and milestones										■					
2	Commencement of *Project*											■	■	■	■	
3	Stage assessment by overview panel													■		
4	Assessment by professional panels															■
5	Exhibition of models and projects															■

Table 2-1 Course plan for Project Research (IDES 4301) and Project (IDES 4351)

Project Research documents the research activities undertaken, and specifies and justifies the relevant design criteria for *Project*. Usually the report comprises text and diagrams of 100 pages approximately. Supervisors of individual students are either full-time industrial-design academics employed within the industrial design program or part-time, industry-employed industrial designers.

The quality of the *Project Research* reports are assessed using a spreadsheet instrument (refer Appendix 40) that has been applied to final-year research reports for now 11 years. Over this time, the determination of quality has proved to be a consistent and reliable determinant of project research quality. The instrument used for assessment is shown in Appendix 40 and has 10 categories of consideration namely:

1. Project management
2. Communication – style/structure/presentation
3. Statement of the problem/aim/methodology
4. Market investigation also analysis of existing products
5. Ergonomic enquiry/testing
6. Functional requirements
7. Technology inquiry/also standards/patents
8. Product appeal issues
9. Production issues/technology/costing
10. Conclusions/design criteria/proposals

Each of the above categories is assessed out of 10 and the final mark is a summation of the categories. Three prior stages of assessed are conducted to review the nature and definition of the project before the final presentation is made. Finally, the individual project reports and the assessment by the supervisor/examiner are reviewed by the course coordinator who confirms the results.

This process seems effective however a number of factors introduce inaccuracy in assessment and these are:

- □ the averaging effect of the various assessed stages;
- □ a diminished emphasis on rigorous examination of the project report;
- □ emphasis on a 10-minute visual presentation to staff.

The quality of the respective *Project* report and model is assessed using a spreadsheet (instrument) that has been applied to final-year research reports for now 8 years (refer Appendix 39). The instrument of assessment applicable to the *Project* phase has 7 categories of consideration namely:

1. Project scope and complexity
2. Users (market) and context of use
3. Management
4. Concept development
5. Design resolution
6. Business issues
7. Communication

The *Project* is examined by full-time academics, part-time industry-based teachers and distinguished professionals from industry however this examination takes place over a presentation period of ten minutes and the assessment associated with the presentation together with examination of the report amounts to 60% of the final mark. There are thee stages of assessment prior to the final presentation each worth 10%, plus a mark for a visual diary of 10%, altogether summing to 40% of the final mark.

In summary, the assessment process associated with the final-year project is typical of most industrial design major projects. In reality, the reports are not subject to rigorous examination and this is because: the growth in student numbers in recent years has made rigorous assessment problematic; there are no instruments or principles to guide the assessment process; and the culture of industrial design projects is focused on the visual result and the presentation of the outcome. Clearly, more research is needed to develop the basis of assessment and to arrive at marking policies and systems that ensure an equitable assessment process. The inherent emphasis by industrial design staff on visual outcomes has to broaden to include a rigorous examination of the *Project Research* and *Project* reports particularly when these combine to include, in most instances, 200 pages of text, images, graphs and renderings.

2.1.6.2 Summary

This section has firstly, considered the history of the studio in order to understand the background of the traditions and how these distinguish the mode of teaching and learning from other disciples. The architectural studio evolved as a special form of education particularly during the nineteenth century and its focus and culture were reinforced in the twentieth century by the Bauhaus and the American schools. Therefore there are great traditions in this form of education and whilst huge changes have affected society the fundamental focus of the studio has remained; namely, a strong emphasis on the visual aspects of the product. The manner of thinking promoted in the studio, that of, random, intuitive, holistic, synthesising and subjective belong to the fields of art, creativity and the skills associated with imagination and synthesis. The separation of the design process from that of making was exemplified by the discussion concerning Wedgwood and how growing levels of production and the need to maintain consistency of quality led to the establishment of the design phase. This meant that design was separate from craft and object and the emergence of large scale manufacturing in the late nineteenth and early twentieth century further delineated industrial design from craft, architecture and engineering. However, industrial design's association with manufacturing was consolidated.

Secondly the research considered teaching and learning and identified the unique characteristic where the setting of ill-defined projects, based on real-world problems, distinguishes the studio mode of teaching and learning. It was found that a tension exists between the imagination driven approach of the studio and the complexity of ill-defined problems and whilst thoroughness and detailed consideration is essential it must not blunt the creative emphasis. However, creativity is not an island and considerable prior learning and confidence in aspects of manufacturing, materials science, and marketing are essential to effective outcomes and spanning these interrelated considerations is difficult for students.

Finally, the course programme at the University of New South Wales (UNSW) was considered particularly in relation to the final-year project so that the circumstances of the major project could be understood including its assessment. The nature of the industrial design studio at UNSW was explained and how various courses are aimed to support and develop knowledge requirements in order that projects of increasing complexity can be introduced with each year. Even though the programme at UNSW has been running for fourteen years and employment statistics are good, there are a lot of research issues that remain unresolved, namely assessment, teaching and learning issues and connections between the various interconnected disciplines.

In conclusion, this section has clarified aspects associated with: the history and development of the studio; studio practice in the current context; and the circumstances of the final-year major project of the industrial design programme at UNSW. The next chapter will consider some of the above issues and introduce the subject of teaching and learning in the studio. Teaching and learning will be discussed together with how the studio encourages the highest level of creative application, which distinguishes the design studio from other pedagogical approaches to learning.

2.2 TEACHING & LEARNING IN THE STUDIO

The studio approach to teaching and learning differs from the dominant models of professional knowledge that apply in science and engineering, which are based on the premise that a collection of principles, rules and methods, can be applied to the solving of rational problems. Fundamental to problem-based and project-based learning in the studio, is the premise that real-world problems are not necessarily rational. In many instances these problems are referred to as ill-defined, as opposed to well-defined problems, that can be solved using well understood procedures and have clearly identifiable, correct solutions.

The industrial design studio project may include responsibility for the design of the *user interface* and product function and emotive aspects such as ‘product appeal’ (visual, tactile ‘style’) together with perceived quality and value. In addition, the designer is working with materials and structures that must have appropriate engineering properties and be manufactured, assembled, distributed, maintained, used, and responsibly disposed of. Industrial design problems thus involve dealing with a very large number of constraints to meet goals that may not be clearly defined (Talbot, 1999). Such design problems are usually ill-defined.

Rowe (1987) provides a summary of the features of ill-defined problems, particularly those that are so ill-defined that they are known as ‘wicked’ problems. Rowe notes: *‘First, there are problems without a definitive formulation, or indeed the very possibility of becoming fully defined. Additional questions can always be asked, leading to continual reformulation. Second, they are problems with no explicit basis for the termination of the problem-solving activity – no stopping rule. Any time a solution is proposed, it can, at least to some significant extent, be developed still further. Third, differing formulations of the problems of this class imply different solutions, and vice versa. Finally, solutions that are proposed are not necessarily correct or incorrect.’* Cross (1989) supports this argument and adds: ‘*that proposing of solutions is a means to understanding ill-defined problems.’*

Hence the setting of ill-defined problems or projects is the essence of design teaching and learning in the studio. Other disciplines employ problem-based learning but the industrial design studio strives to set ill-defined, real-world problems or projects and it this aspect that distinguishes the studio approach.

Within the studio, the use of the critique is central. Critique, as a pedagogical technique has been derived from architecture and fine arts. The definition of critique is fault-finding or more correctly termed *review*, *assessment* or *evaluation*. A project is set and the student then searches for solutions, normally made up of a number of sub-solutions, many considered, discarded or accepted as the design process evolves. The design process itself includes synthesis involving the seeking out of knowledge that is needed and then bringing this together in order to understand and facilitate a solution. The studio encourages disparate thinking in a forum of discussion and idea exchange. Students experience the transient nature of the studio, that is, the struggle for understanding of the requirement: the inclusion of features in a product; the expression of cultural and regional identity; and the appropriateness of a design solution. The nature of the work in the studio may progress from early, vague understandings of the product requirement and finally arrive at a superior outcome.

The studio depends on the prior learning of a student, which is essential in the process of synthesis. Prior learning, from such discipline areas as science, marketing, manufacturing, ergonomics, drawing and rendering, and computer-aided design, is integrated in the form of a problem-based curriculum. Newble and Clarke (1985) established that a problem-based curriculum, one where the focus of student learning is on the problems of the type met in professional life, rather than on academic disciplines taught separately from professional practice, was more likely to encourage students to employ deep approaches than a conventional curriculum. The basic idea that underlies problem-based learning is that: *the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve. Organised forms of knowledge, academic disciplines, are only introduced when the demands of the problem require them (Boud, 1985, p.13).* Boud (1985) believed that the appeal of a problem-based curriculum lay in its ability to develop higher order cognitive abilities and its potential to offer an integrated holistic perspective. Ramsden (1992) defines the theory associated with problem-based learning as: *changing the way in which learners understand, or experience or conceptualise the world around them. The world around them includes the concepts and methods that are characteristic of the discipline or profession they are studying.'*

Project-based learning requires the student to work far more independently. A supervisor may be appointed however the responsibility for driving the project, making decisions, identifying and liaising with sources of advice all remain with the student. Learning through projects is one of the most common activities in courses of all kinds. Morgan (1983, p.66) defines such a form of learning as: *an activity in which students develop an understanding of a topic through some kind of involvement in an actual (or simulated) real-life problem or issue in which they have some degree of responsibility in designing their learning activities.*

The final-year major project is included in a four-year program to demonstrate the capacity of the student that has resulted from their study in the industrial design program. The learning prior to the final year has been based on problems/projects within the studio with knowledge provided by key supporting courses designed to provide specific skills and expertise. Most of the learning in the studio can be categorised as problem-based learning where students, are given a problem by the studio director, and then consider the circumstances of the problem and finally the distillation of a solution.

In the final-year, the student is expected to execute a major project and students are either assigned or select a field. They proceed to research that field in order to define a project. The project is research-oriented and requires that the student, identify a market need and then provide a solution for it. This is an entirely new experience for the student. Moreover the project is year long and there is an expectation of a high degree of project planning and management.

2.2.1 Developments in technology

Compounding the complexity of the studio in setting ill-defined projects are rapid changes in technology all requiring some change in the nature and methods of teaching. Computer-aided drafting and drawing has been integrated into studio projects and in some schools the studio is equipped with workstations to enable a significant amount of the design work to be done on computer. But in most instances students leave the studio to engage with a computer in a laboratory and use this method to develop ideas. The computer also facilitates modelling of concepts and components and enables the integration of rapid prototyping as part of the studio project. The *internet* presents a powerful tool for design research and interferes with the process of solution conjecture and synthesis. In many instances the student will leave the studio to engage in private research to provide background and use internet searching as a source of ideas. The broader considerations of culture, sustainability (materials and disassembly), and manufacture including assembly all place an emphasis on design research and hence the studios uniqueness as a place for intuition and reflection is compromised.

2.2.2 Blending science and art

The design studio exists within the university system but does not sit entirely comfortably. It is a throwback to an earlier mode of education that has been abandoned by other disciplines. Some view the function of the studio as craft-like, lacking in precision and without rigour. Those that take this view support the more methodical approach of the intellectual arts and the methodical approaches of the natural sciences. The schools of the modern university are premised on technical rationality and their perception of professionalism is grounded in systematic, preferably scientific knowledge (Schon, 2000). Thus a certain tension exists between proponents of the studio process where intuition and reflection, processes critical to imaginative problem solving, are in some conflict with scientific training which provides only a range of technical and behavioural knowledge derived from a rapidly expanding data base.

Despite the rapid developments in technology and the breadth of considerations within typical projects, the studio remains a place where art and craft are blended in a process of intuition and reflection. It is a place that, to a large degree, has not embraced scientific and systematic thinking. The nature of the studio inherently considers such approaches constraining and limiting. Certain design methods, such as design-by-drawing, computer-aided design, brainstorming, are employed in the studio but the broader use of systematic techniques has largely been rejected. Although the application of design methods in not new, their application in industrial/product design programs has seldom been encouraged in the didactic sense. Consequently, apart from what is often a disorganised approach, many students tend to concentrate on shallow visual outcomes without the necessary cognitive analysis and synthesis required to achieve sustainable and contemporary designs with justifiable features.

2.2.3 Student learning blocks

Despite the advantages of studio teaching the outcomes can be disappointing where many students depend on lecturing staff for the generation of ideas and the resolution of those ideas. This is a common problem in many design programs where the process of idea generation, screening and resolution of concepts is difficult for the majority of students. Frost (1992), writing of his experience with engineering design students describes the confusion of students when faced with many possible approach alternatives but these are not identifiable as clearly right or wrong. He states that: *'the path from the problem to the solution is not clear, but paradoxically, solutions are legion and heavily, if mysteriously contextual. None, however is clearly right or wrong.'* It is the decision-making process that is difficult, because decisions depend on as-yet-absent experience. It is obviously very difficult to conceptualise and make decisions on issues such as the market, function, usability, manufacturing methods and cost, when these issues have not been experienced by undergraduate students.

Many students are not able to *make-the-connections* between the supporting disciplines, for example, mechanics, materials science, manufacturing and marketing and their relationship to the design process. There is little time for reflection in most undergraduate programs and it is also a major issue in industrial design. The process of *reflection-upon-learning* is strongly advocated by Schon, and consistent with the theories of learning advanced by Skinner and Bruner.

Skinner (in Romiszowski, 1981) defines the occurrence of learning as when an observable change in behaviour is brought about. Desired behaviours are taught by a series of successive approximations, beginning from an already established behaviour and working towards the desired behaviour. The theory does not include any process of internal thinking which is considered irrelevant to the learning process. Skinner's reinforcement theory is relevant in the teaching of some aspects of the supporting subjects, where basic rules need to be conveyed. For example, in standard criteria for design of plastic fits and relationships, draft angles in moulding, shrinkage allowances, and properties of materials are taught in a classroom course but their application may occur in the studio. Therefore the studio project acts to reinforce prior knowledge and to consolidate understanding. If a series of successive complimentary lectures can be developed that link the topic over the respective courses then a strong educational focus may result. Whilst Skinner's behaviourist psychology theories are not fashionable, industrial design practice requires a considerable inventory of standard rules and procedures and learning by rote may be effective if complimented by application in the design process.

Bruner's theory of learning involves the studies and manipulations of instruction to equate with known ideas. His theories have origins in cognitive development and conflict strongly with those of Skinner who dismisses the process of internalisation. Bruner rates the internal thought processes of paramount importance and the final outputs or products, secondary. This is particularly important with respect to teaching and learning of designers where there is perhaps too much to convey and too little time to internalise the subject matter within the context of prior knowledge. The teachings associated with this theory have direct application by linking earlier learning with new ideas taught in the supporting courses. For example, abstract conceptualisations of sheet-metal design conveyed in a supporting course can be built on prior understanding of sheet-metal fabrication learned in earlier workshop technology. Also the incorporation of a component of discovery in the teaching lecture may enable students to work through an issue. The most pertinent example is in the consideration of tooling, where the student must reason the way that an object is made, internalising the circumstances and arriving at understanding. The introduction of key structured tutorials may be the best way of accommodating this method of teaching.

The education of the industrial designer relies on a combination of studio-based teaching and lecture-based instruction in a number of supporting courses. Examples of these are

Materials and Manufacturing, Elementary Marketing, Design Methodology and Ergonomics, where both the studio and classroom are employed to achieve maximum learning and performance outcomes. The lecture is the principal mode of teaching these supporting courses, in which instruction is a process of exposition leading to effective learning. The process of exposition starts with an overview of the subject topic and then the issues are clarified and analogies drawn with the student's past experience and understanding.

Ausubel (1968), refers to this as, intellectual scaffolding, that is, to structure the ideas and facts that students' encounter during their lesson. The process is generally aided by a comprehensive text together with videos of selected processes. Ausubel also advocates the improvement of presentational methods of teaching (lectures and readings), in contrast to those who advocate the discovery method of learning. Ausubel sees the key to efficient instruction as careful sequencing of instruction and ensuring that all necessary prerequisite learning has been satisfactorily completed. The most important single factor, influencing learning, is what the learner already knows. It is believed that the linking and intellectual scaffolding of the courses' presentation can be improved, particularly linking with prior learning in other courses such as Workshop Technology and Materials and Manufacturing. Also the text and presentation material can enhance learning by better visual presentation, and choice of overheads, slides of industrial examples and selected videos. This may strengthen the meaningful reception learning experienced by students when attending lectures.

Expectedly, students in the design studio tend to initially demonstrate inferior application of prior learning. However, at the completion of a particular assignment, they “appear to put-it-together”, thus apparently concluding a hitherto incomplete learning process, suggestive of learning by experience and or by the internalising process as outlined by Bruner. This process of reaching understanding may be explained by the introduction of experience-based learning where Kolb implies that: *for learning to take place the person must not only experience something, but reflect on that experience* (Kolb, 1985). Kolb's development of Lewin's model characterizes learning as occurring in four related settings: 'concrete experience, reflective observation, abstract conceptualization and active experimentation' and argues that: '*while individuals have preferred learning styles, they learn most effectively when all four types of learning are exercised in a balanced and coordinated way*'.

2.2.4 A model of the studio learning process

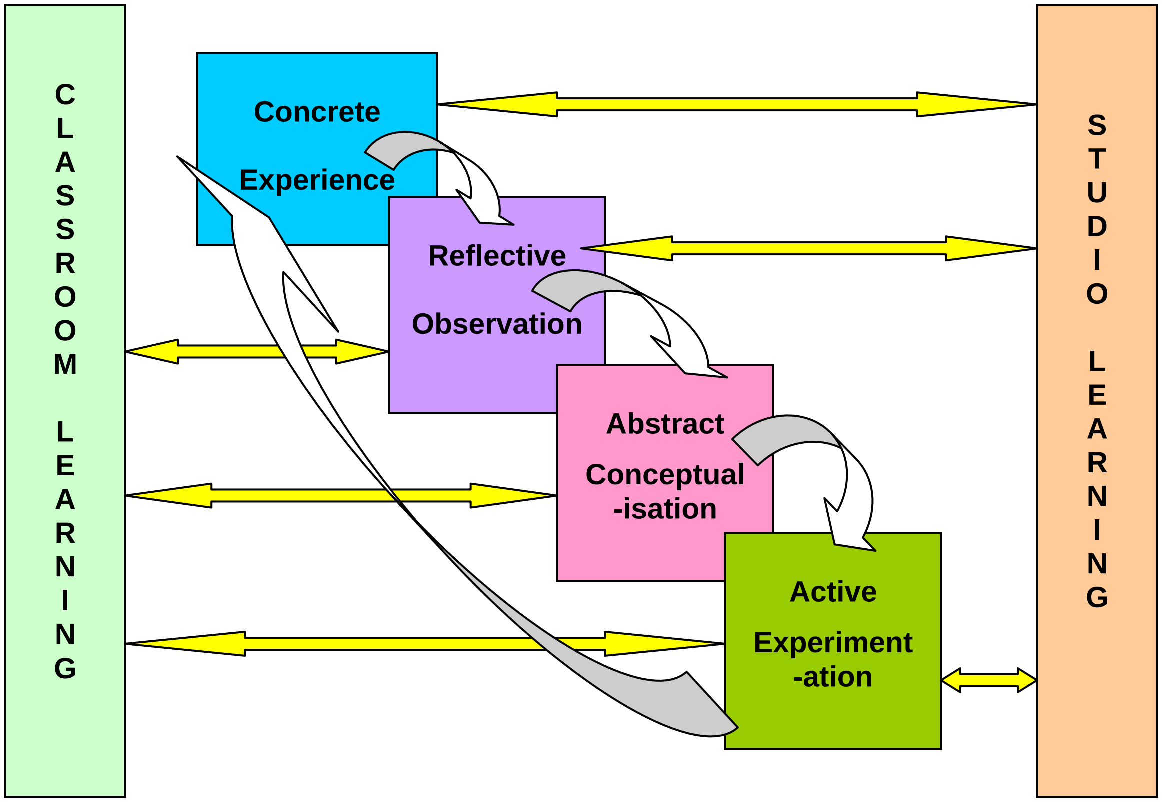


Figure 2.15 Author's application of Kolb's model of learning within the classroom and studio learning situation [7]

The studio is not the only place where design learning occurs and the classroom and prior knowledge play and important role. Figure 2.15 represents the author's depiction of how Kolb's cycle of learning links the classroom and studio learning. The cycle of learning occurs between classroom and studio teaching and there is an interplay and reinforcement that occurs in the two modes of teaching. Courses such as engineering mechanics, manufacturing, marketing and business occur in the classroom supported by tutorials designed to reinforce understanding. The studio depends on this prior knowledge in order that the studio philosophy of learning, that is, to engage the student in projects of increasing complexity over the duration of the programme can be effective. The studio engages the student in concrete experience through studio work and in the process of design conjecture reinforced by model making in the studio or workshop. Criticism, a fundamental component of the studio process, facilitates reflective observation upon the process and outcomes. Reflection on what works or doesn't work by interaction with other students and teachers is a unique aspect of the studio process and is also discussed in

[7] Based teachings from Weil, S.W and McGill, I. (Ed.) (1989) Making Sense of Experiential Learning. P.26

the classroom where, for example, aspects of manufacturing appropriate to a studio solution can be discussed.

The classroom is a place where theories appropriate to disciplines can be discussed and abstract conceptualisation can occur. This form of conceptualisation is different to what occurs in the design process where conceptualisation is process that consolidates ideas towards design proposals. Abstract conceptualisation clearly occurs in studies of mechanics where the principles and scientific basis of understanding is discussed. Active experimentation may occur in tutorials where concepts can be challenged and understanding consolidated. In the study of the behaviour of materials certain conceptualisations can be actively experimented with in the workshop where a physical appreciation of the behaviour under load of certain materials can be achieved. The link with the studio in the phase of active experimentation occurs when studio projects interact with the workshop or indeed the classroom. The studio cannot function in isolation and depends on the sequence of learning and the interaction between the classroom and studio which sums to a stage that the student attains, namely his prior learning. The philosophy of learning associated with the studio is based on increasing complexity in projects over the duration of the programme and this cannot happen without the linkage between the classroom and the studio and the cycle of learning that occurs between.

This section has explored theories of learning and pedagogical approaches applicable to the studio and the effect this has on the development of industrial design expertise. Various specific theories have been discussed in the context of industrial design, namely: Skinner, where an observable change in behaviour results; Bruner, where manipulations of instruction to equate with known ideas; Ausubel, who suggests the use of intellectual scaffolding and structuring ideas that students encounter during their lesson; and Kolb, who argues that students must experience something and reflect upon that experience for learning to occur. The model of the studio learning process derived from Kolb's teachings developed by the author to explain the cycle of learning and the interaction between classroom instruction and studio learning. Thus the studio is not an entity unto itself and studio projects must be linked to instruction and activities outside the studio.

It has been found that there is little research data about the learning process in the studio to substantiate various teaching and learning ideas. As a result the research in this thesis is important towards a stronger understanding of the studio as it accommodates major projects. However the research has not considered, at this stage, the nature of industrial design and how it is defined in relation to product design and engineering. This will be achieved in the following section.

2.3 THE NATURE OF INDUSTRIAL DESIGN

As an aspect of production, industrial design rarely deals with one-off production and is primarily concerned with volume production. The design parameters implied by mass-production introduce a whole set of operational imperatives that situate the designer in a totally different creative culture. Creativity may be measured by the consideration of designing for minimum parts, integration of components across a number of product lines, as well as the form, and function of the product. The industrial designer interprets technology within society and functions as part of a team where other members may come from other disciplines such as marketing, purchasing, engineering, manufacturing and quality assurance. The Industrial Designers Society of America (IDSA) defined industrial design as follows:

Industrial design is the professional service of creating and developing concepts and specifications that optimise the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer (IDSA, 1996).

Industrial design may also be defined as the: *ideation, specification, and development of functions, properties and concepts of industrially manufactured products and systems, mainly regarding aspects of user-product interaction, aesthetics and identity considering a totality of ergonomic, usability, technical, economic and social factors* (Warell, 1999).

In the above definition the industrial designer focuses mainly on three aspects of a product, namely:

- user-product interaction – where the designer considers the user and the purpose of the product to enhance and optimise the usability of a product;
- aesthetics, where not only the style and appearance are specified, but also the meaning, the emotion attached to its use and acquisition and ownership and the visual language associated with its form and function;
- identity may apply to the strategic positioning of the product within a specified market, the linkages with other products to form a family.

Although comprehensive in its scope, industrial design is only part of the overall process associated with product development. The principal components of product development are product planning, product design and preparing for manufacture. The scope of product design includes within it the domains of industrial design and engineering design which is shown graphically below in figure 2.16. Product design may be defined as:

'those activities involving the design of products and which include the activities of engineering design and industrial design' (Warell, 1999).

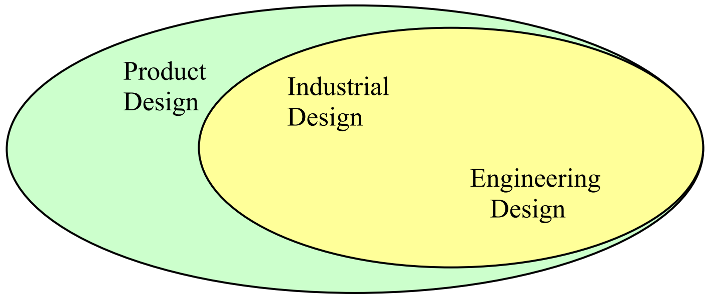


Figure 2.16 The scope of product design versus engineering and industrial design domains.

Engineering design may be stated as: *'design with particular emphasis on the technical aspects of a product and includes activities of analysis as well as synthesis'.*

This definition broadly describes what engineering designers normally do and they may be concerned with aspects of engineering that include machine elements, solid mechanics, strength of materials, aerodynamics, fluid mechanics, hydraulics, electronics engineering, software and systems engineering, quality engineering, industrial economics and human-factors engineering (Warell, 1999).

Literature about 'designing' unanimously refers to the complexity of the process and the difficulty associated with many problems that are ill defined. Talbot (1999) argues that industrial designers and product designers: *'create objects that occupy space and have plastic and visual form. The process of design that they employ involves creativity, the resolution of complex issues and synthesis. Other professions such as analysts, critics, accountants or managers employ synthesis to resolve issues but their work is not necessarily creative and new. In contrast, designers put things together and bring new things into being, dealing in the process with many variables and constraints some initially known and others revealed during the design process'.*

The outcomes of the design process never evolve to one unique and correct answer and it is this single fact that makes the learning difficult because the answers that might apply are legion. One answer might be more appropriate than another and it is the role of design to balance the conflicting requirements and arrive at an appropriate solution. Schon (1987) states that: *'Designers juggle variables, reconcile conflicting values and maneuver around constraints - a process in which, although some design outcomes are superior to others, there are no unique right answers'.*

The process of design is an exploratory experience where solutions are proposed and rejected so that as the problem is better understood and from the solutions considered a result evolves that fits most appropriately. However it may not be the best solution that could have been achieved. Cross (1989) agrees with these conclusions and comments *'that proposing of solutions is a means to understanding ill-defined problems.'*

An industrial design student both learns and executes the process of designing in the industrial design studio. This is not straightforward and involves a constant struggle to develop confidence in decision-making. In the studio setting students learn to visualise solutions, to discuss them and reflect on them and to practise decision-making. Synthesis is used to establish what needs to be known and the studio experience also emphasises identifying what information is needed and then seeking it out. From the known and experienced information, the process of synthesis then clarifies the information towards the making of decisions.

In the modern context, the practice of industrial design has to include and interpret not only the complex expectations of consumers, manufacturers and marketers but also rapidly changing technologies and design methods. Examples of these include: computer-aided design (CAD), ergonomics, user-centred design, universal design, design for manufacture, design for sustainability, emotional design, experience design, rapid prototyping, interaction design, among others.

A constant criticism labelled to industrial design is the emphasis placed on drawing, rendering and creative solutions at the expense of the requirements of the respective customers, namely the manufacturer of the product, the marketeer, and the consumer. The manufacturer seeks a product design that is designed for efficient manufacture and can be produced at a competitive cost. The marketeer seeks a design that meets consumer expectations of style, cost function and performance. Friedman (1996) points out that: *'One of the challenges for designers, in the future, will be developing a wider and deeper range of understandings of the design issues that lie outside the range of aesthetics. Far too many award-winning designs are dysfunctional. Others work nicely while they bankrupt companies. Neither works well in a complex world in which the challenges of innovation require greater, rather than lesser knowledge. The era in which design has been a discipline, emerging from arts and crafts traditions, has come to an end. The aesthetic factor in a design is one of a range of factors, important and equal to other factors'.*

In this section industrial design has been defined along with product design and engineering design. Industrial design is distinguished by emphasis on *user-product* *interaction*; *aesthetics* and *identity*. And these aspects are emphasised in the studio and represent the teaching and learning focus. Industrial design is only part of the product development process as it occurs in industry and only part of the major project process as it occurs in the educational setting. The role of design has to broaden in the interests of producing more comprehensive and viable outcomes. Friedman's comment, reflect the need for wider considerations and argues that the consideration of industrial design as a discipline emerging from arts and crafts must end.

Therefore the role of the studio needs to develop to engage with broader considerations and to include a more systematic consideration of issues beyond the traditional industrial design focus. It is not clear how this can be achieved and in the next section the use of design methods will be considered in particular the importance with respect to student designers.

2.4 DESIGN METHODOLOGY and DESIGN METHODS

Design methodology, as a field of study, evolved from the introduction of new systematic design methods first introduced in the 1960s. Those methods were applied in certain fields of design practice and these included engineering, industrial, architectural and urban design. During the same period, the techniques of creative engineering and brainstorming became more widespread and these provided some bases for idea generation. Some of the early methods did not work very well in practice. They were cumbersome to apply and required considerable input data and paperwork. For these reasons designers did not embrace those methods and believed that they constrained the design process.

Design methodology includes the study of the principles, practices and procedures of design. Its primary focus is to develop a deep and practical understanding of the design process and how this process can be modified, made more effective and transparent and be managed to achieve sustainable design outcomes. Design methodology involves a number of considerations. These include:

- reflection on the nature and extent of design knowledge and how this might be applied to the design process;
- the research and application of new methods, techniques and procedures;
- the study of how designers work and think;
- the establishment of appropriate structures for the design process (Cross, 1984).

Beitz (1994) describes design methodology as being: *used for knowledge about practical steps and rules for the development and design of technical systems, based on the findings of design science and of practical experience in various applications.*

Hein (1994) also defines design methodology as being: *not in itself a method but rather a body of knowledge related to methodical and systematic techniques. The term systematic design is alternately used in lieu of design methodology, particularly in practical applications within industry.*

2.4.1 Design methods

Design methods may be defined as, any procedures, techniques, aids or tools that contribute to the design process. They represent a number of distinct kinds of activities that the designer might use and combine towards the solution of design tasks. Examples of design methods applicable to both product and industrial design are: design-by-drawing; Computer-Aided Design (CAD); Brainstorming; Concurrent Engineering; Value Analysis (VA); Quality Function Deployment (QFD); and Design for X, amongst others. The most common method of design is *design-by-drawing* and all levels of product and industrial design include this method in the conceptual and embodiment phases of the design process.

During the 1980s CAD was introduced and this in itself became a highly accepted design method. Similarly at that time there occurred a greater incidence of application of methodological processes such as Value Analysis (VA), Design for Manufacture and Assembly (DFMA) and in the later period of the 1980s, Quality Function Deployment (QFD).

In the 1990s interest returned to design methods because of a trend towards integrated product development. The integration of various disciplines into the product-development process required that the thinking, upon which the design was based, needed to become more transparent and amenable to internal communication within a company. Shortening the time required for product development became important together with a quality philosophy that sought to *get-it-right-the-first-time*. As a consequence, the design process had to become more sophisticated with greater certainty afforded by high-quality concepts, rather than relying on random inspiration. This required the further use of design methods. Wallace and Hales (1987) argued that in order to coordinate designer activity in Britain and improve design capabilities to compete in the world market the design process needs to be carefully structured.

Other researchers also focused on both design methodology and methods. In particular, the Workshop Design-Konstruktion (WDK) in Denmark, is a design organisation that has sought to establish design research with a major focus on methods, the theory of technical systems and design education (Hubbka and Eder, 1988).

The design methods introduced in the 1960s and 70s drew attention to the need for design to be more transparent and more substantially based on a structure of analysis. However the methods introduced failed to achieve wide acceptance as part of the normal process of designing and were not incorporated into the teaching of design on a significant scale. Other methods either existed or evolved and were universally accepted such as design-by-drawing, brainstorming, computer-aided design (CAD), and modelling and these were included in the teaching of design. A number of methods were introduced including Quality Function Deployment (QFD), Value Analysis (VA), Design for X (DFX), however these were adopted by certain sections of industry but generally the adoption by the design industry was minimal. Various authors have written about the low level of adoption, by industry, of the aforementioned methods.

Maffin (1998) conducted research of sections of industry and reported that quality function deployment, robust design, functional decomposition, concept generation, and evaluation matrices were not widely known, let alone applied. Huang and Mak (1999) refer to other reports by Wright, (1996); Norell (1993); McQuater (1996); Dale & Shaw (1990); (Pandey & Clausing (1991) and the general conclusions point to a low incidence of usage in industry. 'One reason advanced for the limited use of methodologies was that formal design tools have not been taught widely at colleges and universities in the past (Gill, 1990). Gill further summarised the shortcomings of design methodology as a lack of coherence, lack of an agreed vocabulary and taxonomy and a lack of an overall suitable design methodology (Hein, 1994).

Research by Spring *et al* (1998) has shown that 'designers do not make use of simple tools such as Pareto analysis, cause and effect, control charts and checksheets and such are perceived by design staff as contributing little to the design and development process and are viewed almost with disdain. There is even reluctance to utilise techniques that have direct application to design such as QFD, design of experiments, fault tree analysis and failure mode and effects analysis (FMEA)' (Spring *et al*, 1998).

Thus, design methods are seen as something outside the design process, additional and optional. Designers come to learn of design tools through short-course training. However, the problem arises, that designers cannot readily include these tools in the design process, because it is difficult to change established and proven techniques of design.

Many of these tools and methods require significant input data and paperwork and as a result they are time-consuming. Since most design is done under the pressure of deadlines it is difficult to introduce new ways under these circumstances (Green & Bonollo, 2001).

In summary, it may be argued the experienced designer does not employ certain methodologies because:

a) The designer, over time, has developed a data base of expertise that facilitates effective design decision making;

b) many methods are cumbersome requiring significant input data and paperwork and as a result are time consuming;

c) formal design tools were not taught at universities in the past and currently.

The implications of the above are that the little scholarship applies in the understanding of systematic approaches, particularly as they apply to the studio teaching and learning process and to the development of procedures and techniques that are not cumbersome in use and that compliment the creative design process. Clearly, the application of design methods is not efficient and this only highlights the need for further research and the development of systems to encourage systematic approaches.

It has become obvious that methods and process are not included in the curriculum of many university and college courses. Certainly, CAD and modelling is widely taught but methods such as VA or QFD, FMEA, are not widely adopted. In addition, the design and product development process is not formally taught as a means of understanding the way design is carried out. This leaves the student designer in an invidious situation; *trying to do what he does not know how to do, in order to get the sort of experience that will help him learn what designing is* (Schon, 1987).

Eder (1998, p.366) writing about engineering designers explains that certain methods are accepted by industry and examples are TQM, QFD and Taguchi. He further laments that such methodologies are used only in a small fraction of industry. Frost (1999) responded to Eders' comments arguing that much design in industry is incremental and not original, therefore not requiring methodological approaches. Maffin (1998) considers the low use of methods in industry and argues that much design in industry in non-original and design is based on established concepts and does not require elaborate exploration.

These comments by engineering academics apply equally to the field of industrial design and whilst experienced designers may not formally employ a particular design method they nonetheless go through a process that informally lists and considers many issues clarified by formal methods. For example, many designers employ “brainstorming” techniques but they do not necessarily include Osborne’s idea generation techniques. Nor do they necessarily establish a brainstorming committee (Osborne, 1953). This capacity to design and informally apply methods to arrive at outcomes is something that comes with experience and it might be argued that experienced designers do not need to broadly use design methods.

Ahmed, *et al* (1992) describe the differences between experienced and novice designers in engineering design in the aerospace industry. In their study they observed novice designers between 1 and 5 years of experience and experienced designers between 8 and 32 years of experience. Experienced designers: were more aware of trade-offs in decision making; questioned data; did not need to gain an understanding of how things work; could visualise more effectively 3-dimensional situations; and did not necessarily work in a sequential manner. It is interesting that the novice designers in the study have a great deal more experience than the student designer. Therefore the situation of the student designer is far more problematic and they have considerable problems in developing a design strategy; screening alternative concepts and deciphering data.

2.4.2 The Importance of Design Methods to Student Designers

Many student designers struggle with the design or product development process. They tend to approach a major design task in an ad-hoc manner and do not define a process that will help them navigate the various stages. Whilst the respective models of the design process appear as commonsense approaches students do not use the process, as a structure, upon which to base their actions. For example, the first stage of a final-year major project involves consideration of the market environment of the product, that is, competitors, direction of the market, market share, and achieved profit margins. In addition, the scope of the project is defined. The student may focus on this stage of the process and clarify the pertinent issues. Clearly, certain methods can be useful and these might include: a standardised checklist to identify types of information requiring clarification; a method that enables comparison of competing product features (benchmarking and features analysis); and a standardised project time plan to consider and prioritise the sequence of the project.

The experienced designer, with many projects completed, may approach this phase with considerable prior knowledge and not need to consciously research the marketing environment. In addition, the use of methods may not be necessary because the designer may be able to assess competing features without resorting to formal approaches. Similarly the educationalist designer can speak of and recognise issues in this stage and can articulate these to the student. But the student may not make the connections and in many instances has no real foundation of knowledge to summon. Therefore the student designer can only benefit from structure and method.

The *task clarification* phase provides an opportunity for the student to reflect on the design brief and to confirm the project intent. It enables the time plan to be revisited and the sequence of tasks confirmed. Without the formality of this phase the student's emotions may mask the real intent of the project and whilst an experienced designer can challenge data and can make decisions before implementing them, the student designer cannot readily do this. Various methods can structure the thinking and clarify the ranking of the requirements of the design. The design method, *objectives trees* applied to design objectives can help to better understand the competing objectives and their relative importance.

The *conceptualisation* phase is particularly difficult for the student designer where anxiety and emotions can hinder the iterative development of a solution. Concepts can become personal and the ability to reject a concept in favour of another is not well established in the student. The formal methods of brainstorming, idea generation, and patent search can broaden the extent of consideration. The free generation of concepts can still prevail and the formal method of *concept selection* can assist the student to arrive at the best concept by consideration of the weighting of desired features and requirements.

In the *evaluation and refinement* phase the experienced designer can call upon experience associated with assembly, manufacturing and finishing processes and can even recall past projects and refer to earlier designs. But the student designer has no such inventory of fabrication. In this situation QFD, CAD and design-by-drawing can serve to explore the options and assist in evaluation of the design concept.

The student designer who has used a formal approach to the product development process and design methods may, during progression from a novice designer to experienced, rely less and less on a structure and methods. And eventually may not need such an approach at all. This is because the designer's inventory of judgement, intuition and experience develops sufficiently to ensure good design outcomes. If this is the case, then this is fine and the earlier reliance of structure and method has served to get the student to this point. The issue being argued in this section is that the student needs structure whereas ultimately the novice or designer may not.

However the increased incidence of development teams working on complex projects creates a need to make the basis of design decision-making more transparent the basis of design decision-making and the expertise associated with certain methodological approaches can lead to the designer attaining considerable expertise in focused areas. Examples are QFD, FMEA and design of experiments.

The literature reviewed by the author clearly shows there is a need to better understand how designers design. Designers juggle variables, reconcile conflicting values, and manoeuvre around constraints – a process, in which there are no unique right answers (Schon, 1987). Student designers face a paradox where they do not really understand what *design* is but must embark upon it in order to gain experience. Hence a situation exists where design, is viewed by the student, as an ill-defined process that addresses ill-defined problems. Little wonder the student designer struggles within the educational situation, that provides very little in the way of structure, process and methods.

The experienced designer can consider relevant issues more effectively, is aware of the reasons behind the use of materials or components, can refer to past designs or situations that are analogous, can question whether an approach is worth pursuing, question data, keep alternative options open and uses intuition developed over time effectively (Ahmed, *et al*, 1992).

Earlier attempts to introduce design methodologies have not met with universal acceptance and have been rejected by many experienced designers. And as a consequence, educationalists in the field of industrial design, have not extensively included process and methodologies beyond the normally accepted, namely, design-by-drawing, CAD, and ergonomic analysis. A survey conducted by the candidate has indicated that capacities of students, are lacking in their management of final-year major projects and their use of design methods is not comprehensive. The survey further confirms the emphasis on fundamental methodologies ie., CAD, design-by-drawing, and ergonomic analysis and confirms the low level of adoption of QFD, features analysis, benchmarking, patent searching among others. .

A greater emphasis on the design or product development process, as a means of providing a roadmap for the passage through ill-defined problems, would be of great assistance to the student designer. In addition, the teaching of selected methodologies may enable the student to more effectively categorise information and support the stages of design making that occur as design progresses. It is recognised that eventually the student when progressing beyond education, may not need the crutch of process and methods however, in the period of university application, confidence and competence can be enhanced by utilisation of systematic techniques.

This section has highlighted the low use of design methods by industrial design professionals and students in the design studio and the fact that such methods are not taught at universities and colleges. In addition, the debate concerning the value of systematic approaches has overlooked the situation of the student designer who struggles with the process of design. There is a need to promote scholarship particularly in the above area of application of design methods to studio processes and the author during the course of this research has published a number of refereed papers to clarify questions associated with industrial design and research questions in this area. The discipline of industrial design lacks a firm base of epistemology upon which to build understanding of the role of the profession and the nature of methods and process that can clarify its role and purpose. Papers published by the author that are directed to the above issues are noted as follows: Green (1999); Green[1] and Bonollo (2001); Green[2] and Bonollo (2001); Green and Bonollo (2002); Green[1] (2003); Green[2] (2003).

The next section considers the process of designing in order to better understand the nature of the design process as it applies to both the professional and undergraduate studio process and to distinguish the studio solution-focused approach.

2.5 THE PROCESS OF DESIGNING

A typical design process applied to a product development in industry might include consideration of thousands of issues associated with cost, assembly, appearance, usability, manufacture, sustainability, export, competitiveness, standards, patents among many others. A design project includes tasks that can be categorized as designing or managing. Management aspects include the context of the product, client requirements, the validity of the brief, and time and cost issues. The designing aspects can range from broad concepts to the clarification of details. Tasks can include issues associated with patent and design registrations, engineering, manufacture and assembly, competitors' products, disposal and a host of both minor and major considerations.

2.5.1 The Studio Design Process

The design process may be represented by models that serve to explain the phases or steps in the process. Darke (1978) proposed the simple model shown in figure 2.17 and is based on interviews with established architects. The process starts with a generator or some fundamental potential solution.

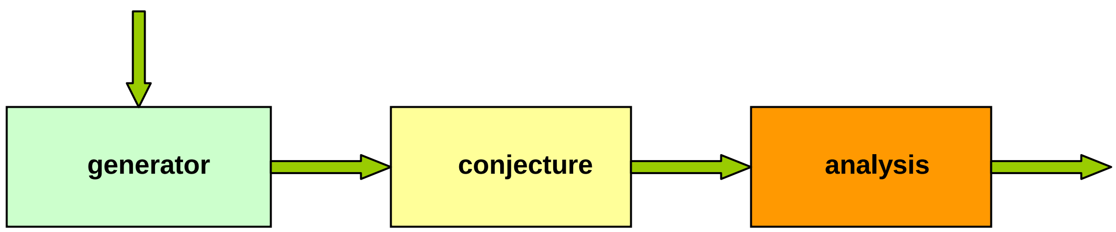


Figure 2.17 Darke's model of the design process (Darke, 1978)

The choosing of a generator is critical. Experienced practitioners might derive a generator by observations and discussions and usually can see beyond the generator to conjecture and analysis. The considerations included the architect's views on housing and how they perceived the provision of housing and finally their experience of similar housing projects. But this model does not include feedback loops that in reality are the *comings and goings* between the phases that is the reality associated with complex considerations.

A simple and generalised model of the design process is shown in Figure 2.18. The *analysis* phase represents the ordering or structuring of the problem. The *synthesis* phase represents the generating of solutions and the *evaluation* phase the appraisal of a solution against the objectives identified in the analysis phase.

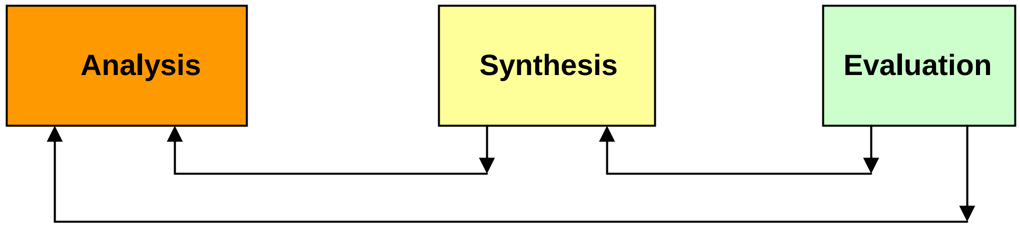


Figure 2.18 Simple model of the design process (Lawson, 1997)

This presupposes a logical progression from analysis to evaluation and even though the model includes return loops between the phases, in practice, the progress would involve a multiplicity of iterations, sometimes fleeting, and at other times considered. In addition, the model does not suggest the levels of consideration from conceptual to proposition to detail.

A more realistic model applicable to architectural situations is the Markus-Maver model (refer Figure 2.19) that proposes that the process of *analysis*, *synthesis*, *appraisal* and *decision* at increasingly detailed levels of the design process.

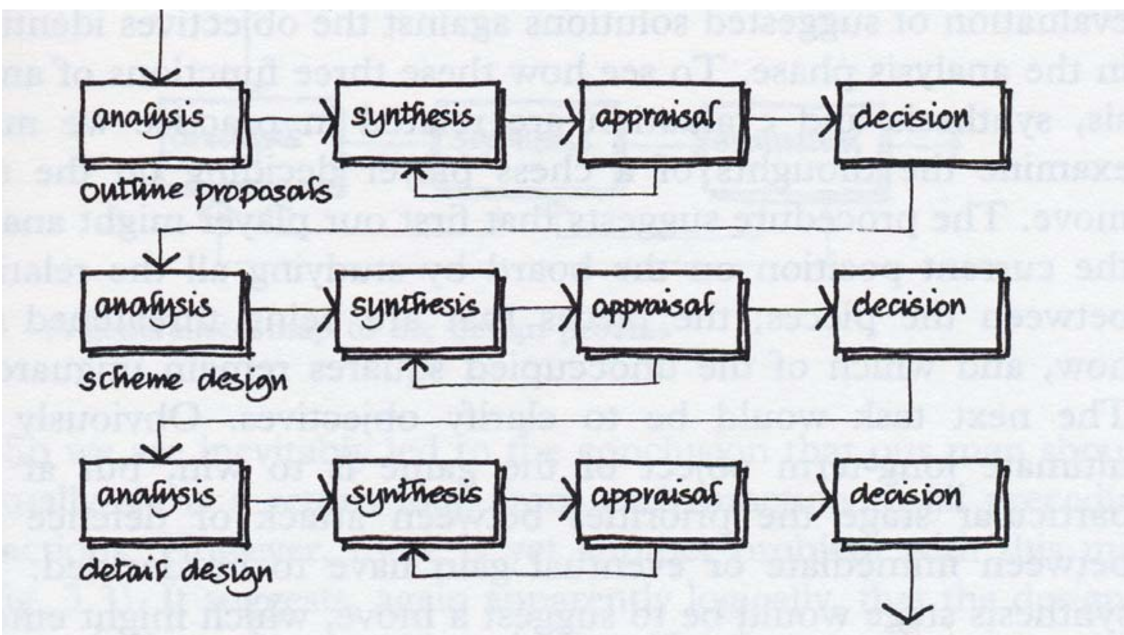


Figure 2.19 The Markus / Maver design process [8]

The outline level considers conceptual issues where the phases of analysis→ synthesis → appraisal → decision lead to a concept proposal. The second level would involve evaluation of the concept that also involves phases of consideration and finally the detail design level that also involves the phase sequences of analysis, synthesis, appraisal and

[8] *(Markus, 1969: Maver, (1970)*

decision. This model more effectively describes the multi level / multi phase characteristic of the design process. However the preceding models have been derived from and are applicable to professional situations and do not appropriately describe the design process that occur in studio projects.

In the earlier years of the degree program the studio focus is aimed to enable the student to gain experience in design decision-making. The studio is premised on a particular kind of learning by doing. The studio project requires the student to start the design process even though the student does not understand the process and does not know what designing means (Schon, 1987, p.117).

The rational models of the design process described in figures 2.17 and 2.18 do not represent the typical student approach within the studio. Elements of analysis, synthesis, evaluation and decision-making still occur, but the progression through, and between, is generally chaotic. The rational models assume a logical progress through the process but the heavy emphasis on the right-brain, solution-focused approach does not encourage a reliance on process. In the final-year the student embarks upon a significant, year-long project, requiring planning and careful management. However the industrial design student's whole approach is in conflict with the left-brain project management approach.

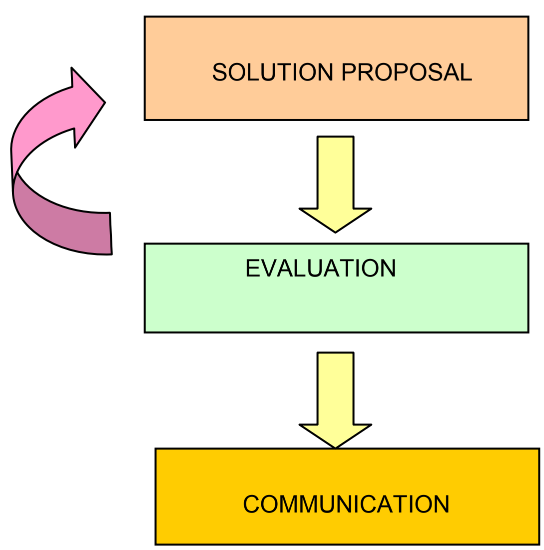


Figure 2.20 Basic design process employed in the studio

The design process conducted within the studio of an undergraduate degree is more limited in its scope. The student designer has been coached towards a solution-driven approach which seeks to *create* a solution proposal → *evaluate* the proposal → *decide* its appropriateness → and then *communicate* the solution (refer Figure 2.20). This model is generally accepted within the industrial design fraternity as the solution-focused approach.

A brief is provided which describes the requirements and background of the studio project however, because of the student's lack of understanding, limited iterations between the solution and evaluation occur. Solutions are not aggressively challenged and there exists a fear to challenge a solution and many inappropriate solutions are retained and not discarded. When the proposal is finally resolved it is then communicated to the class and studio director. There is ample anecdotal evidence from the industrial design fraternity to support the above argument in favour of the solution-focused approach. It represents one of the great strengths of the studio process in that it allows great freedom for creative application but however very great weakness because the approach does not accommodate analysis.

This situation of weakness is compounded as the complexity of the studio project increases, as the student progresses into years 2 and 3. The student grows in confidence and capability due to the extensive coaching in the studio however the span of considerations is greater, that is, the span now includes issues of user-centered design, manufacturing and technology.

Alternative models of the design process are more suited to student major projects. The Archer model provides a comprehensive structure to underpin both the studio and final-year project. The respective phases encompass the full potential of the design process. A generic model of the industrial design process (Bonollo and Lewis, 1996, p.8) is included as a basis for superimposition of a variety of design methods, tools and procedures. These models are discussed further in the theoretical development in Chapter 3.

In summary, it is emerging from the research that there is a need to develop a model that explains the major project development process and that includes methodologies to aid the design process yet not constrain it. In the next section of Chapter 2, the author reflects on 12 years of experience supervising major studio projects. The observations that follow provide both an understanding of, and a basis for interpreting the needs of, the educational process in the studio. The observations are substantial in importance and establish an imperative to survey other programmes to substantiate the conclusions that are emerging from this research.

2.6 AUTHOR'S OBSERVATIONS

On the supervision of student final-year projects and in teaching studio-supporting courses as a participant observer.

Observations of student approaches to final-year projects over the period 1993 to 2004 by the author has revealed that many students demonstrate aspects that are problematic, and these are:

- Poor time management
- Inadequate creative thinking
- A tendency to regard industrial design as a skill and not an integration of disciplines.
- Lack of confidence in design decision-making
- Insufficient engagement with the project
- Insufficient appreciation of the link between design and manufacturing
- Inability to make the connections between learning arising from other courses in other faculties, namely marketing, commerce, engineering, science and manufacturing
- A fixation with the product as compared to an understanding of the need
- A capacity to evaluate alternative concepts is lacking

Some students demonstrated an outstanding capability to plan their projects, creatively develop concepts and engage fully with the project[9], however the majority did not and the above-listed issues apply to a significant proportion of the student cohort. Generally, students confirm the above issues. Findings determined in this research project, associated with the 2003 cohort and their responses to the open-ended question: "how aspects of their final-year project work could have been improved", included, poor time management, a lack of confidence in design decision-making, the need for a more systematic approach, a more concrete structure for the development process, and a need to more effectively engage with the project. Further findings, associated with the 2004 cohort and their response to the open-ended question, "how the MPD System (a computer-based system of design methods) could have been improved", revealed a strong empathy and need for the provision of more rigorous teaching of systematic approaches. The findings are fully discussed in Chapter 5, and are briefly referred to in this section to emphasise the students' comments with respect to the above problematic issues.

To confirm or repudiate the above problematic issues it was considered necessary to conduct a structured survey of industrial design academics and this is discussed in the following chapter.

---

[9] Bonollo's PhD study "Designing Courses in Industrial Design," The University of Melbourne, confirmed that the better students take considerably less time in their project work.

2.7 A STRUCTURED SURVEY

Of other academics regarding their experience in the supervision of final-year projects

In the light of the previous comments it was clear that a structured survey of academics would be helpful in confirming the noted problematic issues. The structured survey, described in Chapter 4 and documented in Chapter 5, determined the effectiveness of various aspects of students' approaches and the methods they use as they progress through their major projects. In summary, the findings of the survey revealed that design methods are seriously under utilised in major projects. In addition, knowledge of the formal design process was not really understood by students as a means of navigating through major projects. The more common skills and methods such as CAD, design-by-drawing, brainstorming, solid-modelling, and ergonomic analysis are highly utilised by students however this would be expected because they are traditionally used in industrial design. Design methods, poorly utilised, include patent searching, features analysis, concept selection, function analysis, among many others of a more rigorous nature.

The survey indicated that design methods are not widely embraced in many industrial design programs and that students are not confident with time management, generation of ideas and understanding of the product development process and its potential role in guiding their project work. In summary, the survey determined that students in their final-year project experience significant problems:

1. In planning and managing their projects;
2. Making decisions associated with design alternatives;
3. Understanding the design and product development processes:
4. Creative thinking;
5. The ability to make the connections between various disciplines; and
6. The ability to employ design methods to aid design decision-making.

The findings obtained in the survey are consistent with the experience of the author and confirm that there are indeed significant problems associated with students' engagement in major studio-based projects. The survey of the 2003 and 2004 cohorts, referred to in the previous Chapter 2.6, are also confirmed the above findings.

The next chapter will discuss possible strategies for this research project that can provide direction and focus towards a theoretical framework associated with the aims of the thesis.

2.8 POSSIBLE STRATEGIES

For advancing the research aims of this thesis.

The studio presents a learning environment, which encourages creative thinking, intuitive decision-making processes and a holistic consideration of issues. Students are coached in all the studio discussions, critiques and projects to focus on aesthetics, feeling and creativity. Studio teaching is based on a spontaneous environment where ideas are discussed and critiqued as part of the learning process.

Aesthetic considerations are embedded in the industrial design psyche and dominate the culture of the studio. This is despite the fact that industrial design has moved closer to engineering and marketing and that the breadth of considerations in the design process now includes user-centred design, design for manufacture, sustainability, cultural and universal issues, among others. Industrial design is now a broader process and not predominantly product focussed. The historically-emphasised, right-brain approach should broaden to accommodate a more whole-brained approach where the teachings of disciplines supporting the studio are more effectively integrated into projects.

Evidence from the literature, observations from the author's supervision of major projects and the results from the structured survey of industrial design academics, all point to the fact that it difficult to integrate systematic and creative thinking to achieve a more whole-brained approach to final-year projects.

A need exists for some model of the studio process to support the student in the design process. The model should include left and right brain approaches and provide some platform to accommodate systematic thinking with a range of design methods simple and direct in application. Previously published design methods have been cumbersome in application and the literature does not refer to these as computer-based systems. Workstations are now common in the studio and a model or system should be computer based and with links to external sources of information such as patent data bases, relevant internet sites and extensive references accumulated over time. The model should serve as an educational reference to clarify aspects of various methods, for example, bionics and synectics, to provide examples of their application and suggestions where they can be applied.

The next chapter explains the need for further research in order to better understand the basis of possible strategies for advancing the aims of this research project.

2.9 THE NEED FOR FURTHER RESEARCH

The preceding discussions have outlined the nature of the problems in the design studio particularly in relation to significant design projects. More research is needed to better understand how possible strategies may be introduced. The history of attempts to introduce a higher level of systematic approaches to the field of industrial design and indeed engineering is littered with failure as noted in Chapter 2.4.1. The industrial design studio culture and focus has not markedly changed in 60 years and clearly, broadening of the focus to include systematic considerations is difficult to achieve. The present solution-focused approach has unique value in that it strives for the highest level of lateral and creative thinking. This needs to be preserved because ill-applied systematic thinking can lead to a narrowing of focus.

Greater emphasis on the design or product development process, as a means of providing a roadmap for the passage through ill-defined problems, would be of great assistance to the student designer. In addition, the teaching of selected methodologies may enable the student to more effectively categorise information and support the stages of design making that occur as design progresses. It is recognised that eventually the student when progressing beyond education, may not need the tools of process and methods, however, in the period of university application, confidence and competence can well be enhanced by utilisation of systematic techniques.

Further research in this thesis will focus upon:

- Theories of learning; including left and right brain modes of thinking, and experiential learning;
- The design process and other models that introduce procedure into the design and product development process;
- Design methods appropriate to the phases of student projects;
- Clarification of typical tasks that are essential in project work;
- Development of a method that determines the complexity of projects.

This research is described in the following chapter where a deeper consideration of thinking approaches in the studio and models of the design and development processes are considered.

•

Chapter 3

Theoretical Development and Constructs

A theory of teaching and learning that best relates to the studio-learning situation is described. Other design and product development processes together with a range of design methods are considered in order to arrive at a model that is best suited to student major projects. The author has compiled a development process and a comprehensive list of design methods. The development process and methods are further rationalised to arrive at a major project development model (MPD Model), a model consisting of process and methods suitable for final-year projects and which facilitates a whole-brained approach within the studio. A computer-based system of design methods (MPD System) suitable for application to student projects and based on the MPD Model is explained. Finally, the author presents a model for analysing the tasks involved in major projects and also describes a model that enables determination of the relative complexity of projects.

3.0 THEORETICAL DEVELOPMENT and CONSTRUCTS

3.1. A Theory of Studio Learning

Various theories of learning may be applied to understand how students acquire effective learning during their execution of final year projects. As a discipline that stands between Mathematics and Science on one side and Arts on the other, Industrial Design teaching and learning is explained by neuroscience as three physiological-based theories of learning namely, the brain-based theory of learning and the left and right-brain learning theory.

Right Brain Traits:

- *Intuitive*: Follows hunches, or feelings, takes leaps of logic.
- *Nontemporal*: having little or no awareness of time.
- *Random*: arranges events and actions haphazardly.
- *Causal and Informal*: deals with information on basis of need or interest at the time.
- *Concrete*: relates to things as they are commonly known or understood. Explicit, precise.
- *Holistic*: sees whole things all at one, overall patterns. Leading to divergent ideas.
- *Visual*: uses imagery, responds to pictures, colors, shapes.
- *Nonverbal*: responds to tones, music, body language, touch.
- *Visuo-spatial*: uses intuition to estimate, perceives shapes.
- *Responsive*: listens to music.
- *Originative*: interest in ideas and theories imaginatively.
- *Emotional*: suspicious judgment until it feels or seems right.
- *Learning*: through exploration

Left Brain Traits:

- *Methodical*: organises information, classifies, categorizes, structures.
- *Temporal*: keeps track of time, thinks in terms of past, present, future.
- *Sequential*: arranges events and actions in consecutive succession.
- *Linear*: thinks in terms of sequence, one thought directly following another. Leads to convergent conclusions.
- *Factual*: deals with details, items, the particulars, and features of a thing.
- *Verbal*: used words to name, describe, and define things.
- *Systematic and Formal*: processes information methodically, in a well-planned way.
- *Learning*: through systematic plans

Brain-based learning theory lends its credibility to recent discoveries by Neuroscience defined as the study of the human nervous system, the brain and the biological basis of consciousness, perception, memory and learning. Neuroscientists have discovered the physiological basis of cognitive development. Edelman (1992) asserts that our brain contains three brains; the lower reptilian brain that controls basic sensory motor functions; the mammalian brain that controls emotions, memory and biorhythms and the neo-cortex or thinking brain that controls cognition, reasoning, language and higher intelligence. The neo-cortex has two hemispheres, the left and the right brain, named literally for their physical position in the human body. Various experiments by neuroscientists and psychologists revealed a dichotomy of functions exercised by these two hemispheres. McCarthy (1996) illustrates the distinctions associated with the left and the right brains, and noted below:

The brain-based learning theory complements the left and right brain theory in its recognition of the physiological foundations of learning. Unlike the left and right brain theory, however, the brain-based learning theory highlights the significance of holistic learning. Hart (1983) asserts that the brain is a parallel processor, for example, the brain performs several activities at once like tasting, smelling and seeing, and that it processes wholes and parts simultaneously. The complementary aspects of both theories of learning can be gleaned from the similar strategies of teaching applied by both proponents, that is, giving balanced emphasis between the analytic, objective on the one hand and creativity and subjectivity on the other hand, in the learning outcomes.

The left and right brain theory has attracted interest from Industrial Design researchers. A study by Lawson (1997) on the left and right brain approaches was conducted with two different groups of students, namely final-year students of architecture and postgraduate science students. The group of scientists focused their attention on the underlying rules (a problem-focused strategy) whereas the architects focused their efforts in achieving the desired result (solution-focused strategy). The different approaches of the scientists and architects are attributable to the educational style of their respective courses. Architects are taught by a series of design studies and the outcome is criticised rather than the method. Scientists are taught theoretically where science proceeds via a method that can be replicated by others. The right brain's contribution to the design process is in the area of visualisation and drawing, creative thinking and in appearance design. In addition, the particular cognitive style, that of the solution-focused approach, which Lawson, drawing from Darke's (1978) model, has concluded lies at the heart of the designer's approach to solving problems, consists of three phases:

- decide on an important aspect of the problem (generator);
- develop an elementary solution (conjecture);
- examine the solution to see what can be discovered about the problem (analysis);

The first stage is consistent with Darke's model (see Section 2.5.1) and consists of whatever sketchy information is available to allow the formation of a possible solution. The perceptive nature of right brain thinking will recognise sufficient information upon which to develop the conjecture. Thus the solution becomes a vehicle for synthesis and to substantiate a deeper understanding of the problem itself.

The left-brain approaches problems logically, analytically and includes the activity of acquiring and comprehending information upon which to base solution proposals. In addition, the left brain will be concerned with controlling the design in words and numbers, relating to the brief and managing such aspects as performance and design specifications.

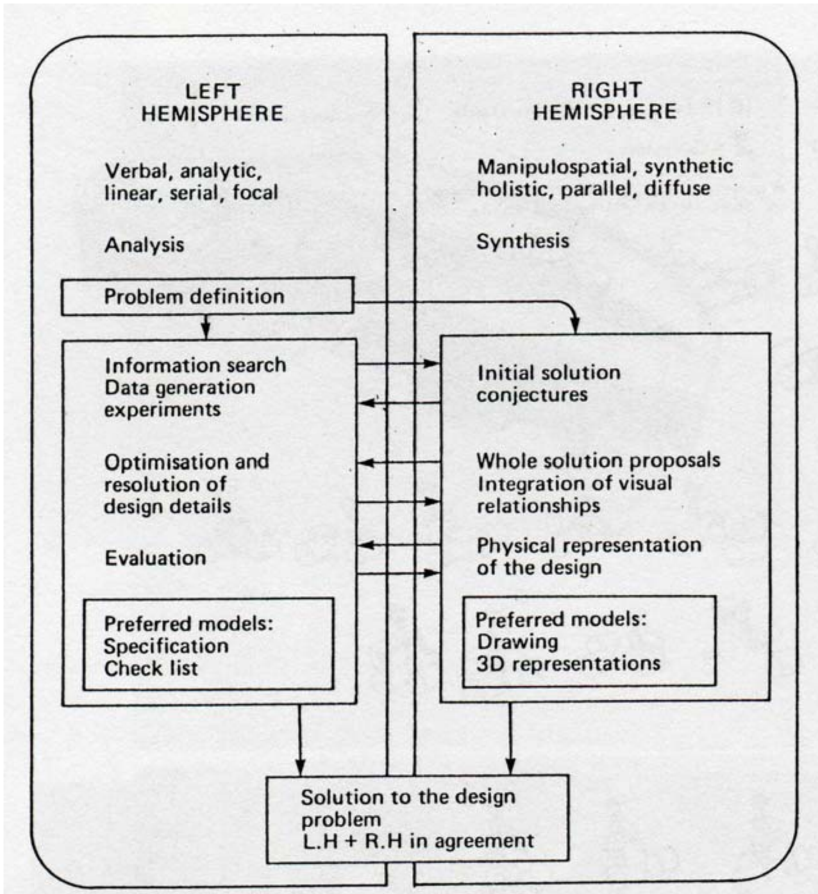


Figure 3.1 Tovey's dual-processing model incorporating left and right brain thinking modes[10]

3.1.1 Tovey's dual-processing model of design thinking

Tovey (1986) argues the balanced contribution of the left and right brains during the studio design process. His dual-processing model is shown diagrammatically in figure 3.1.

Effective design thinking necessitates the simultaneous and complimentary interaction of the two hemispheres. Tovey explains that an analytic, linear strategy (left brain) would be at work in the process of data generation, organisation to produce a design specification and in the evaluation of design proposals. The right hemisphere synthesises solution conjectures, integration of visual relationships and the physical presentation of the design

[10] Tovey, M., (1986) *Thinking styles and modelling systems*, Design Studies, Vol 7, No 1, p.20-30.

as drawings and 3D models. The design process will be concluded when the two processing modes are in agreement as to the outcome.

Tovey's model, with its structural limitations nevertheless, presents a model that accommodates duality of the mind process. More importantly, the model explains the situation of students in their final-year projects. General observation and teachings from the literature confirm the culture and nature of the studio does not accommodate left-brain thinking. The creative, solution-focused approach has dominated studio culture and the knowledge associated with market research, engineering principles, and manufacturing considerations have largely resided in the supporting courses associated with marketing, engineering and manufacturing. In short, the dual processing model conflicts with the model associated with studio project execution. The techniques associated with project planning, specification development, questionnaire design, problem definition and project framework are not part of the studio process and are not taught in the supporting courses (see the results of the survey of academics in Chapter 5.1).

3.2 DESIGN PROCESS MODELS

A number of models of the design process have been developed and these serve to describe the various stages of designing. In the educational setting a model can help students understand the steps involved and the relationship between the steps. In addition, the model can serve as a roadmap for the studio project to assist the students in determining connections between essential knowledge related to other disciplines.

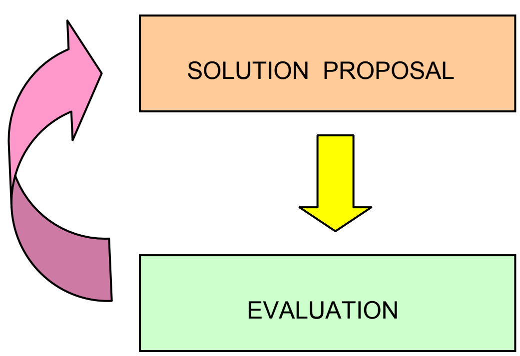


Figure 3.2 Simple model of solution versus evaluation

Design models are different ways of interpreting the design process applicable to a product or system. These are representations of philosophies or strategies proposed to show how design is or may be carried out (Sivaloganathan *et al*, 1995 p.456). Descriptive models of the design process usually emphasise the importance of generating a solution concept early in the process thus reflecting the solution-focused nature of design thinking where an initial solution is proposed and then subjected to analysis, evaluation, refinement and development. In most solution conjectures a fundamental shortcoming is discovered in the initial solution and it is then discarded and another solution proposed.

This process is described above in Figure 3.2, also seen earlier in Chapter 2.5.1, and the model itself, although simple, is nonetheless important in reinforcing understanding of the iterative nature of design thinking. Evaluation of the solution proposal may be based on a multitude of considerations, namely the goals of the design brief, marketing issues, manufacturing, cost constraints, among others and the model itself may be simple but the considerations can be complex.

Models of the design process are typically drawn in the form of a flow diagram with the development of the design proceeding from one stage to another but with feedback loops that allow revisiting of earlier stages to refine or challenge a solution or partial solution. The ultimate outcome of the process is to resolve and communicate a final design proposal and the additional step, that is, to communicate the solution, may be as shown in Figure 3.3.

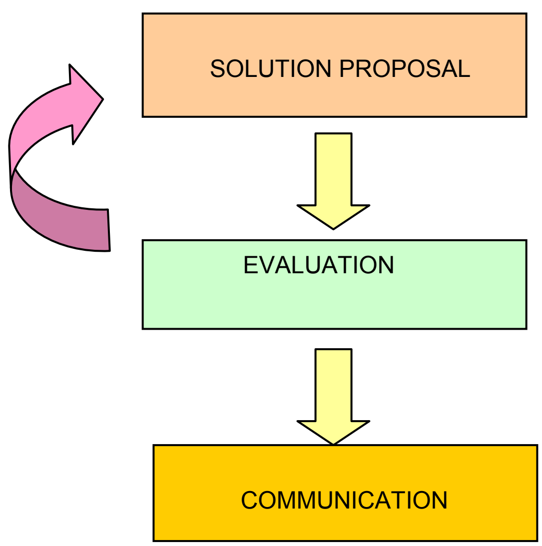


Figure 3.3 Simple model extended to include communication of the solution

This model typifies the process employed by most students during studio projects. It is also the most common model that is conveyed by teachers. A project is assigned and immediately a solution proposal is sought, evaluated and the proposal accepted or a new solution proposal sought. This process continues until the solution proposal is accepted and then finally communicated. And this is basically where the fundamental problem with studio teaching stems. The narrow process does not offer an overarching structure to guide the student and present an integrated platform that facilitates the introduction of appropriate methodologies. For example, the model described in Figure 3.3 may suffice for typical studio projects however it would not be appropriate for a final-year project because it does not include nor accommodate the many stages and considerations of a substantial project.

3.2.1 Archer's industrial design process model

Archer (1966) proposed a model that included six steps of the industrial design process as shown in Figure 3.4. The steps are:

a. Programming
b. data collection;
c. analysis; synthesis;
d. development and communication.

The model presents a far more integrated process that includes phases referred to as analytical, creative and executive. The model belongs in the professional/educational category of design process models and acknowledges the initial requirements of training and experience, which might be termed prior learning. The programming phase is a combination of the brief, training and experience that provides an introduction to enable the project to commence.

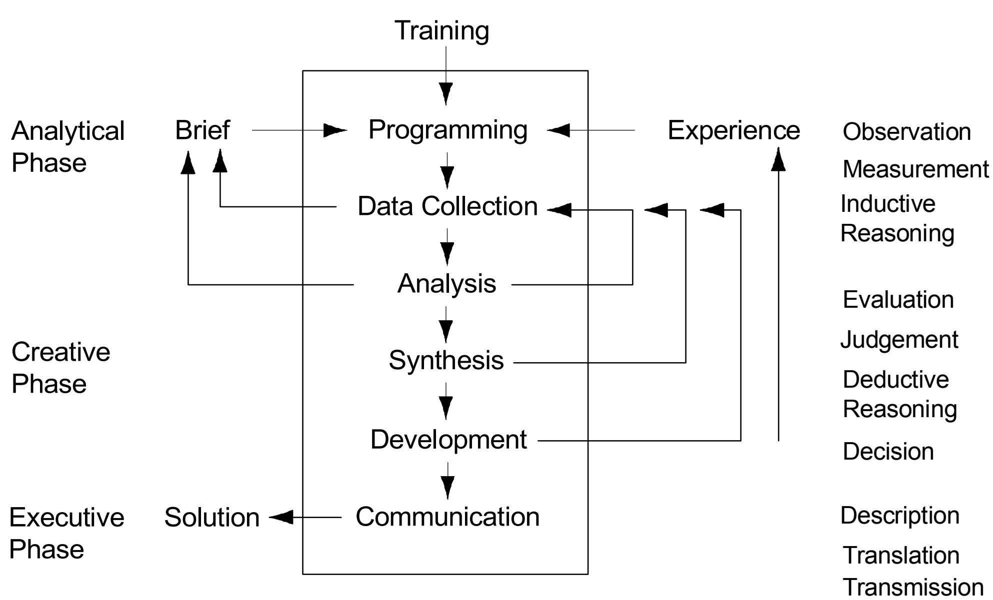


Figure 3.4 Archer's design process model

The Archer model however, was a subject of substantial criticism articulated principally by Hillier *et al* (1984), where the analysis-synthesis model of design, in which exhaustive problem analysis must be concluded before solution synthesis, is not in keeping with actual practice. It was argued by Hillier *et al* that the designer must first generate a solution conjecture, which may then be subjected to analysis and evaluation. However the ability to engage in solution conjecture that precedes analysis presupposes considerable confidence and experience. A designer of many years experience may bring to the ill-defined problem their own preconceptions and these are essential towards proffering solutions. Such experience and preconceptions are lacking in undergraduate students.

Archer, proposed six stages, which was a relatively simple macro-structure and intended that a micro-structure could be determined based upon the complexities and needs of particular projects. Archer constructed his model on a linear basis but was fully aware of the iterative characteristics of actual design processes. Therefore the model has considerable inherent flexibility and can be applied and adapted to a wide variety of projects. Whilst the model suits educational and professional needs, it is not considered appropriate to describe the major projects of students. The model does not include a stage that enables consideration of the market and finally does not include a final stage that enables consideration of investment and preparation for production, which is an essential consideration in student final-year projects.

3.2.2 Cross's industrial design/engineering design process model

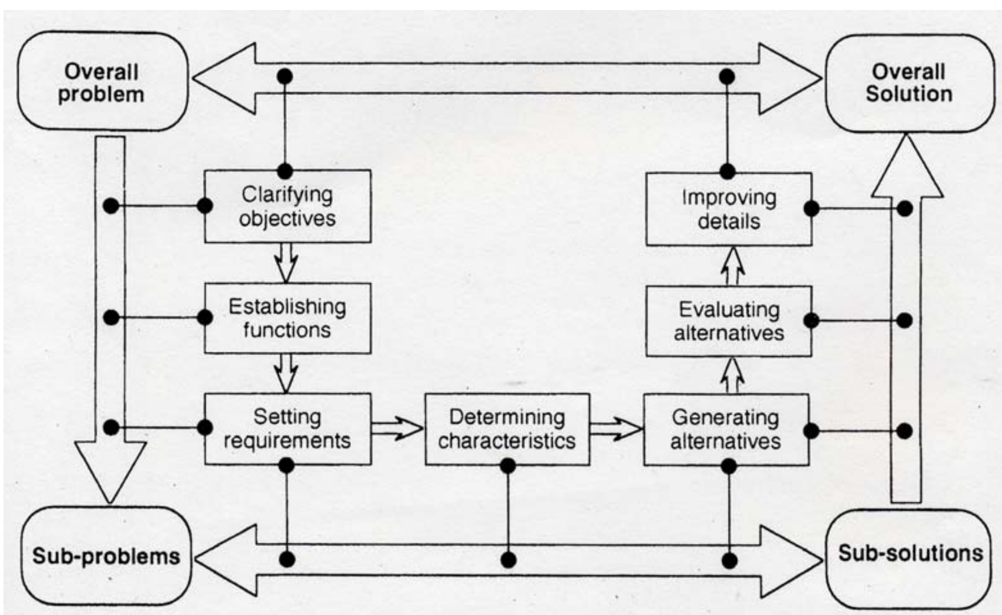


Figure 3.5 Cross's seven stages of the design process positioned within the symmetrical problem-solution model[11]

[11] Cross, N. (2000) *Engineering Design Methods,* Third Ed., John Wiley & Sons,

Cross's model shown in Figure 3.5, describes the engineering design process and can also effectively apply to the typical industrial design studio project. The "analysis of the problem" leading to an output as a "statement of the problem". The statement of the problem is fundamentally important because it clarifies the design objective.

The model encourages solution conjectures as a means of clarifying the problem. At a lower level there is a similar relationship between sub-problems and sub-solutions. The interaction and iteration between the overall problem and overall solution and sub-problems and sub-solutions enables this process to be effective in industrial design situations which are characterised by ill-defined problems. The suggested oscillation in the designer's thinking by the double-ended arrows, as defined by Cross, is realistic and more in keeping with the actual design process.

The descending arrow from the initial overall problem down to the identification of sub-problems and then across to sub-solutions suggests a progression through the process in a sequential manner. This is emphasised by the design methods that are implicit within the stages identified by *clarifying objectives*, *establishing functions*, *setting requirements* and so on. Cross, has specified various methods (refer Chapter 3.4.1) that can be applied within these stages. These activities and methods promote and assist the design process, whether this is exploring the problem-solution relationship, decomposing problems into sub-problems of synthesising sub-solutions (Cross and Roozenburg, 1992)

When applying the model to students' major projects, a major shortcoming becomes clear. There is, generally, due to a lack of experience and guided exposure to design processes and methods, a lack of ability in many students, to generate alternative proposals and to review these towards selection of an effective few. These selected few are then subjected to embodiment where the extent of design proceeds further into each selection until the concept is proved viable or conversely, nonviable. Cross has developed his design process and designed specific design methods appropriate to each phase (Cross, 2000, p.58).

The model is highly effective but does not accommodate the marketing stage of investigation, the determination of a project itself, a clear stage of conceptualisation and a stage of communication.

3.2.3 The consensus engineering design process model

Further models of the engineering design process have been developed and over the years a consensus model has evolved. This is manifest in the VDI model of the engineering design process described by Cross and Roozenburg (1992). Figure 3.6

shows this process as a sequence of activities leading to intermediate results, namely performance specification, function structure, principal solution and so on.

The activities associated with this model of the design process are usually grouped into four phases, namely: clarification of the task; conceptual design; embodiment design; and detail design. Whilst this is a proven model, within the domain of engineering, it does not easily accommodate the industrial design process.

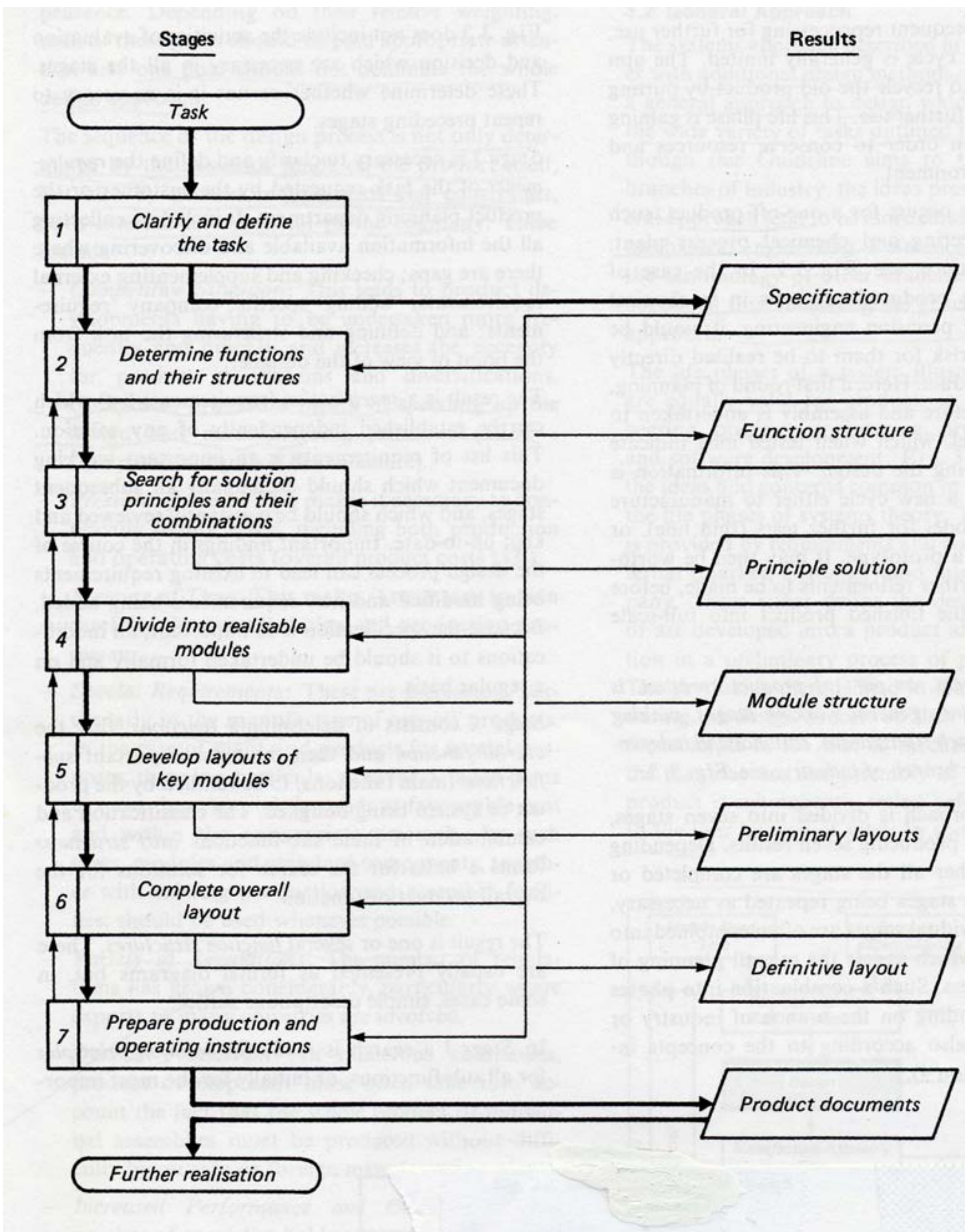


Figure 3.6 The consensus engineering design model[12]

[12] Cross and Roozenburg (1992) Modelling the Design Process in Engineering and Architecture. Journal of Engineering Design Vol. 3, No.4.

3.2.4 The Bonollo and Lewis industrial design model

Bonollo and Lewis (1996, p.4-19) investigated the industrial design profession and models of the design process. Particular emphasis was placed on design knowledge and the educational goals relevant to the industrial design educational process. A generic model of the industrial design process was presented which served as basis for superimposition of a variety of design methods, tools and procedures. The model includes a number of stages, namely:

a. task clarification;
b. concept generation;
c. evaluation and refinement of design concepts;
d. detailed design;
e. and communication of results.

No	Symbol	Subordinate Process	Proposed Macrostructure
1	TC	Task Clarification	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. Output: *Design brief (including design specification) project plan with time-line and cost estimates; TC study or client report*.
2	CG	Concept Generation	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. Output: *A folio of concept sketches, supported by simple models (mock-ups) providing a visual classification of design ideas; the client may be consulted at this phase.*
3	ER	Evaluation and Refinement (of design concepts)	A set of analytical and creative tasks in which the concepts in (2) are evaluated (using weighting and ranking techniques) and reduced to a small number of refined candidate solutions. Output: *A folio of refined concepts sketches, supported by a concept model (if required) and relevant technical information, illustrating a preferred concept, possibly with one or two alternatives, for client approval (usually).*
4	DD	Detailed Design (of preferred concept)	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. Output: *A folio of layout and detailed component drawings and technical report (preliminary manufacturing information).*
5	CR	Communication of Results (of the design concept)	A set of tasks whereby the concept detailed in (4) is communicated to the client and/or manager via appropriate two and three-dimensional media and written report. Output: *A folio of presentation drawings (including technical drawings etc., from (4), supported by a refined three-dimensional model or, if required, a first-attempt prototype (additional communication and manufacturing information).*

Table 3-1 Bonollo and Lewis generic model of the design process[13]

[13] Bonollo, E., and Lewis, W. P. (1996) The Industrial Design profession and Models of the Design Process. Design and Education. Vol. 6, No. 2. See also Bonollo and Lewis (2002).

The model suggests sequential progress through the process though a lot of activities may be carried out concurrently. In addition, iteration within the process is envisaged which means that at any phase it may be necessary to go back to an earlier phase to re-examine the results and develop alternative ideas and concepts. The model has been tested in the educational setting within a significant research project and has been examined and validated as suitable for investigating the design of courses in industrial design. This generic model has since been adapted and applied successfully to a complex product design and development project in a sanitary-ware, manufacturing company (Cummings and Bonollo, 1999). A table describing the stages of the process is shown above in Table 3-1.

The Bonollo and Lewis model is proven in its suitability to the industrial design process in both the industrial and the educational setting however because of its generic nature of the model it would require specific adaptation to the final-year project. Firstly, for example, students at UNSW are required to carry out research in an area of interest, which usually requires research of market segments to identify a product opportunity. Students are not presented with a brief. Rather, they have to establish the brief and this establishment phase precedes the *task clarification* phase described by the Bonollo/Lewis model. Secondly, in the major project considerable educational emphasis is placed on the consideration of manufacturing, the identification of materials and processes, establishment of levels of investment and determination of the cost of a product. These aspects extend beyond the *communication* phase described in the model. Consideration of the stages of the engineering and industrial design processes revealed similarities in many respects. Table 3-2 sets out the respective stages, based respectively on the consensus engineering design process model and the Bonollo and Lewis, industrial design model.

Engineering Design	Industrial Design
1. Clarification	1. Task Clarification
2. Conceptualising	2. Concept Generation
3. Embodiment	3. Evaluation and refinement
4. Elaboration and detailing	3. Detailed design
	5. Communication of results

Table 3-2: Comparison of phases between the engineering and industrial design processes[14]

[14] Author’s tabling of the consensus engineering model and the Bonollo and Lewis model.

3.3 ALTERNATIVE DESIGN-DEVELOPMENT PROCESSES

The preceding investigation has identified a number of design processes and although effective in describing the phases of industrial and product design they are nonetheless not totally appropriate or need to be adapted for application to final year projects. The following reviews apply to the product development process, which normally precedes and extends beyond the product and industrial design process. The product development process (PDP) can be defined as: *'the total sequence of activities required in order to create a new product, including design, development, manufacture, assembly, installation and operation'* (Warell, 1999).

The final-year project seeks to identify and create a new product, to carry out the design and to address certain aspects of development and preparation for manufacture. Therefore clarification of the various models of the PDP may provide a process suitable for student major projects.

3.3.1 The Product Development Process

The product-development process employed by industry typically follows a sequential process that includes a number of stages. Figure 3.7 shows a process specified by Rosenau that spans idea generation to market follow-up. Whilst there are differences in various PDP models they are in principle, similar and several are discussed.

The process specified by Rosenau (1990) consists of eight stages, titled the 'product development cycle' (PDC). The model commences with idea/concept generation, which does not suggest a study of the market or competitors and therefore does not provide an initial platform to support student research. The second stage of new technology feasibility and specification development prior to design is more suited to engineering innovation. The model is basic and the technical discussion by Rosenau does not include a range of sub-stages and tasks. Therefore this model would not be appropriate to provide a structure for the student project.

Jones' (1997) product development process has three principal phases namely: the *inception* phase, which include pre-design activities; the *creation* phase, which includes the core development stages associated with generating a product concept and taking it through to a working prototype; and the *realisation* phase which takes the final design, puts it into manufacture and launches it onto the market.

The *inception phase* includes stages that apply to market research and research and development. The stages of new product opportunity, need identification, idea generation, feasibility assessment and project planning align effectively with tasks associated with the student project. Similarly the *creation phase* includes stages, namely concept, design, development, modelling and testing, that closely align with the design process. Modelling may apply to a student computer model or a fabricated model that may test response to form or usability. The *realisation phase*, which includes the stages of product preparation,

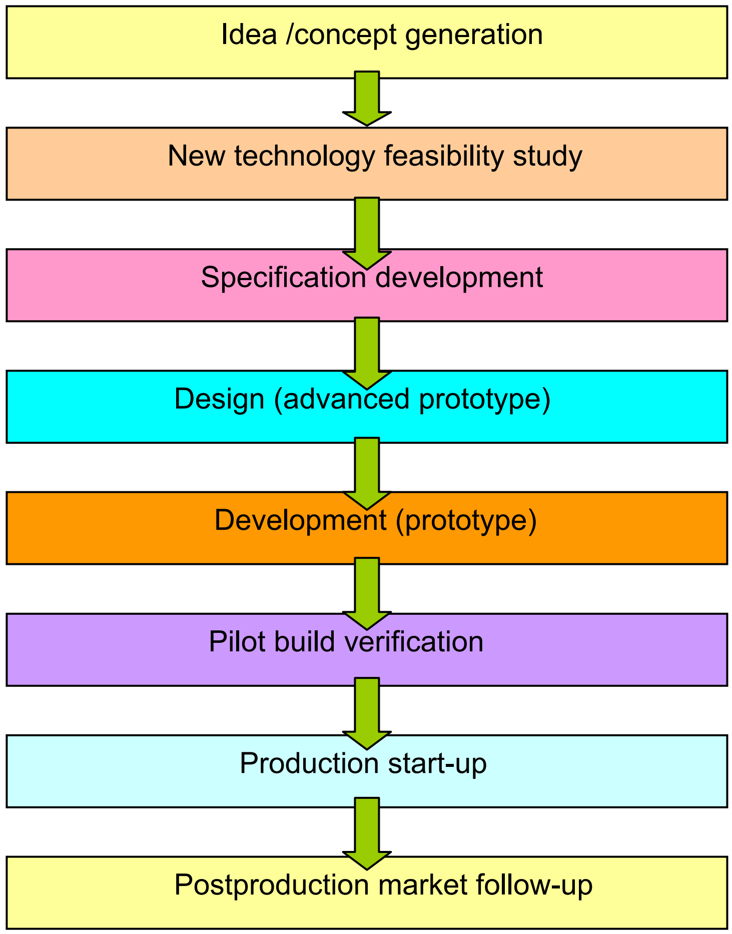


Figure 3.7 Eight-stage product development cycle[15]

product introduction, distribution, and operation and evaluation, extends well beyond the expectations of the student's project, for example the stages of product launch into the market, distribution and evaluation of market performance. The PDP process whilst not directly appropriate to the student situation, nonetheless presents a model that can be adjusted to suit various companies, projects of varying design difficulty and management requirements.

---

[15] Rosenau, M. D., (1990) Faster New product Development. Amacom, New York

3.3.2 Generic Model of the Product Development Process

Bonollo and Tan (2001) present a model of the Product Development Process (PDP), which spans activities ranging from the initial product idea through to launch of the product, market feedback and finally, model planning. The eight phases of the model is shown in Table 3-3. Product design is included as the third phase and the sub-phases of product design are similar to that described in Table 3-1, the generic model of the industrial design process. Therefore if the PDP is expanded to include the sub-phases of product design the entire process would include 12 phases. The model presents a concise and practical description of the PDP in the context of industry product development. Each of the phases in the model can be divided into sub phases and although laid out in a sequential manner the model envisages concurrent activities and iteration between the phases. Whilst the model comprehensively addresses issues in product development it is considered not appropriate to guide student work in final-year projects because it includes stages beyond the scope of a final-year project and would require modifications. In addition, it has a strong industry focus.

On commencement of major projects students are encouraged to explore particular markets and identify opportunities. This is not consistent with the model's direct identification of a product idea. The students' project concludes with consideration of *production* however the phases of *marketing and sales*, *market feedback* and *new model planning* extend beyond expectations of the student project.

3.3.3 Summary

The purpose of the prior discussion in Chapters 3.2 and 3.3 was to identify a process model that might align with the phases of consideration in the student major project.

Archer's model is proven in its application to the design process however it does not accommodate the product planning research and adaptation to the student major project is not immediately obvious. The Bonollo and Lewis model has been tested and validated in relation to student projects and its adaptation to the requirements of this research project is a definite option. The engineering models by Cross, and Cross and Roozenburg, together with the product development models exemplified by Rosenau, Jones and Bonollo and Tan, are appropriate to industry situations. In the next section, design methods, proposed by various authors, together with models supporting the application of those methods, are researched to determine methods appropriate to student projects.

PHASE	TYPICAL TASK CONTENT AND OUTPUT
Product Idea Definition	The tasks include identification of a good product idea and critical analysis of the idea from the corporate position. The product idea can be a new product or a new model of an existing product. The idea may originate from a number of possible ways such as new technology, new market, customers' feedback, new corporate strategy, new product features, employee suggestion, etc. The decision for a new product idea is normally made in the corporate management level with consultations with relevant personnel in the company. *Output: product Strategy – which includes product direction, market identification, preliminary business plan, preliminary product specifications, resources requirements, etc.*
Market Study	The tasks include market survey strategy, benchmarking or competitive products study, preparation of survey questionnaires, conducting the surveys results, and make conclusions and recommendations. *Output: A complete market study report, which is a vital piece of information for subsequent business decisions and the formulation of the actual business plan for the product.*
Product Design	The tasks include preparation of the Design Brief, concept generation, concept evaluation and refinement detailed design and communication of the design results. *Output: A Design Brief, proposed concepts in sketches, concept evaluation results, selected design, detailed design drawings, and specifications, 3D model or first prototype, market and user trials, evaluation, and feedback on the product aesthetics and semantics.*
Prototype Testing	The tasks include building a fully working prototype, conduct comprehensive tests on functions, aesthetics, ergonomics, manufacturability, reliability, packaging, maintainability, and evaluation on production requirements. If necessary, different versions of working prototype may be built for refined testing. *Output: A thorough prototype testing report, which and a complete set of design drawings and specifications ready for production.*
Production	The tasks including production and process planning, procurement of components, design and development of tooling, production control and management, assembly, quality assurance, packaging and logistics management. Output: product system and documentation, and completed products ready for delivery to the distributors, retailers and customers.
Marketing and Sales	The tasks include product pricing, preparation and implementation of marketing plan, sales and promotion, delivery and customer services. *Output: Marketing and sales system, and timely delivery of product to the customers.*
Market Feedback	The tasks include gathering feedback from customers, distributors and retailers, analysis of feedback and make recommendations. *Output: Timely reports on market feedback for immediate and future plans.*
New Model Planning	The tasks include synthesis of market feedback and reports, and all relevant information in the entire product development process, in order top prepare the product direction, for subsequent models. *Output: A report on recommendation for the new model product direction.*

Table 3-3 Generic model of the Product Development Process[16]

[16] Tan A.K. and Bonollo E., (2001) *Integrated Genome-Like Product database and Management System*. ASME International 21st Computer and Information in Engineering (CIE) Conference September 9-12, 2001 Pittsburgh, Pennsylvania.

3.4 DESIGN METHODS

The discussion in Chapters 3.2 and 3.3 has considered a range of models of the design process. In this section design methods specified by various authors will be discussed with the aim of identifying a list of methods appropriate to the educational circumstances of the final-year project.

Stage	Design method	Aim
Clarifying objectives	Objectives tree	To clarify design objectives and sub-objectives and the relationships between them.
Establishing functions	Function analysis	To establish the functions required, and the system boundary, of a new design.
Setting requirements	Performance specification	To make an accurate specification of the performance required of a design solution.
Determining characteristics	Quality function deployment	To set targets to be achieved for the engineering characteristics of a product such that will satisfy customer requirements.
Generating alternatives	Morphological analysis	To generate the complete range of alternative design solutions for a product, and hence to widen the search for potential new solutions.
Evaluating alternatives	Weighted objectives	To compare the utility values of alternative design proposals on the basis of performance against differentially weighted objectives.
Improving details	Value engineering	To increase or maintain the value of a product to its purchaser while reducing its cost to its purchaser.

Table 3-4 Cross's design process, methods and aims[17]

3.4.1 Design methods proposed by Cross

Cross (1989) cites a number of factors that may contribute to a greater need for the use of systematic design. These include:

- □ Increasing complexity of products and production;
- □ Rapid increases in the development of new product types and new materials;
- □ Increased need for teamwork in design and development;
- □ Greater awareness of the need to reduce risks associated with product failure;
- □ The need to reduce product development lead times.

[17] Cross, N. (2000) *Engineering Design Methods,* Third Ed., John Wiley & Sons,

Figure 3.5 specifies a framework that includes seven stages. These stages facilitate the consideration of issues appropriate to that stage and which may be clarified by the use of certain design methods. For example, the *clarification of objectives* is a stage that includes the aim of clarifying design objectives and sub-objectives and the relationships between them. The *objectives-tree method* is particularly useful in making apparent such objectives.

3.4.2 Design methods proposed by Baxter

Some of the more recent prescriptive models of design attempt to improve the management of the design process while still fostering the creative development of new ideas. Baxter (1995) outlines the development of a staged plan or framework for the overall process and suggests a range of systematic methods or tools that can be applied at the various stages.

Stage	Design method	Aim
Strategy development	SWOT analysis PEST analysis Tracking study Product maturity analysis Competitor analysis Product development risk audit	Consideration of company strategy and development of a product development strategy
Product planning – (Opportunity specification)	Delphi technique Market needs research Opportunity specification	Identifying and specifying opportunities for product development.
Concept design	Product function analysis Life cycle analysis Synectics Product features permutations Orthographic analysis Scamper Analogies and metaphors Cliches and proberbs Parametric analysis Problem abstraction Brainwriting	Evaluation and selection of the preferred concept schemes.
Further product planning – (creating quality, adding value).	Design specification Kano model of quality Quality function deployment Project planning	Consider issues of quality and value that includes detailed evaluation of the chosen concept and creation of a detailed specification for development of the concept.
Embodiment and Detail Design	Idea generation Design integration Prototyping Failure-mode and effects analysis	To clarify the design issues associated with the concept and to produce a range of detail drawings that describe the chosen concept.

Table 3-5 Author's interpretation of Baxter's framework, suggested methods and aims[18]

[18] Author's development of table describing Baxter's (1995) approach to product development process and methods.

His approach includes the flexible use of a range of design methods and tools. The framework that he has developed can be understood by reference to Table 3-5.

The author has studied the text produced by Baxter and has adapted the sequence of the tasks and methods to determine its suitability for adoption of a process model on which to base student projects. The resultant model is highly effective and includes methods that can contribute to good project outcomes. However the model is more suited to the professional workplace and is not adapted for major projects in education.

3.4.3 Design methods proposed by Maffin

Maffin (1998 p.315-327) provides a critique of contemporary models of engineering design and highlights how design is practiced in industry. He argues that the design context has a large bearing on the design strategy of an organisation and suggests that design researchers should be more sympathetic to the design context and needs of design practitioners. In Table 3-6 Maffin lists the stages of the design process, namely market → specification → concept → detail. These stages are intended to provide flexibility in industry application. Listed alongside the stages are design methods, many of which are appropriate to the industrial design profession. For example, the *market* stage includes methods such as: literature search; matrix analysis; competition analysis; SWOT analysis among others, and other phases similarly include many useful combinations of methods.

Maffin's research highlighted the use of certain methods however he reports on the use of design methods where their application is more likely to be applied to substantial or complex innovations. *'The application of several generic design techniques (functional decomposition, concept generation matrices, brainstorming, design evaluation matrices and patent searching) for the generation and evaluation of potential product concepts among the case study projects was strongly correlated with higher levels of product innovation'.*

More generally, he cites the poor utilisation of design methods across industry and highlights the recurring issue with the use of design methods, namely their tendency to be inconvenient and time consuming in application:

'Significantly, some of these, including quality function deployment, robust design, functional decomposition, concept generation, and evaluation matrices, were not widely known, let alone applied. This may reflect that few companies had a clearly defined role for consideration of enabling technologies and methods. However some companies

indicated that they had found techniques such as quality-function deployment to be too demanding on time and resources'.

Design stage	Method

Market	Literature searches
	Parametric analysis
	Matrix analysis
	Competition analysis
	    Literature, sales reports, trade fairs & exhibitions
	    SWOT analysis
	    Reverse engineering
	Market research analysis
	Need analysis (customer requirements)
	    Market feedback mechanisms
	    Customer interviews & customer questionnaires
	    Competition benchmarking
	    Quality function deployment (QFD) matrices

Specification	QFD Matrices
	    Engineering requirements
	    Competition benchmarking
	    Engineering targets
	Performance specification method
	Specification checklists & questionnaires

Concept	Concept generation
	    Objectives tree & functional decomposition
	    Principle of division of tasks
	    Design catalogues
	    Literature and patent search results
	    Function-concept mapping (morphological charts)
	Concept evaluation
	    Feasibility judgment (gut feel)
	    Technology readiness assessment
	    Go/no-go screening (customer requirements)
	    Evaluation matrix (relative or weighted objective)
	    Graphical or physical mockups
	    Design review
	QFD Matrices

Detail	Product generation
	    Component design specification
	    Engineering design standards
	    Producability engineering (materials, form, process)
	Product evaluation
	    Evaluation matrix (engineering matrix)
	    Evaluating performance
	    Analytical, physical & graphical model development
	    Evaluating costs
	    Design review
	Design for manufacture and assembly (DFMA)
	Taguchi/robust design
	Failure mode effect analysis (FMEA)
	Value analysis & engineering (VA/VE)
	Functional cost analysis
	QFD Matrices
	Prototyping & testing

Table 3-6 Maffin's summary of the most commonly prescribed formal methods in relation to the product design stage[19]

[19] Maffin, D. (1998) Engineering Design Models: *Journal of Engineering Design*, Vol. 9, No. 4

Maffin's stages of the design process, aligned with a range of design methods presents a reasonable approach to project management however these are strongly focused towards engineering and product design and do not include the phases of *communication* and *preparation for production*. In view of this the author believes Maffin's system could not be easily adapted to student, final-year projects.

3.4.4 Design methods proposed by Eder

Eder (1998) allocated various design methods in each stage of product design, as shown in Table 3-7. The stages of design that specified, namely: clarifying the problem; conceptualising; embodiment; and elaboration and detailing; stages that are based on the consensus model of engineering design discussed in Section 3.2.3. These stages are referred to as the *product realisation process,* which he argues is sometimes preceded by *product planning* and continues after designing with issues associated with manufacturing, referred to as *preparation for production*.

Hence a process is specified that aligns with industry practice commencing with product planning and including other stages such as clarifying the problem, conceptualizing, embodiment, elaboration and detailing and preparation for production. Eder acknowledges the use of various methods such as TQM, QFD, Taguchi, among others and refers to these as methods accepted and used by industry. However he concedes that only a relatively small segment of industry actually use such methods and he laments that industry as a whole does not use some of the newer design methods such as, benchmarking, morphological analysis, concept selection, and value analysis, In addition, it is argued that emphasis is placed on the application of methods in the early stage of the process in order to avoid costly mistakes and alterations that may surface later in the project.

Table 3-7 lays out the stages of the design process and lists industry accepted methods as well as newer methods and these are aligned with the appropriate stages. The process concentrates a number of very powerful methods in the early stages namely market research, benchmarking, brainstorming, TQM and QFD and this places emphasis on understanding and clarification. This approach is consistent with the range of methods specified by Maffin in the early stages. The model presented by Eder is comprehensive, highly technical and suited to sophisticated project development in industry and although highly useful as a guide for product development departments of industrial companies it is too complex for the major project in an educational setting.

Design stage	Method
Product Planning	Trend studies Market research Benchmarking Integrated product development Total quality management Brainstorming
Clarifying the problem	Integrated product development Total quality management Brainstorming Iteration
Conceptualising	Benchmarking Integrated product development Virtual reality Iteration Recursive decomposition Dialog method Function structure Morphological matrix Design catalogues Concept selection (Pugh) Value analysis / Value engineering
Laying out, embodying	Iteration Recursive decomposition Design catalogues Concept selection (Pugh) Value analysis/Value engineering Cost pre-calculation Fault tree analysis Failure mode and effects analysis CAD Design for manufacture and assembly
Elaborating, detailing	Quality function deployment Iteration Design catalogues Concurrent/simultaneous engineering Design of experiments Fault tree analysis Failure mode and effects analysis Design for manufacture and assembly CAD CAD/CAM Rapid prototyping
Preparation for production	Quality function deployment Total quality management Iteration Value analysis/ Value engineering Concurrent/simultaneous engineering Design of experiments (Taguchi) Fault tree analysis Failure mode and effects analysis Design for manufacture and assembly Computer-aided design CAD/CAM Rapid prototyping Statistical process control

Table 3-7 Author's interpretation of the most commonly prescribed formal methods in relation to the product design stages[20]

[20] Eder, E.W., (1998) Design modeling: A Design Science approach. *Journal of Engineering Design*, Vol. 9, No. 4

3.5 PROPOSED SUMMATIVE MODEL OF PROFESSIONAL/ INDUSTRIAL DESIGN PROCESS AND PRACTICE

From the various models of the design and product development processes and the methods appropriate to those models the author has constructed phases of the design process and grouped a list of design methods as shown in Table 3-8.

Phase	Design Method
Product Planning	Project time plan Literature searches Parametric analysis PEST Analysis Product maturity analysis Competitor analysis Product development audit Matrix analysis Brainstorming Brainwriting Integrated product development Competition analysis . Literature, sales reports, trade fairs & exhibitions . (SWOT) analysis . Features analysis . Peeves analysis . Reverse engineering Market research analysis . Trend studies . Tracking study Need analysis (customer requirements) . Market feedback mechanisms . User interviews . questionnaires . Competition benchmarking . Quality function deployment (QFD)
Task Clarification	QFD Matrices . Engineering requirements . Competition benchmarking . Engineering targets . Performance specification method . Specification checklists & questionnaires . Design specification
Concept Generation	Concept generation . Objectives tree & . functional decomposition . Brainstorming . Principle of division of tasks . Design catalogues . Literature and patent search results . Morphological analysis . Brainwriting . Synectics . Bionics
Evaluation and Refinement (of design concepts)	Concept evaluation . Feasibility judgement (gut feel) . Technology readiness assessment . Go/no-go screening (customer requirements) . Value analysis (VA) . Concept selection . Kano model of quality . Ergonomic Analysis . Design for manufacture & assembly (DFMA) . Computer Aided Design (CAD) . Evaluation matrix (relative or weighted objective) . Graphical or physical mock-ups . Design review QFD Matrices
Detailed Design (of preferred concept).	Product generation . Component design specification . Engineering design standards . Producability engineering (materials, form, process) Product evaluation . Anthropometric analysis . Task analysis . Evaluation matrix (engineering matrix) . Evaluating performance . Analytical, physical & graphical model development . Evaluating costs . Design review . Rapid prototyping . DFMA . Taguchi / robust design . Failure-mode-effect (FMEA) . Value analysis/engineering . Functional cost analysis . QFD Matrices . Prototyping & testing
Communica -tion of results	Design drawings Renderings Solid modelling Models Rapid prototyping Prototypes
Prepare For Production	Total quality management . Statistical process control (SPC) . Fault tree analysis . QFD matrices Integrated product development Computer integrated manufacture (CIM) Rapid prototyping Computer-aided design (CAD) Computer-aided engineering (CAE) Design for manufacture and assembly Design of experiments (Taguchi) Failure mode, effects analysis Computer Integrated Manufacture Total Quality Management

Continued next column

Table 3-8 Author's proposed summative model of the design process and applicable methods

The list of design methods is categorised into sections that correspond to the proposed Major Product Development process to be described in Section 3.6.1. Additionally, it includes various methods from the prior discussion from industry journals. The list itself serves to illustrate the extensive array of design methods and as a result the obvious difficulty in their inclusion, in a rational way, in the curriculum of university design programmes.

There are numerous factors, arising from the internal and external arrangements of the company that influence the requirements and characteristics of design projects (Maffin, 1998). This is why the phase of product planning or marketing analysis is included. Modern approaches to product development such as *concurrent engineering* and *integrated product development* involve the formation of teams and increasingly engineers and designers are included and deal with market and business considerations. Certain methods occur in more than one category, a particular method, for example, *brainstorming,* may be equally valid in *product planning* or *concept development*.

The need to consider *preparation for production* is significantly important to the design process because aspects of the product's design will hinge on the constraints of the existing manufacturing system and the need to include considerations of design for manufacture and assembly. In addition, the design itself may include innovations in manufacturing and therefore consideration of this has to occur in the detailed design phases as well as the preparation for production phase.

3.5.1 Key questions relevant to this thesis

How can design methods be made relevant to students involved in design projects? How can these be integrated into design teaching so that they become a fundamental part of the design process and not an optional extra? They cannot all be taught, just as not all CAD packages can be taught. An effective approach is to firstly rationalise the range of methods. For example, included in the *evaluation* stage are the QFD and VA methods. These have certain similarities and one might be eliminated. This approach applied to the broad range of methods may yield a reduced suite of complimentary methods that can be taught as a group. Additionally, the learning of an entire method such as value analysis can be daunting, however within VA there are discrete methods that can have a focused application to specific aspects of the design process. An example of this might apply to Function Analysis, a part of VA that can be applied as a discrete method to considerations of product design, ergonomics or mechanical design. In the light of these issues an MPD Model is proposed overleaf which takes into consideration the perceived capabilities of final-year students.

3.6 PROPOSED MAJOR PROJECT DEVELOPMENT (MPD) MODEL

In this chapter, models of the design and product development process are reviewed and their applicability to the final-year major project process discussed. A new model is needed to better meet the unique considerations associated with the industrial design project. The following description of the MPD Model considers firstly the stages of the model and then rationalises the methods that are considered appropriate to those stages.

3.6.1 Process

No	Symbol	Subordinate Process	Proposed Macrostructure
1	PP	Product Planning	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. Output: *Strategic review of the market; competitor analysis report; Identification of a project/product opportunity; produce project time plan*.
2	TC	Task Clarification	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. Output: *Design brief (including design specification) project plan with time-line and cost estimates; TC study or client report*.
3	CG	Concept Generation	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. Output: *A folio of concept sketches, supported by simple models (mock-ups) providing a visual classification of design ideas; the client may be consulted at this phase.*
4	ER	Evaluation and Refinement (of design concepts)	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. Output: *A folio of refined concepts sketches, supported by a concept model (if required) and relevant technical information, illustrating a preferred concept, possibly with one or two alternatives, for client approval (usually).*
5	DD	Detailed Design (of preferred concept)	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. Output: *A folio of layout and detailed component drawings and technical report (preliminary manufacturing information).*
6	CR	Communication of Results (of the design concept)	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. Output: *A folio of presentation drawings (including technical drawings etc., from (5), supported by a refined three-dimensional model or, if required, a first-attempt prototype (additional communication and manufacturing information).*
7	PP	Preparation for Production	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. Output: *product system and documentation that includes a folio of engineering drawings that define specifications that clarify manufacturing details; a bill of materials; estimation of tooling and manufacturing equipment; and the financial return on investment.*

Table 3-9 Proposed model of The Major Project Development Process (without detailing relevant methods).

The proposed MPD Model is based upon the established industrial design process presented by Bonollo and Lewis described in Section 3.2.4 where their process commences with a brief and finishes with the communication of results. Their model has been extended, by the author, to include the phases of *product planning* (concerned with exploration of the market, competitors, and strategic positioning of the product, issues normally carried out by the marketing department of an organisation and *preparation for production* (concerned with manufacturing investment and return on investment).

Final year students engaged in a major project have to research the market, carry out competitor analysis and understand requirements in order to create their own brief. Similarly the major project requires consideration of production, for example determination of product cost, investment in tooling and financial analysis to determine viability of the project. For these reasons the phases, namely, *product planning* and *prepare for production* have been added to the Bonollo and Lewis model.

3.6.2 Methods

In Chapters 3.4.1 to 3.4.4 design methods proposed by Cross, Maffin, Baxter and Eder were reviewed and this led to the proposal of the author's summative model of the design process and applicable methods (refer Table 3-8). The purpose of compiling the list was to bring together the range of methods from the literature so that the full array of design methods could be understood. Clearly, the number listed is beyond the capability of a student or indeed a professional to master and apply in project work. In addition, many of the methods are applicable to engineering design and not useful in industrial design considerations. Therefore, it was essential to assess the compiled list and rationalise to a range of methods about which the student might be educated and then subsequently apply in studio project work. The rationalisation was based on the tasks anticipated in student work in major projects. Table 3-10 lists the seven phases of the major project development process and against these are listed a reduced number of methods.

In the next section the previous considerations are adapted to arrive at a Major Project Development Model, (the MPD Model) which is proposed and explained.

Phase	Method
1. Product Planning	Literature Search Features Analysis Benchmarking Patent Search SWOT Analysis Project checklist Peeves Analysis Project time plan
2. Task Clarification	The Objectives-tree method Cost visibility Pareto Analysis Function analysis Cost-function analysis Performance specification
3. Concept Generation	Brainstorming Synectics Bionics Design-by-drawing Concept selection Design catalogues Patent search Morphological analysis
4. Evaluation and Refinement	Interaction matrix House of quality (QFD) Design-by-drawing CAD Design Review Design for Manufacture and Assembly
5. Detailed Design	CAD Value engineering Taguchi/robust design Cost determination Failure mode and effects analysis Component design specifications Life-cycle analysis
6. Communication of Results	Design drawings Renderings Prototypes
7. Preparation for Production	Revised cost visibility Change proposal Statistical process control Fault tree analysis CAD

Table 3-10 The author's proposed suite of design methods-aligned with the respective design process phase.

3.6.3 The "**MPD Model**" (an integration of process and methods)

In the previous section a major project development process, suitable for student final-year projects, has been proposed (refer Table 3.9). In addition, a suite of methods has also been proposed that enhance usability of the process (refer Table 3-10). The combination of these proposals is termed the Major Project Development Model (MPD Model) described in Table 3-11 below. The model includes seven phases, ranging from *Product Planning* to *Preparation for Production, listed in column 3,* and included in the Model are 43 design methods, as listed in column 5. The proposed macrostructure in the MPD Model is explained in column 4 (refer Table 3-11), for example, in the *Product Planning* phase the outputs are:

- Strategic review of the market
- Competitor analysis report
- Identification of market opportunity
- Project time plan

The Product Planning (PP) phase enables the student to: identify a project/product opportunity; review the market; and prepare a competitor analysis report. This initial research of the final-year project differs from studios in earlier years where the student is provided a brief. In the Product Planning phase the student must conduct research upon which is based the subsequent establishment of a brief. Similarly, the Task Clarification (TC) phase provides a structure to: establish the design brief; conduct a human factors and materials technology study; and prepare a project time plan.

The tasks specified in each phase of the model are proposed in Table 3-12 and aligned with the respective tasks are proposed methods that can be used to support the design research of the student and to facilitate a structured approach to information gathered. For example, the task of *strategic review of the market* can be supported by the use of methods such as SWOT Analysis, Benchmarking or Features Analysis. Similarly, the task of *competitor analysis* can be assisted by the use of design methods, namely Benchmarking and Features Analysis and Patent Searching. The purpose of the MPD Model is to establish a structure and methods that will 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.

The MPD Model is complimented by a significant development, the MPD System (a suite of computer-based design methods) and this will be described in Chapter 3.7. The tasks included in the MPD Model are shown in Table 3-12 and discussed in Chapter 3.6.4.

No	Symbol	Subordinate Process	Proposed Macrostructure	Design Method
1	PP	Product Planning	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. Output: *Strategic review of the market; competitor analysis report; Identification of a project/product opportunity; produce project time plan*.	Literature Search Features Analysis Benchmarking Patent Search SWOT Analysis Project checklist Peeves Analysis Project time plan
2	TC	Task Clarification	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. Output: TC study, *Design brief (including design specification) project plan with time-line; Materials and technology study, Human factors study*, *Project time plan (revised).*	Objectives tree method Cost visibility Pareto Analysis Function analysis Cost-function analysis Performance Specification
3	CG	Concept Generation	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. Output: *A folio of concept sketches, supported by simple models (mock-ups) providing a visual classification of design ideas; the client may be consulted at this phase.*	Brainstorming Synectics Bionics Design-by-drawing Concept selection Design catalogues Patent search Morphological analysis
4	ER	Evaluation and Refinement (of design concepts)	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. Output: *A folio of refined concepts sketches, supported by a concept model (if required) and relevant technical information, illustrating a preferred concept, possibly with one or two alternatives, for client approval (usually). Project time plan (revised).*	Interaction matrix House of quality (QFD) Design-by-drawing Computer Aided Design Design Review
5	DD	Detailed Design (of preferred concept)	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. Output: *A folio of layout and detailed component drawings and technical report (preliminary manufacturing information).*	Computer Aided Design Value engineering Taguchi/robust design Cost determination Failure mode and effects analysis Component design specifications Life-cycle analysis
6	CR	Communication of Results (of the design concept)	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. Output: *A folio of presentation drawings (including technical drawings etc., from (5), supported by a refined three-dimensional model or, if required, a first-attempt prototype (additional communication and manufacturing information).*	Design drawings Renderings Prototypes
7	PP	Preparation for Production	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. Output: *product system and documentation that includes a folio of engineering drawings that define specifications that clarify manufacturing details; a bill of materials; estimation of tooling and manufacturing equipment; and the financial return on investment.*	Revised cost visibility Change proposal Statistical process control Fault tree analysis CAD

Table 3-11 Author's proposed MPD Model to support final-year industrial design project.

3.6.4 Tasks associated with the MPD Model

In Table 3-12, a suite of tasks associated with the MPD Model is 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.

Phase	*Output*	*Task #*	*Typical Macrostructure Tasks*	*Available method*
PP	▪ Strategic market review, ▪ Identify project/product opportunity ▪ Competitor analysis ▪ Project time plan (initial)	1 2 3 4 5	Strategic review of the market Competitor analysis Patent searching Identify opportunities for a project Planning and scheduling project	Literature Search Features Analysis Benchmarking Patent Search SWOT Analysis Project checklist Peeves Analysis Project time plan
TC	▪ Task clarification study ▪ Materials and technology study ▪ Human factors study ▪ Design brief ▪ Project time plan (revised)	1 2 3 4 5	Setting design objectives Materials research Technology research Human factors research Development of a brief	Objectives tree method Cost visibility Pareto Analysis Function analysis Cost-function analysis Performance Specification
CG	▪ Folio of concept sketches ▪ Simple models ▪ Visual classification of design ideas	1 2 3 4	Solution conjecture Generation of ideas Folio of concept sketches Simple models (mock ups)	Brainstorming Synectics Bionics Design-by-drawing Concept selection Design catalogues Patent search Morphological analysis
ER	▪ Folio of refined concept sketches ▪ Relevant technical information study ▪ Preferred concept ▪ Concept model ▪ Project time plan (revised)	1 2 3 4	Evaluation of concepts Refinement of candidate solutions Relevant technical information Determination of preferred concept	Interaction matrix House of quality (QFD) Design-by-drawing Computer Aided Design Design Review
DD	▪ Folio of layout and detailed component drawings ▪ Technical report (preliminary manufacturing information)	1 2 3 4	Development of preferred concept Specification of materials Layout drawings Dimensional specifications	Computer Aided Design Value engineering Taguchi/robust design Cost determination FMEA analysis Component design specs Life-cycle analysis
CR	▪ A folio of presentation drawings and renderings ▪ Refined model ▪ Additional communication and manufacturing infor'n	1 2 3 4 5	Folio of presentation drawings Technical drawings Refined three-dimensional model Manufacturing information Financial information (ROI)	Design drawings Renderings Prototypes
PP	▪ Folio of engineering dr'gs ▪ Spec'ns re manufacturing details, inc. bill of materials ▪ Product cost, investment & Return on investment (ROI)	1 2 3 4	Analysis of costs Consideration of tooling Estimate production investment Consider DFA	Revised cost visibility Change proposal Statistical process control Fault tree analysis CAD

Table 3-12 Author's proposed MPD Model including associated tasks and available methods

Table 3-12 lists the phases of the MPD Model, namely PP, TC, CG, ER, DD,CR, and PP, in column 1, aligned with the particular phase, are anticipated outputs. Then the typical macrostructure tasks are listed in column 4 and the most appropriate method is shown in column 5.

This model has provided an aligned pedagogical methodology (phases → tasks → methods) for teaching and learning associated with major projects. It represents a very 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. 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 Table 3-13. 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 application of this table is described in Part 3, Chapter 4, the Research Methodology and Experimental Programme.

Student... Student number..

Project...

Major Project Development Process Worksheet

Student name:
Project:

Phase	#	Tasks	Weighting factor	Score											Total score	Total possible
				0	1	2	3	4	5	6	7	8	9	10		
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 |

Table 3-13 Tasks associated with stages of the MPD Model

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.

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. 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 is part of the assessment process. Therefore the score of a particular, task multiplied by its weighting produces a definitive score.

3.7 PROPOSED "MPD SYSTEM" (a suite of computer-based design methods)

The design-teaching/learning instrument developed in this thesis 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 (discussed in Chapter 5.1). In addition, the MPD System has been based on teachings associated with the design and product-development processes discussed in Chapters 3.2 and 3.3 and the development of a range of design methods described in Chapters 3.4 and 3.5.

The MPD System is explained in this section and also contained on a CD located in Appendix 47. It consists of a suite of computer files, arranged around phases of the MPD Model, namely: Product Planning; Task Clarification; Concept Generation; Evaluation; Detailed Design; Communication of Results; and Preparation for Production. It is based upon the proposed macrostructure and methods in Table 3-11 which identifies the phases of the design process, describes each phase and lists design methods appropriate to each phase. 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.

3.7.1 The MPD System: computer-integrated software

Figures 3.8 to 3.14 represent a number of screens from the MPD System of software developed by the author. Forty-three (43) design methods are assigned to the various phases of the system. Figure 3.8 shows the front page of the system, which displays the title "Studio Design Methods" and in the lower section of the page the phases of the MPD Model are listed on the left-side of the screen and on the right an introduction to the system is shown. Left clicking on "System Introduction" takes the user into a second page, shown in Figure 3.9 which explains and defines each phase. For example, *Product Planning* is defined as "*the stage that precedes the design process wherein the circumstances of the market and the consumer is considered along with competitors and strategic objectives* ".

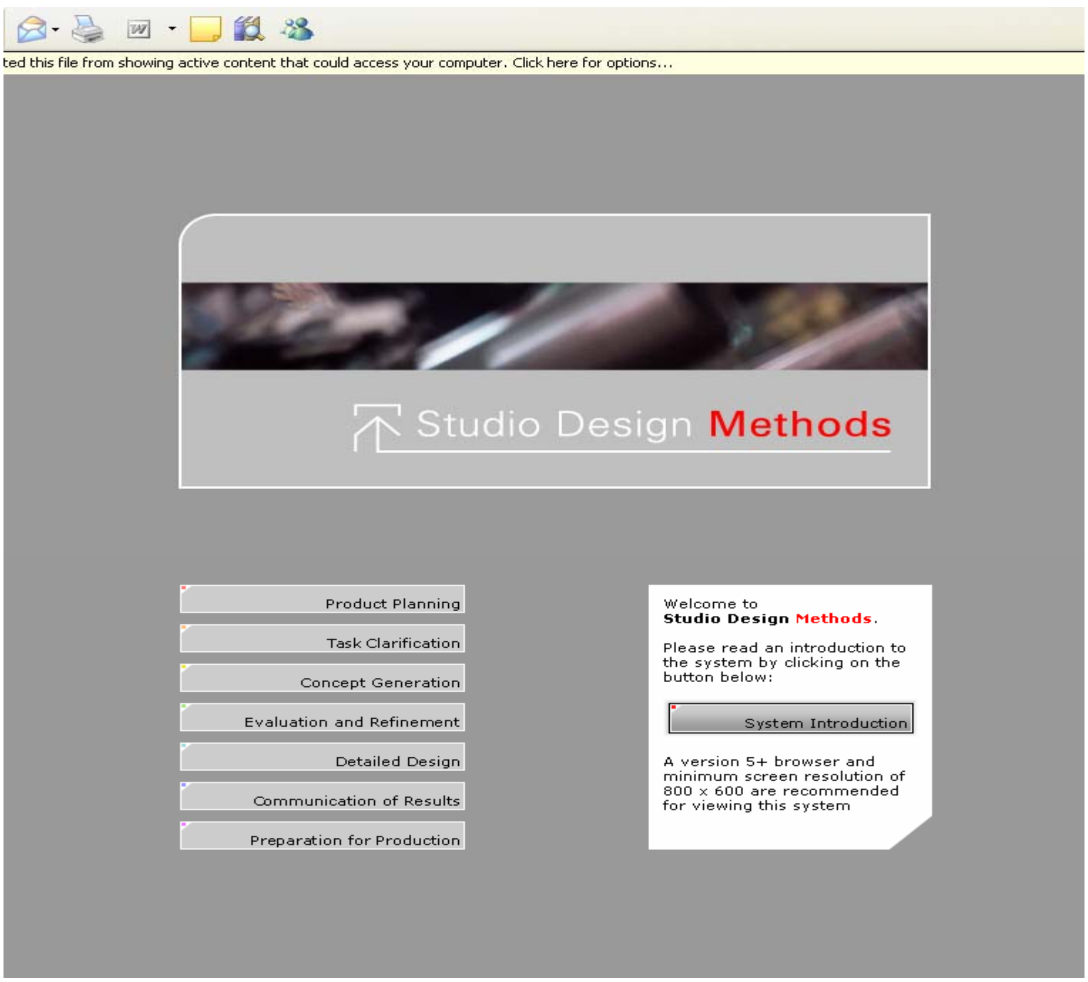


Figure 3.8 The menu page which lists the sections of the MPD System

The phases shown in Figure 3.8, namely Product Planning, Task Clarification, Concept Generation, Evaluation and Refinement, Detailed Design, Communication of Results and Preparation for Production are accessed by left clicking with the computer mouse on any particular phase. This will take the user into a further page, for example, which shows the phase "Product Planning" (refer Figure 3.10).

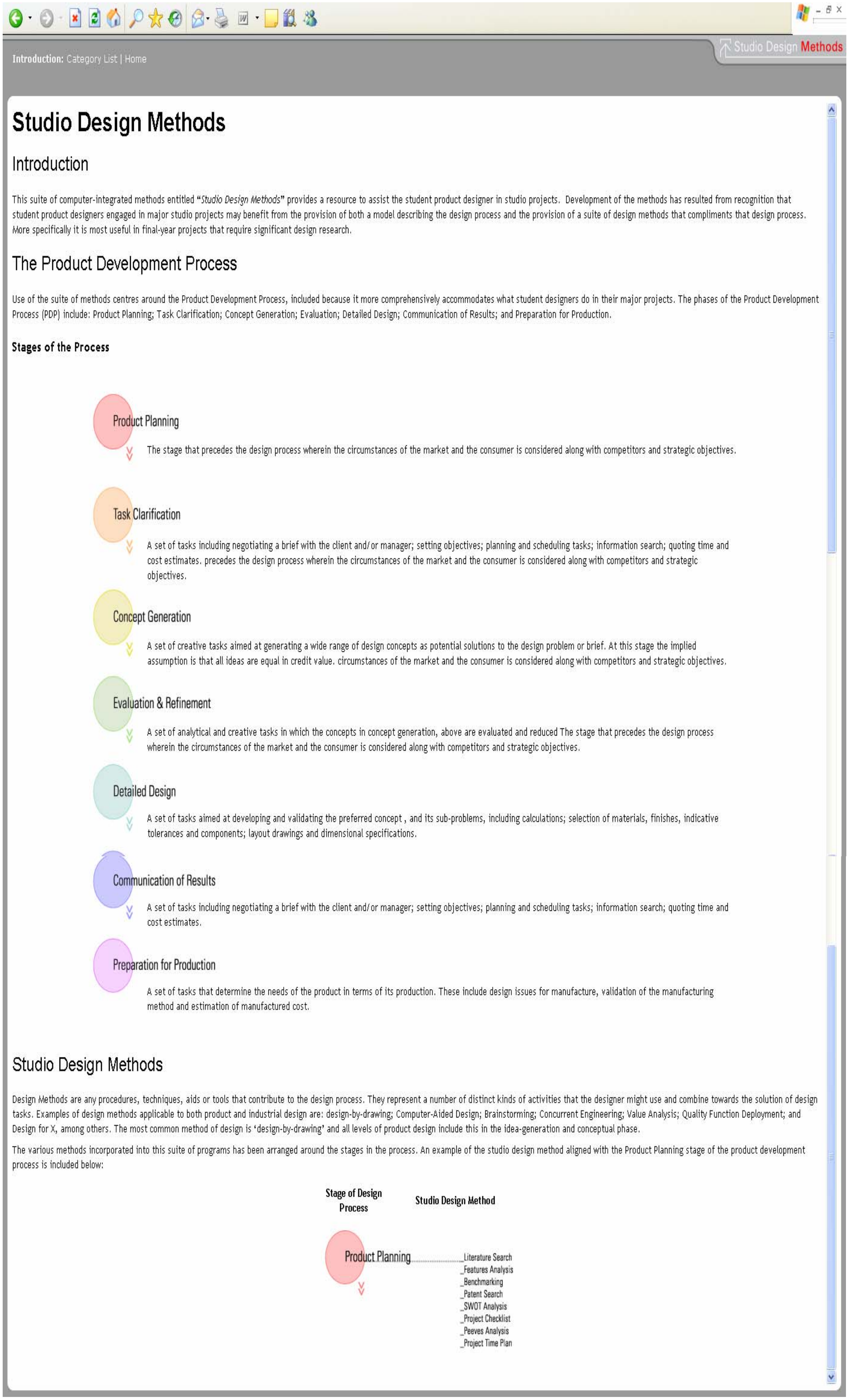


Figure 3.9 The "introduction page" presents a general introduction to the MPD System.

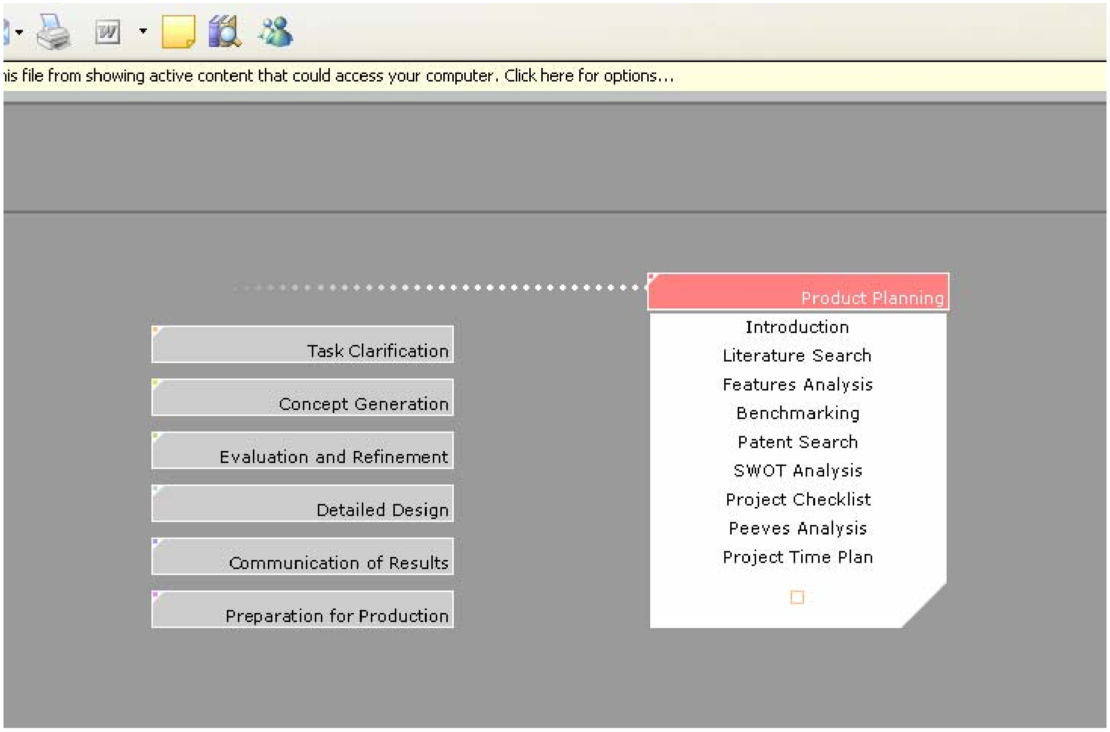
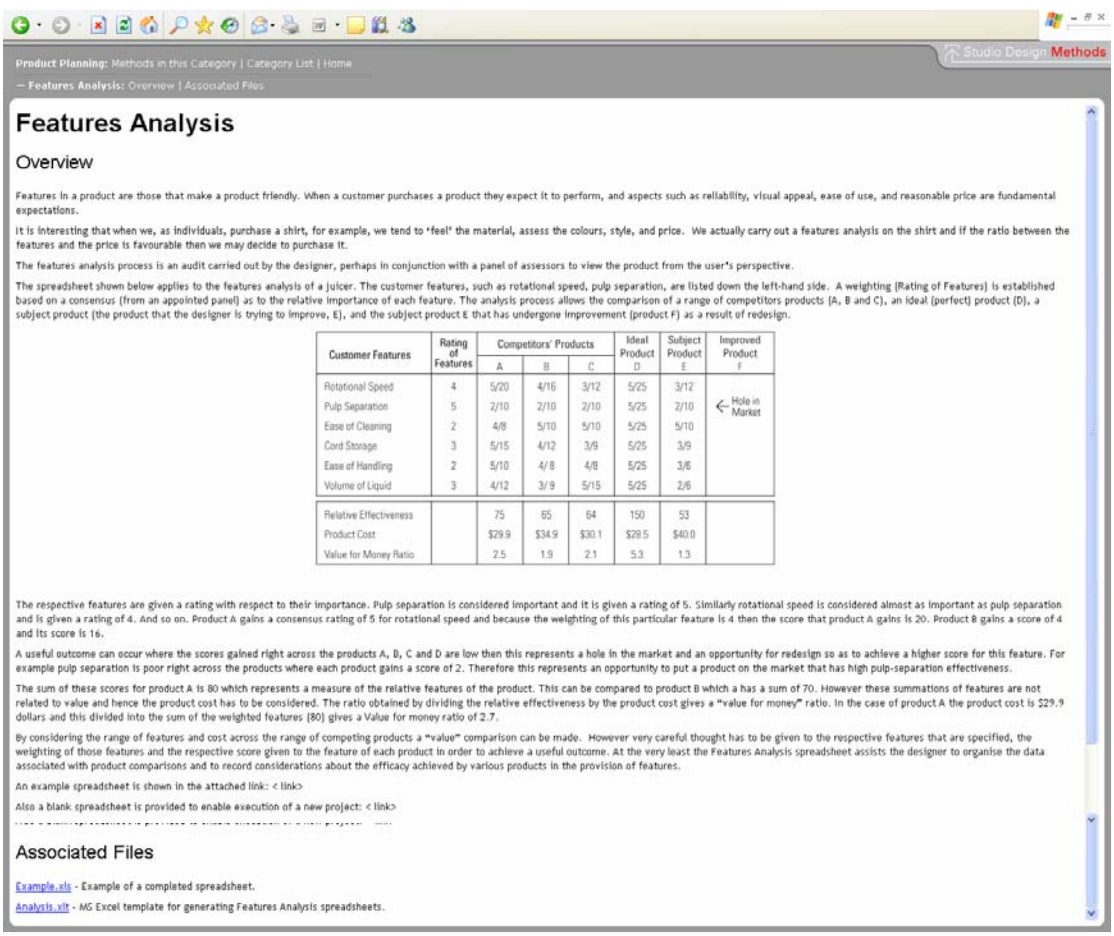


Figure 3.10 A selected page showing the phases of the system and design methods in the Product Planning phase.



Product Planning: Methods in this Category | Category List | Home

— Features Analysis: Overview | Associated Files

Studio Design Methods

Features Analysis

Overview

Features in a product are those that make a product friendly. When a customer purchases a product they expect it to perform, and aspects such as reliability, visual appeal, ease of use, and reasonable price are fundamental expectations.

It is interesting that when we, as individuals, purchase a shirt, for example, we tend to 'feel' the material, assess the colours, style, and price. We actually carry out a features analysis on the shirt and if the ratio between the features and the price is favourable then we may decide to purchase it.

The features analysis process is an audit carried out by the designer, perhaps in conjunction with a panel of assessors to view the product from the user's perspective.

The spreadsheet shown below applies to the features analysis of a juicer. The customer features, such as rotational speed, pulp separation, are listed down the left-hand side. A weighting (Rating of Features) is established based on a consensus (from an appointed panel) as to the relative importance of each feature. The analysis process allows the comparison of a range of competitors products (A, B and C), an ideal (perfect) product (D), a subject product (the product that the designer is trying to improve, E), and the subject product E that has undergone improvement (product F) as a result of redesign.

Customer Features	Rating of Features	Competitors' Products			Ideal Product	Subject Product	Improved Product
		A	B	C	D	E	F
Rotational Speed	4	5/20	4/16	3/12	5/25	3/12	
Pulp Separation	5	2/10	2/10	2/10	5/25	2/10	← Hole in Market
Ease of Cleaning	2	4/8	5/10	5/10	5/25	5/10	
Cord Storage	3	5/15	4/12	3/9	5/25	3/9	
Ease of Handling	2	5/10	4/8	4/8	5/25	3/6	
Volume of Liquid	3	4/12	3/9	5/15	5/25	2/6	
Relative Effectiveness		75	65	64	150	53	
Product Cost		$29.9	$34.9	$30.1	$28.5	$40.0	
Value for Money Ratio		2.5	1.9	2.1	5.3	1.3	

The respective features are given a rating with respect to their importance. Pulp separation is considered important and it is given a rating of 5. Similarly rotational speed is considered almost as important as pulp separation and is given a rating of 4. And so on. Product A gains a consensus rating of 5 for rotational speed and because the weighting of this particular feature is 4 then the score that product A gains is 20. Product B gains a score of 4 and its score is 16.

A useful outcome can occur where the scores gained right across the products A, B, C and D are low then this represents a hole in the market and an opportunity for redesign so as to achieve a higher score for this feature. For example pulp separation is poor right across the products where each product gains a score of 2. Therefore this represents an opportunity to put a product on the market that has high pulp-separation effectiveness.

The sum of these scores for product A is 80 which represents a measure of the relative features of the product. This can be compared to product B which a has a sum of 70. However these summations of features are not related to value and hence the product cost has to be considered. The ratio obtained by dividing the relative effectiveness by the product cost gives a "value for money" ratio. In the case of product A the product cost is $29.9 dollars and this divided into the sum of the weighted features (80) gives a Value for money ratio of 2.7.

By considering the range of features and cost across the range of competing products a "value" comparison can be made. However very careful thought has to be given to the respective features that are specified, the weighting of those features and the respective score given to the feature of each product in order to achieve a useful outcome. At the very least the Features Analysis spreadsheet assists the designer to organise the data associated with product comparisons and to record considerations about the efficacy achieved by various products in the provision of features.

An example spreadsheet is shown in the attached link: < link>

Also a blank spreadsheet is provided to enable execution of a new project: < link>

Associated Files

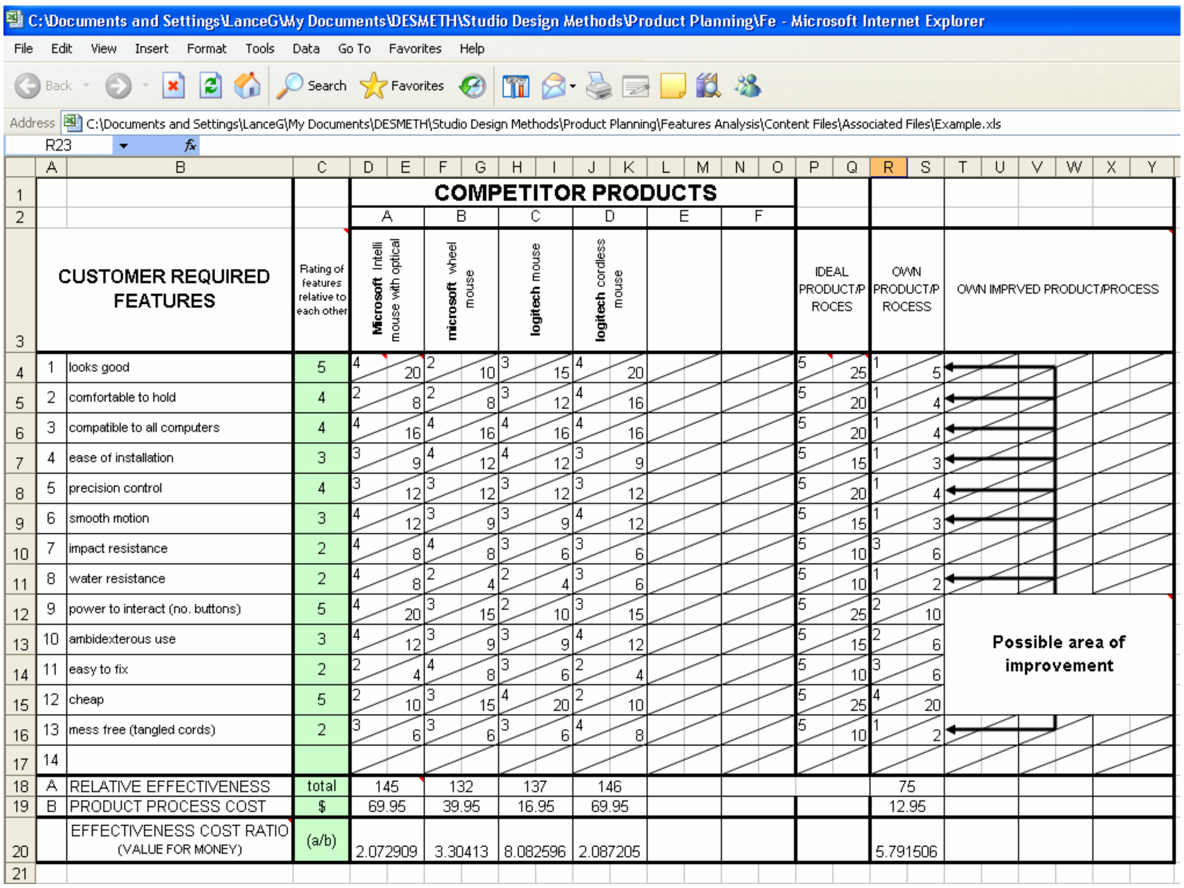
Example.xls - Example of a completed spreadsheet.

Analysis.xlt - MS Excel template for generating Features Analysis spreadsheets.

Figure 3.11 The "Feature Analysis" section of the MPD System

Figure 3.10 shows the seven phases and highlights the Product Planning phase together with the eight design methods contained in that phase, 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 determines the features of a product, the weighting of those features and a comparison of features across a number of products. The *Features Analysis* page shown in Figure 3.11 includes a link to an example on an Excel spreadsheet. This is shown in Figure 3.12 which presents an example of application to *features analysis* to guide the student when they select a blank worksheet.



	CUSTOMER REQUIRED FEATURES	Rating of features relative to each other	COMPETITOR PRODUCTS A: Microsoft Intelli mouse with optical	B: microsoft wheel mouse	C: logitech mouse	D: logitech cordless mouse	E	F	IDEAL PRODUCT/PROCES	OWN PRODUCT/PROCESS	OWN IMPRVED PRODUCT/PROCESS
1	looks good	5	4 / 20	2 / 10	3 / 15	4 / 20			5 / 25	1 / 5	
2	comfortable to hold	4	2 / 8	2 / 8	3 / 12	4 / 16			5 / 20	1 / 4	
3	compatible to all computers	4	4 / 16	4 / 16	4 / 16	4 / 16			5 / 20	1 / 4	
4	ease of installation	3	3 / 9	4 / 12	4 / 12	3 / 9			5 / 15	1 / 3	
5	precision control	4	3 / 12	3 / 12	3 / 12	3 / 12			5 / 20	1 / 4	
6	smooth motion	3	4 / 12	3 / 9	3 / 9	4 / 12			5 / 15	1 / 3	
7	impact resistance	2	4 / 8	4 / 8	3 / 6	3 / 6			5 / 10	3 / 6	
8	water resistance	2	4 / 8	2 / 4	2 / 4	3 / 6			5 / 10	1 / 2	
9	power to interact (no. buttons)	5	4 / 20	3 / 15	2 / 10	3 / 15			5 / 25	2 / 10	Possible area of improvement
10	ambidexterous use	3	4 / 12	3 / 9	3 / 9	4 / 12			5 / 15	2 / 6	
11	easy to fix	2	2 / 4	4 / 8	3 / 6	2 / 4			5 / 10	3 / 6	
12	cheap	5	2 / 10	3 / 15	4 / 20	2 / 10			5 / 25	4 / 20	
13	mess free (tangled cords)	2	3 / 6	3 / 6	3 / 6	4 / 8			5 / 10	1 / 2	
14											
A	RELATIVE EFFECTIVENESS	total	145	132	137	146				75	
B	PRODUCT PROCESS COST	$	69.95	39.95	16.95	69.95				12.95	
	EFFECTIVENESS COST RATIO (VALUE FOR MONEY)	(a/b)	2.072909	3.30413	8.082596	2.087205				5.791506	

Figure 3.12 A spreadsheet example of the features analysis of a group of products.

An alternative design method in the Product Planning phase is *Benchmarking* (shown in Figure 3.13) 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 (refer Figure 3.14).

Product Planning: Methods in this Category | Category List | Home

— Benchmarking: Overview | 1 | 2 | 3 | 4 | 5 | 6 | 7

Studio Design Methods

Benchmarking

Overview

A benchmark is a point of reference against which other items are measured. Benchmarking enables a company or designer to establish the best practice that will enable it to become the best by finding the gap and then filling in the company. Benchmarking, while it can be applied selectively, is most effective when applied to all aspects of a company or product to give total quality and best practice across the board. Despite other methods of Quality Management constantly being developed, benchmarking is one of the most powerful as it allow comparison with best practices in the world and therefore allows for constant improvement on all levels. By comparison a company can find its weakness and strengths and improve on both.

When benchmarking it is important to look beyond one's competitors, otherwise all that will be achieved is parity. While parity would make a company equal, to be truly competitive and to gain greater market share, a company should be looking beyond parity. To do this the best practices should be based on the best practices in the world not just those of a competitor. For example, A mobile phone company such as Nokia may be trying to improve its billing processes. Rather than just looking at it's competitors, other manufacturers, it could benchmark against specialists in the financial sector such as American Express or Master card and observe their processes in billing.

There are seven phases in a benchmarking process. Use the flowchart diagram on the right to work through the benchmarking process, or click the links below to see each phase in detail.

1. Select Products & Processes
2. Develop Process Measurement
3. Identify Benchmark Partners
4. Identify Practices & Measure Performance
5. Programs & Actions To Close The Gap
6. Implement Changes
7. Measure Results

1. Select Products & Processes

The first part of the benchmarking process is to select the products and processes that are to be benchmarked. It is important that at this point the chosen product is broken down into appropriate subsections to gain a better understanding of what needs to be changed to become a competitive force. For example, if benchmarking a mobile phone it could be broken down into its parts and process such as case, keypad, display unit, transmitter/receiver, processor, usability and aesthetics. Then the individual processes and materials used to manufacture those parts could be benchmarked, as well as the materials and parts handling in the manufacturing process. Following the previous example the case could be benchmark on the basis of the material used, injection moulding and storage and transport of the case parts, and finally assembly of the case.

2. Develop Process Measurement

The next part is to decide how you are going to measure the products and processes selected in the first part. These measurements have to be made in such a way, which is controllable and countable, so that proper comparison can be made to benchmarks. In doing so you must consider driving factors in the marketplace and consumer desires as these will help to determine what is to be measured. There is no point measuring something, if changing it is not going to give you an edge in the marketplace. Continuing with the mobile phone items to measure could be processor speed in number of bytes or transmitting range in metres. However, there is probably no need to measure satellite capability for a standard mobile phone, as consumers who need this feature will buy a purpose built satellite phone.

3. Identify Benchmark Partners

Next you should identify businesses that be prepared to share information with you about their processes, usually for mutual benefit. The advantage for your partners is that the benchmarking will show up any gaps in their processes. For you it gives accurate information. Direct competitors should also be benchmarked, however, information on direct competitors may not be entirely accurate or easily available. As mentioned before benchmarking against direct competitors will probably result in only in parity. Benchmarking against similar processes in specialist organisations in other industries will result in a competitive edge. Sony, Ericsson and Philips all share information about communication equipment so they are partners. They might compare their product with a competitor such as Nokia. However, to find the best practise for the feature menu on the phone they might also partner with a leading software company such as Microsoft where feature menus are an vital part of their product.

4. Identify Practices & Measure Performance

At this stage, a data collection method should be designed for benchmarking. Data must be collected in such a way that the measurements provide a meaningful comparison. This includes product dissection of own product and competing products. Some useful tools such as peeves analysis, feature analysis, and SWOT analysis could also be implemented alongside with competition benchmarking. Data collection should be carried out your company or a trusted partner, a competitor could be feeding you false information. In addition by doing this you ensure that the collection is consistant.

Click here to access an Excel spreadsheet detailing the benchmarking process of the mobile phones shown below.

Click here to access a blank spreadsheet.

5. Programs & Actions To Close The Gap

Results which carried out from product benchmarking should be then examined closely to make recommendations. This includes identifying gaps between your product and the products you have chosen to benchmark against. Determining current performance levels is very important. If current levels are not known then it will not be known which areas to change. Changes and improvements or redesign for company's own product are outlined for developing action plans to "close the gap" and improve in areas related to the company's critical success factors. These action plans should be designed to gain the required support within the product team and senior management. The attitude that current levels are satisfactory should not be allowed to stand. The level that is being attempt is that of the best in the world. No plan should be initially considered too drastic, spending $100,000,000 to save $600,000,000 is well worth it. An example of a change in product was when Nokia first brought out interchangeable covers. This allowed customers to personalize the phone and dramatically affected the market place. Now many companies have a similar feature. Using the example sheet we can see that Siemens, Ericsson and Samsung has a gap with this feature and could use this to improve their phones to compete with Nokia.

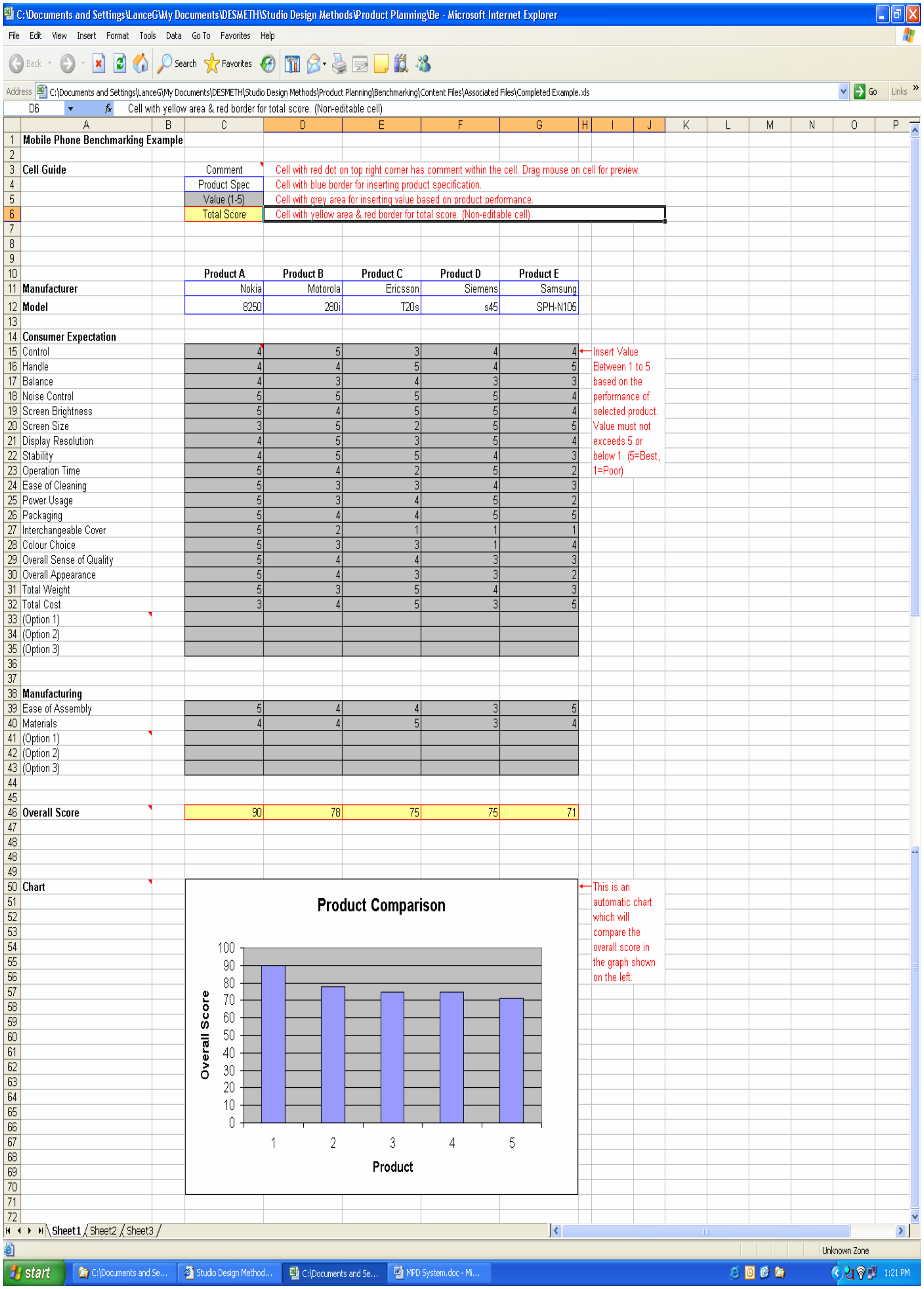
6. Implement Changes

This is the part when theory becomes action. Implement each action plan according to the recommendation to "close the gap". The implementation could be as small as spraying an antistatic aerosol on components to the drastic change of refiting an entire factory. It is important that the plans are adhered to, otherwise the potential effectiveness will be greatly reduced.

7. Measure Results

Finally, monitor the new improvement process. This includes collecting data on new levels of performance as improvements are implemented. Using problem-solving teams to investigate problems, and adjusting the improvement process if goals are not being met. Not only does this ensure that the improvements achieve the goal of a better product, it also reviews the benchmarking procedure so that next time the benchmarking procedures will be better.

Figure 3.13 The "Benchmarking" section of the Product Planning phase.



	Product A	Product B	Product C	Product D	Product E
Manufacturer	Nokia	Motorola	Ericsson	Siemens	Samsung
Model	8250	280i	T20s	s45	SPH-N105
Consumer Expectation					
Control	4	5	3	4	4
Handle	4	4	5	4	5
Balance	4	3	4	3	3
Noise Control	5	5	5	5	4
Screen Brightness	5	4	5	5	4
Screen Size	3	5	2	5	5
Display Resolution	4	5	3	5	4
Stability	4	5	5	4	3
Operation Time	5	4	2	5	2
Ease of Cleaning	5	3	3	4	3
Power Usage	5	3	4	5	2
Packaging	5	4	4	5	5
Interchangeable Cover	5	2	1	1	1
Colour Choice	5	3	3	1	4
Overall Sense of Quality	5	4	4	3	3
Overall Appearance	5	4	3	3	2
Total Weight	5	3	5	4	3
Total Cost	3	4	5	3	5
(Option 1)					
(Option 2)					
(Option 3)					
Manufacturing					
Ease of Assembly	5	4	4	3	5
Materials	4	4	5	3	4
(Option 1)					
(Option 2)					
(Option 3)					
Overall Score	90	78	75	75	71

Figure 3.14 A spreadsheet-based example of Benchmarking

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

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

The author explained the relevance of Kolb's model to the studio and classroom teaching and learning process in Chapters 2.2.4 and in Figure 2.15. Chapter 2.8 describes the difficulty of introducing a higher level of systematic thinking and procedures in the design studio without compromising the creative, solution-focused approach and more effectively

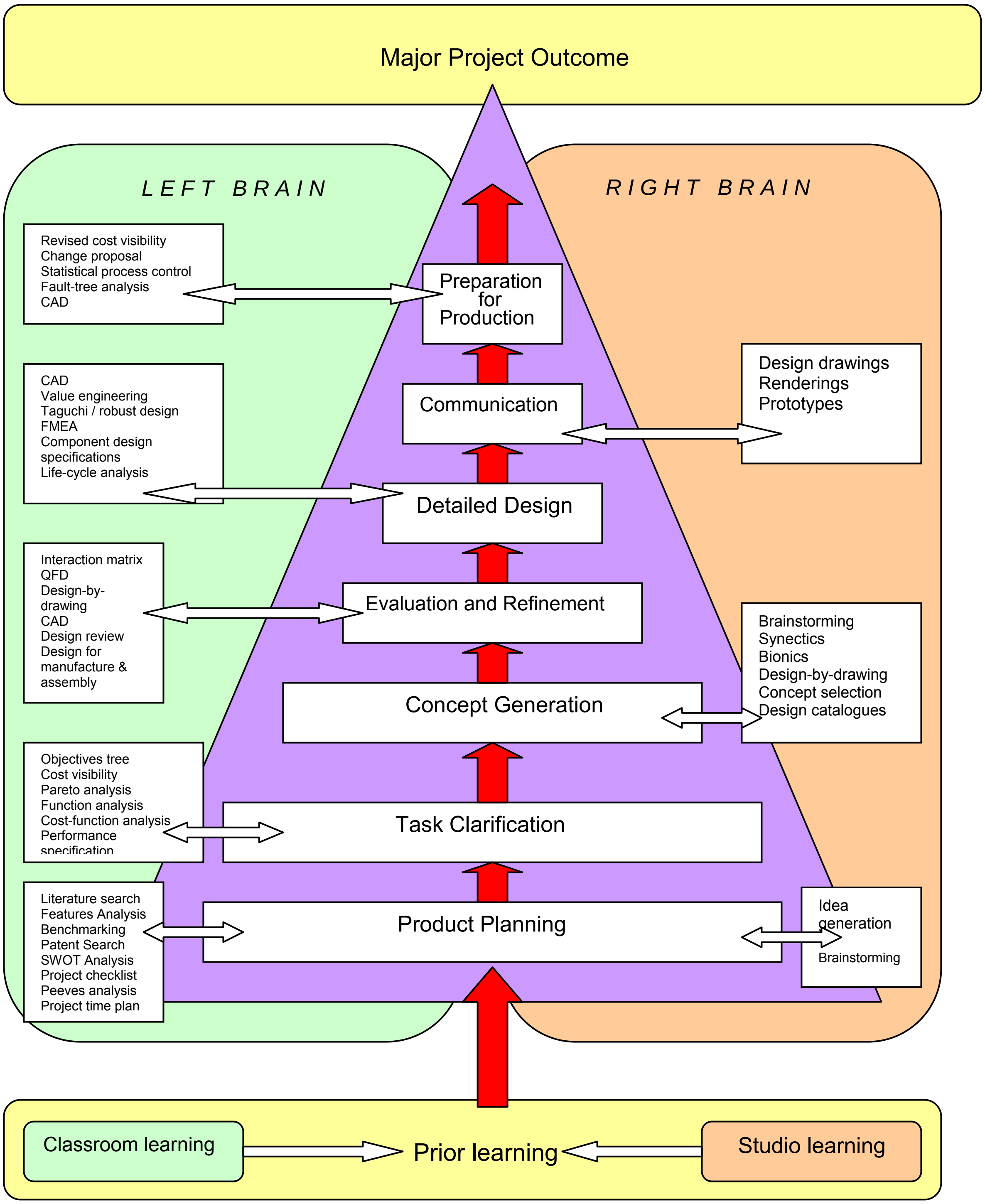


Figure 3.15 Author's application of the MPD Model superimposed over left and right brain activities within the context of a major project

integrating teachings from associated disciplines. In Chapter 3.1.1, Tovey's dual-processing model was discussed and a constraint was identified where the incorporation of left-brain thinking needed some foundation to facilitate its relevance in the studio environment.

The MPD Model proposed above in Chapter 3.6.3 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 theoretical tasks of how the MPD Model is applied to project-based and studio learning is depicted in Figure 3.15.

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 3.15. 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 3.15 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. The next section investigates the *Complexity* of projects, another critically important issue that has received scant attention from researchers.

3.9 A MODEL FOR MEASURING COMPLEXITY OF PROJECTS

Final-year projects exhibited by students at the UNSW in 2004 revealed a wide cross section of design difficulty or complexity. Examples included: *Baystrider*, a collapsible powered watercraft; *Ruler*, a downhill mountain-bike frame with internal gearbox; *R-Jet*, a surf-rescue craft; and *Huggy*, children's furniture. The *Baystrider* demonstrated a product that included extensive functions and its project management involved considerable research of associated technologies. In contrast, the *Huggy* product has few functions and minimal technologies associated with its development. As a result of the contrasting nature of the projects, product complexity was seen as an important factor in assessing the difficulty associated with projects and the extent to which varying levels of complexity affect the need for the use of design methods.

The notion of *complexity* is difficult to measure and define with precision. Moody *et al* (1997) define a system that considers 'design difficulty' and the resources required to execute the project. Figure 3.16 provides examples of projects and presents their

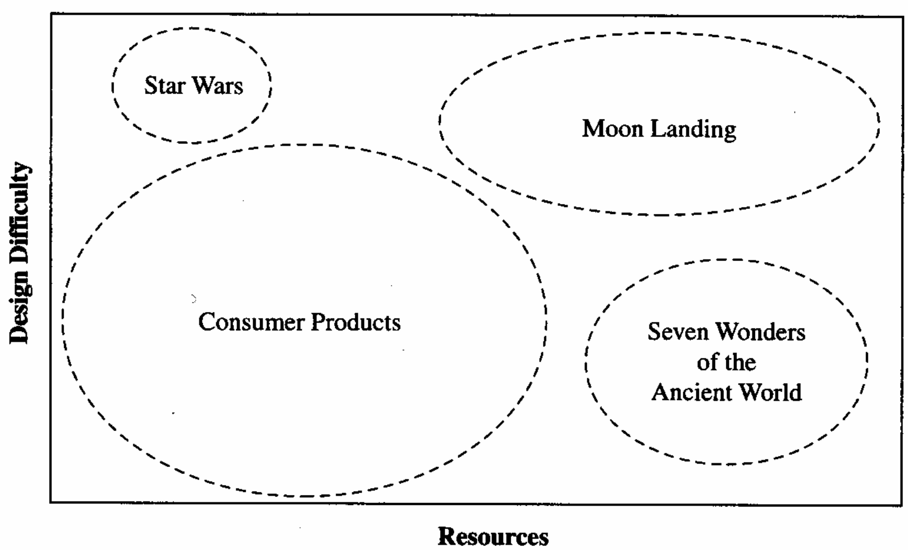


Figure 3.16 The four regions of the Design Difficulty versus Resources plane[21]

respective difficulty and resources required, in matrix form. Moody *et al* (p.1-7) define Design Difficulty by allocating categories, namely: design type; complexity of knowledge needed to create the design; number of steps needed to complete the design; quality implementation effort; process design; and aggressive goals for selling price. Project complexity differs from design difficulty. *Design difficulty* captures the extent of difficulty in

[21] Moody, J., Chapman, W., Van Voorhees, F., and Bahill, A. (1997) Metrics and Case Studies for Evaluating Engineering Designs. Prentice Hall, New Jersey.

providing a solution to the problem. The scores for *Design Difficulty* on the vertical axis of the graph, represent a combination of the following categories:

1. design type, reflects whether feasible solutions exist and how much original thought goes into the project;
2. complexity of the knowledge required to complete the design;
3. number of steps needed to complete the design;
4. quality implementation effort;
5. process design; and
6. aggressive goals for selling price.

The scores for *Resources* on the horizontal axis, represent a composite score of the following categories:

1. costs to develop the product through to the first production unit;
2. time score is for time spent from the beginning to the first production unit;
3. infrastructure required to achieve the design.

The above system of quantifying design difficulty is more appropriate to case studies within particular industry groups, for example, the automobile or aircraft industry. Their system presented metrics designed to assess design difficulty as one aspect of system design. It is not considered appropriate for application to the determination of the complexity of student projects because of its emphasis on resources and key learning objectives associated with final-year major project, such as, design research, patent searching, consumer research are not easily accommodated.

Burns *et al* (1996, p. 166-169) define complexity in terms of the *internal product structure* and the *user interface* shown in Figure 3.17. The model considers two dimensions applied to the product, that is, “complexity of the product user interface” (CPUI) and “complexity of internal product structure” (CIPS). The CIPS scale represents the complexity of a manufacturing point of view.

This may include the:

- number of components that make up the product;
- number and complexity of production steps;
- interfaces involved in the development effort;
- level of technological difficulty;
- severity of trade-offs among different components.

The CPUI represents the complexity of the new product from the point of view of the end-user. This may include the:

- number and specificity of the performance criteria the product must meet;
- subtle verses the overt and well specified characteristics of new products;

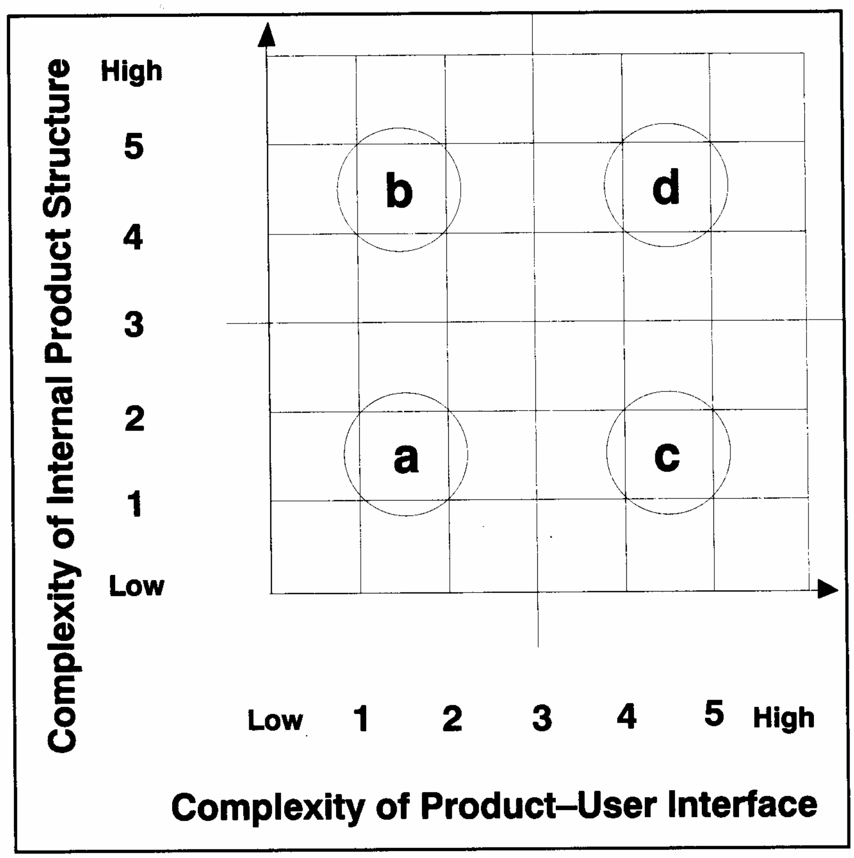


Figure 3.17 Concurrent engineering complexity assessment and evaluation matrix[22]

The model described by Burns *et al* was based on original work by Clark and Fujimoto (1991), and their study of the automobile industry. The main premise associated with their study is that different combinations of internal and external complexity of new products gives rise to different issues in managing the product development process. The work of Burns *et al* resulted from collaboration between Temco Ltd. of the UK and Liverpool University and was focused towards the development of a model that facilitated 'tailoring' the concurrent engineering management of a particular product development where complexity was a major consideration in the model.

Bonollo and Lewis (2002, p.389-390) describe the difficulty of measuring complexity and refer to studies by Samuel and Weir (1997, p.390) and describe Bonollo's experience and

[22] Burns, J., Barclay, I., and Poolton, J. A Structured methodology for implementing concurrent engineering in C J Backhouse and N J Brooks Concurrent Engineering Gower Publishing (1996)

judgement in accordance with the criteria enunciated by the Burns *et al* model to student projects. A finding was that the students scored very low on the criteria suggesting non complex projects however the criteria of assessment weighted towards industrial projects may not have adequately covered aspects relating to student's work and learning objectives.

Samuel and Weir describe a process of problem enformulation which is based upon what they refer to as *problem intensity*. Five dimensions of problem intensity are cited, namely: complexity, seriousness, discordance, novelty and modelability. A generic approach to problem intensity is to identify the key measures of a problem and use these in forming a scale of problem intensity. These problem components are:

- Complexity – measure the cognitive load on the designer;
- Seriousness - identifies the social, economic and environmental impact of the problem;
- Discordance – measures the conflict between constraints, values and physical reality in a problem;
- Novelty – measure of the technical novelty of the problem;
- Modelability – a measure of the scale of resources needed to generate an acceptable model.

These metrics produce a means by which problem intensity can be compared among a number of projects.

The Burns *et al* model is similar to that described by Griffin (1993, p.115-116) who credits Clark and Fujimoto (1991) for the model. Griffin argues that the dimensions apply to four general categories of projects and that the definitions of how to slot projects into the categories are vague. In terms of applicability to the measurement of final-year projects it is the opinion of the writer that the emphasis on manufacturing is too focused to be applicable to the broad considerations of an industrial design project.

Samuel and Weir (1997), Griffin (1993), and Bonollo and Lewis (2002) all refer to the need for metrics associated with the measurement of design difficulty, *complexity and problem intensity*. The various prior models and their strengths and weaknesses have been previously discussed. There is a need for a model that will measure the relative complexity of student projects. The model should be influenced by certain learning objectives that are essential in a final year, for example, research of constraints arising out of patents, standards and other regulatory systems and health and safety awareness. In addition, the research of scientific issues is important to develop an awareness of the technology and the role of the designer, that of, capitalising upon and packaging scientific developments.

Therefore a complexity model is needed that is more focused towards industrial design, differing from those developed and applied by other researchers, namely, Burns *et al*, Clark and Fujimoto, Samuel and Weir, Griffin, and Moody *et al*.

3.9.1 Proposed complexity model for industrial design projects

Ten categories of assessment are proposed and these are listed, 1 to 10 in table 3.14. Project category is defined as the design action carried out in the product development. For example, *design research* (DR) applies to broad considerations appropriate to the project such as complexity of the market where research may be applied to strategic product positioning, competitor analysis, consumer research among others. Similarly regulatory issues is categorised as design research (DR). Aesthetic requirements are categorised as product research (PR) and ergonomic considerations categorised as *product research* (PR) applying specifically to the product, such as, usability, prototyping, anthropometric analysis.

A weighting applies to each issue of complexity, for example, complexity of the market a weighting factor of 5 because it is considered an essential component of the major project development. Conversely engineering/production design considerations has a weighting of 3 because their inclusion in an industrial design project is important but not central. The weighting of 5 applies to those functions that are considered central to the industrial design process.

The descriptors, of the respective issue of complexity, seek to clarify the specific emphasis, for example, sustainability considerations would include life-cycle analysis (LCA), recycling and disposal as well as energy consumption, and environmental legislation. This research is applied directly to the product therefore it is categorised as product research (PR). Health and safety considerations may involve the broad research of issues of physiology, anatomy and respiratory considerations where such products associated with sports injury prevention or asthmatic products are involved. This area would be categorised as design research (DR).

A high level of aesthetic considerations may include issues of form, colour, texture and emotional response and would be categorised as product research (PR) because it is directly focused on the product. Manufacturing issues apply, in this sense, to broad aspects of manufacturing research aimed at clarifying the complexity of processes and philosophies applicable to design for assembly and disassembly. This is categorised as design research (DR). The classifications and definitions are included in Table 3-14 which represents a proposed model for the determination of project complexity.

No.	Complexity Issue	Project Category	Weighting Factor	Typical Descriptor
1	Complexity of the market	DR	5	Complexity and diversity of the market segment, strategic implications, intensity of competition, relative sophistication of consumer, patents,
2	Scientific considerations	PR	3	Noise, light, power, sound, energy, physics, chemistry, corrosion, galvanic action, solar energy, GPS navigational systems, communications technology.
3	Regulatory issues	DR	3	Australian and international standards, Code of Good Manufacturing Practices (GMP), Device regulations, Miscellaneous Codes, Transport test requirements (aircraft / train / automobile). Federal Drug Authority (FDA). OECD and European Community (EC) requirements.
4	Ergonomic considerations	PR	5	Anthropometric factors, human scale, usability issues, prototyping models, experience-based considerations, task analysis, universal design, experience-based design.
5	Health and safety considerations	DR	3	Human factors. Issues associated with the body, e.g. physiology, anatomy, circulatory, cardiac, sports injuries, sound, hearing loss.
6	High level of aesthetic requirements	PR	5	Issues associated with emotional response, relationship to art and high design, where predominant function is visual, where issues of finish (texture, colour, resolution of detail) are subtle but critical.
7	Sustainability Considerations	PR	4	Global warming, ozone effect, environmental impact, environmental legislation, energy consumption, considerations of insulation and energy loss, life-cycle analysis (LCA), disposal, recycling.
8	Manufacturing issues	DR	3	Number of manufacturing technologies involved, complexity of processes, broad consideration of design-for-assembly and disassembly, materials research.
9	Political/global/racial/ /cultural considerations	DR	2	Balance of payments, exchange rate, import replacement, tariffs, export potential, emissions, sponsorship (medicare); government contracts, overseas aid, legislation, national agendas. Cultural issues-religion, race, ethnic, global- packaging in OECD countries, trading blocs.
10	Engineering / production design considerations	PR	3	Issues associated with mechanical function, e.g. mechanisms, friction, forces involved in product use. Issues with strength, stress, impact, stiffness, materials specification, process considerations, detail design for manufacture (DFM).

Table 3-14 Proposed model of complexity assessment for final-year projects in industrial design[23] (note for product and engineering design the weighting factors would have to be modified).

[23] Author's proposed model for defining complexity *(DR = design research, PR = product research).*

3.9.2 Proposed worksheet for scoring issues of complexity

The major projects executed by the 2003 cohort include: a *face mask* that can withstand high temperatures and toxic environments to facilitate increased prospects of survival in major building fires; a *life vest* for rock fishermen; an *office workstation*; a *water filter* and *chiller* for use by cyclists; among 47 others. Some range from: an apparently simple *stackable stool;* a relatively complex *musicians seat*; a straightforward domestic *lounge; and* to a *compact child seat* for use in aircraft for children aged three to five years. These projects differ widely in complexity and current assessment of major projects does not consider, in a formal sense, the degree of complexity.

In comparing projects in the ten categories of assessment, shown in Table 3.15, the range of projects are considered and the extent to which a student, in a particular project, has executed these. For example, *Ergonomic considerations* would apply in the comparison of a *stackable stool* and a *musician's seat* in terms of relative complexity.

Student………………………………………………………… Student number……………………………………..

Project…………………………………………………………

Student name:

Project:

Complexity Worksheet

#	Tasks	Weighting Factor	Score 0	1	2	3	4	5	6	7	8	9	10	Total Score	Total Possible
1	Complexity of the market	5													50
2	Scientific considerations	3													30
3	Regulatory issues	3													30
4	Ergonomic considerations	5													50
5	Health and safety considerations	3													30
6	High level of aesthetic requirements	5													50
7	Sustainability considerations	3													30
8	Manufacturing issues	3													30
9	Political/global/cultural/racial considerations	2													20
10	Engineering design considerations	3													30
													Sum………………		350

Table 3-15 A worksheet that enables checking the issues of complexity in a project and the summation of a specific complexity score.

Table 3.15 shows a proposed scoring instrument that enables consideration of a range of projects. Application of the instrument to the final-year projects is described in Chapter 4 – Research Methodology and Experimental Programme where a total of 60 projects were measured by the application of the complexity model (refer Table 3-14) and the scoring instrument shown in Table 3-15. The instrument includes ten categories of assessment explained in column 2 of the instrument. The weighting factors are listed in column 3. The range, of possible scores, is accommodated in columns 4 to 14 and a particular score is entered in the appropriate column. The product of the score and the weighting factor is entered in column 15. The sum may be tallied and entered at the bottom of the 'total score' column.

The results of the respective assessments may be presented as shown in Figure 3.18 which displays the scores in descending order. This figure has resulted from the examination of a range of student projects and the determination of *complexity* using the instrument shown in Table 3-15. The methodology associated with this examination is explained in Chapter 4, Part 3 and the results documented in Chapter 5. The results in the form of Figure 3.18 are included to demonstrate the means of presenting the complexity findings.

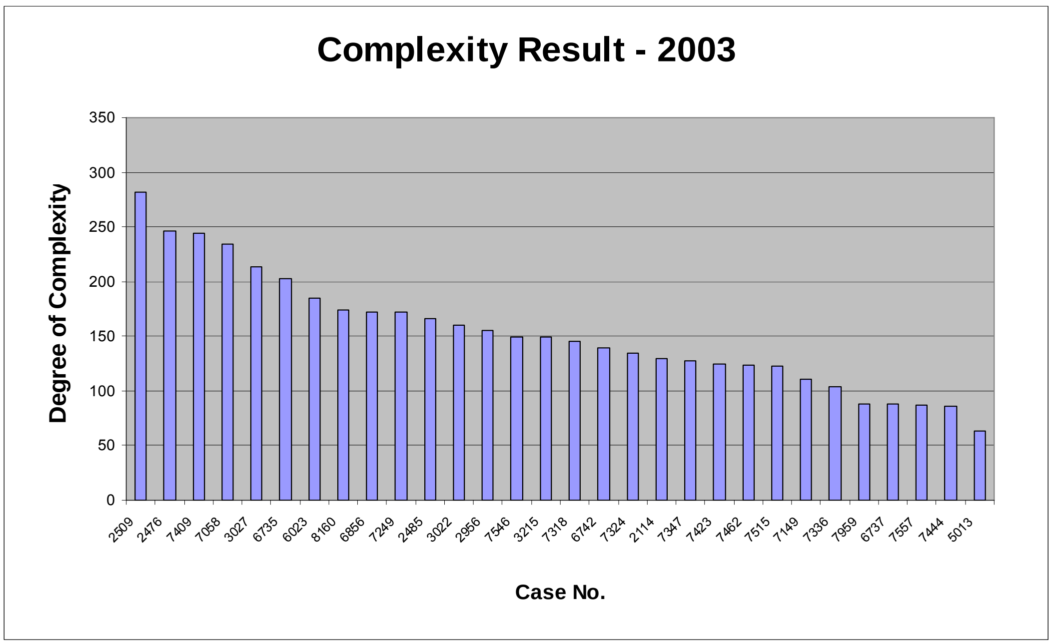


Figure 3.18 Bar chart showing the assessed scores associated with the Complexity of 30 projects.

3.9.3 Alternative Complexity assessment using an evaluation matrix

A complexity matrix is proposed based upon two dimensions. The issues of consideration that apply to design research (DR) and arranged on the X-ordinate and issues associated with product research (PR) arranged on the Y-ordinate. The respective lists are shown in Table 3-16 arranged in two columns, namely DR and PR. The scores assessed in the instrument shown in Table 3-15 are transferred to the appropriate column in Table 3-16.

This enables the calculation of a total score for DR and PR respectively. The respective total scores enable the determination of the X and Y coordinates for a particular project.

As far as the literature is concerned little published information has been found as applied to industrial design projects. Clearly, project complexity is an important issue which needs investigation, application and testing.

Design research (DR)					*Product research (PR)*			
Tasks	Weighting Factor	Total Score	Total Possible		Tasks	Weighting Factor	Total Score	Total Possible
Market complexity	5		50		Scientific	3		30
Regulatory issues	3		30		Ergonomic	5		50
Health and safety	3		30		Aesthetic issues	5		50
Manufacturing	3		30		Sustainability	4		40
Political/global/	2		20		Engineering	3		30
			160					200

Table 3-16 Arrangement of complexity issues to facilitate construction of an evaluation matrix.

The results of the use of Table 3-16 above, to classify the findings, may be presented as shown in Figure 3.19 which displays the scores in matrix form. This figure has resulted from the examination of a range of student projects and the determination of complexity using the instrument shown in Table 3-15 and then classified using Table 3-16. The methodology associated with this examination is explained in Chapter 4, Part 3 and the results documented in Chapter 5. The results in the form of Figure 3.18 are included to demonstrate the means of presenting the complexity findings in this case in matrix form.

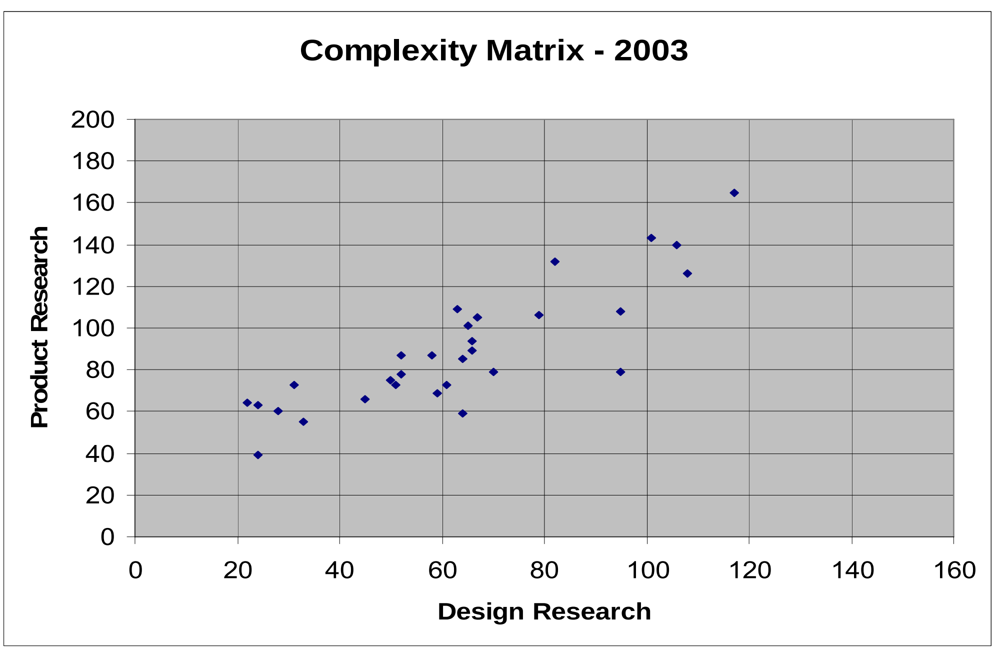


Figure 3.19 An evaluation matrix of the dimensions of Product Research and Design Research

The models and instrument previously described and shown in Tables 3-14, 3-15 and 3-16 are applied in the next section to investigate complexity issues.

This particular proposal represents an important development within the thesis. The subject of *Complexity*, particularly in the area of industrial design, is not included in the literature and the potential contribution in classifying and assessing projects is substantial.

The next chapter explains the Research Methodology and Experimental Programme associated with this research.

.

Chapter 4

Research Methodology and Experimental Programme

This Chapter will describe the research methodology that was used and how it was implemented.

4.0 RESEARCH METHODODOLOGY and EXPERIMENTAL PROGRAMME

This research was carried out in the University of New South Wales, within the Industrial Design department, where the author was a principal architect of, and senior lecturer responsible, for the industrial design degree programme. This degree, first implemented in 1990, was of four-years duration post the Higher School Certificate (Year 12) and was characterised by the final year (Honours) where students are expected to achieve professional standards in design project work in order to prepare them for employment as professional designers.

The Honours year was primarily taken up with a final-year major project designed to consolidate and showcase the professional expertise of the students that had resulted from their prior three years of instruction and education. The final-year project is described in Chapter 2.1.6, together with clarification of the associated assessment. Whilst the final-year project has been developed in conjunction with industry, practitioner representatives from professional organisations and experience gained over 14 years since the programme was established little information in the form of data bases of temporal and performance information appeared to be available to aid understanding of the final-year educational process.

This lack of ordered theoretical and empirical course design information, together with the author's experience in the supervision of final-year major projects (noted in Chapter 2.6) provided the author with the basic reasons and motivation for undertaking the research work under the supervision of the University of Canberra. These insights into the need for research were subsequently confirmed in the critical review of the literature presented in Chapter 2 and 3 as part of developing the noted theoretical framework for the development of the MPD Model that consisted of structure, tasks and design methods to guide the major project development process. The theoretical work reported in the thesis was commenced early in 2000 with the author in the position of participant observer as well as Head of the Industrial Design degree programme.

Over the duration of the degree programme, the author and other staff noted the manner in which students in their Honours year applied themselves to the final-year project. This was generally chaotic with great inefficiency in time management and unclear goals and strategies for the various phases of the project work. In particular, the management of the entire process and information analysis was very poor together with a general inability to evaluate design options and then resolve them. In addition, it was noted that the assessment process associated with the final-year projects, although based on an instrument of assessment, was arbitrary in findings and continuous assessment over the year diluted the importance of the final outcome as exemplified by models, presentations and project documentation in the form of project reports (refer Chapter 2.1.6.1). From 1996 onward the author sought to emphasise the teaching of design process and design methods and a particular course, Design Methodology (course number IDES2091), was reviewed to provide a substantial basis and framework for project execution. This course included instruction in a range of design methods, for example, features analysis, function analysis, design objectives tress, literature search, patent searching, value analysis and quality-function deployment. The outcomes associated with the emphasis on this course was indifferent; a large number of the final-year cohort were still characteristically chaotic in the manner of execution of their final-year projects.

It was concluded, by the author, that a system of software was needed to streamline the students' application of the design process and methods and from 2000 individual methods were developed. For example, for the design method, *features analysis*, a spreadsheet was developed that accommodated the information associated with product feature comparison and examples developed to provide advice to the student (refer Figures 3.11 and 3.12). Hence, the module for particular method included instruction on features analysis, examples and a blank spreadsheet. The development of further modules of the software followed and completed in 2003. This development work to produce this suite of *Studio Design Methods* involved many hundreds of hours of the author's time. The software was not used in the design methods course however various hard-copy spreadsheets were distributed to students to increase the ease of application of the various methods.

The literature research phase of this study identified the importance of design process and the history of problems associated with the application of design methods to the industrial design process. It became obvious that the situation, in other industrial design programmes, needed to be better understood and the writer made contact with programmes in Australia and overseas that included a major project similar to that conducted at UNSW. A questionnaire was designed to establish the approach of students to their major projects and this is described in more detail in Chapter 4.1, Part 1 below. The results of this survey are discussed in Chapter 5, however it was found that the experience in many other programmes was similar to UNSW and the findings confirmed the author's observations about the approach and problems associated with students' application to significant projects.

The research of the literature and the development of a theoretical framework led to the development of a major project development model which clarified the phases, tasks and methods appropriate to a major project. This model is called the MPD Model. The computer-based software, up to that time a collection of design methods, was modified to conform to the structure of the MPD Model and this produced a theoretical underpinning of the software system. The system, now a structure and a suite of methods reflecting the MPD Model is called the MPD System. Examples of pages of the MPD System are shown in Figures 3.8 to 3.14.

As part of this research study, it became necessary to evaluate the pedagogical contribution to teaching and learning in the final-year projects and a research methodology was developed to test the application. It was decided to evaluate two consecutive years of the industrial design programme, namely a cohort that executed their final-year projects in 2003 and a cohort that completed their final-year project in 2004. Both cohorts received identical prior education in design methods however only the 2004 cohort were provided with the MPD System at the commencement of their final year. A questionnaire applicable to each cohort was designed and distributed to the 2003 and 2004 cohorts in December 2004 (after the 2004 cohort had completed and were assessed in their final-year projects). This questionnaire is described in Chapter 4.2, Part 2 below. In order to understand the quality of assessment of student projects it was necessary to develop instruments (refer Chapter 3.6.4 and Tables 3.12 and 3.13) related to the MPD Model that would provide a basis for rigorous assessment of the project reports. The application of this experimental programme using an independent assessor is described in Chapter 4.3, Part 3.

The following details, within this Research Methodology and Experimental Programme chapter, explain the respective questionnaires and the experimental approach. The experimental data obtained in this thesis has been applied in three sections:

Part 1: A structured survey of academics, referred to earlier in Section 2.7 sought to gain the opinions of academics with respect to the quality of the major-project work and the extent to which design methods normally featured in student projects.

Part 2: A survey of graduates and graduands involving a questionnaire that sought their opinions with respect to their results, experience and process/methods employed in their final year major projects.

Part 3: The evaluation of student final-year project reports with respect to the project development tasks incorporated into their project work and the determination of the comparative complexity of the respective projects.

4.1 PART 1: SURVEY OF INDUSTRIAL DESIGN ACADEMICS

A questionnaire was sent to academics in industrial design programmes in Australia and overseas. The list of those programmes is shown in Table 5-1 and the demographics of the respondents discussed in Chapter 5.0.1.

The research proposition that guides the research methodology and investigation associated with Part 1 is expressed as follows:

> *1. Industrial design students engaged in final-year major projects do not include design methods and methodology to any significant extent in their project work and in their Project Research and Project reports .*

In section 2.6 the author reflected on 12 years of supervision of final-year projects. This reflection revealed certain issues in the approaches of students in their project work. It was necessary to confirm these issues and a structured survey was conducted. A key objective of the research was to determine the effectiveness of various aspects of students' approaches and the methods employed in major project work.

The questionnaire was divided into four sections and sought to determine the general approaches of students related to:

1. Aspects of management and design research;
2. Conceptualisation demonstrated;
3. Embodiment of design and resolution of detail; and
4. Design methods and tools employed.

4.1.1 Questionnaire structure

The questionnaire development and construction has followed the total design method (TDM) devised by Dillman (1978). Visual aspects of the questionnaire were closely modeled on questionnaires used in two previous studies: *Emerging Exporters* (Australian Manufacturing Council & McKinsey and Company, 1993, 73 81) and *Leading the Way* (Australian Manufacturing Council & Manufacturing Advisory Group (NZ), 1994).

Each questionnaire was accompanied by a personally addressed and signed cover letter explaining the nature of the research, advising that the results would be available on request and it has reassured the recipients of strict confidentiality. The cover letter is included in Appendix 1. Dillman (p.124) advises that similar questions should "be placed together rather than intermingled with others". Therefore the questionnaire was designed with four main sections: Management and Research; Conceptualisation; Resolution and

Presentation; and Design Methods and Process (see figure 4.1). The questionnaire was 4 pages in length including the cover letter and title page.

Figure 4.1 Four key sections of the questionnaire

The objective of the questionnaire was to understand the approaches of students to major project work with particular reference to their use of *design process* and *design methods*. The first stage sought to establish the level at which tasks associated with the major project were executed. These tasks are associated with the overall management (project coordination, time management, engagement with the project, identification and liaison with industry sponsors) and the research work (identification of a particular product opportunity, market, competitor, and user studies) associated with the project. For example, the task of time management for the project, indicated by the general efficiency demonstrated, preparation of timeline and management thereof, identification of critical tasks and the sequence associated with their execution. The survey goal was to seek an over-all impression from the experience of the lecturer. Certainly, some students are effective at time management, but many are not. The overall general impression of the lecturer may be that the bulk of the students are unsatisfactory at a score level of 2 for this item. An extract from the questionnaire relative to this category is shown in Table 4-1.

4.1.1.1 Management & Research

	unsatisfactory ← 1	2	3	4	excellent → 5	N/A
Time management…………………….…………………………	☐	☐	☐	☐	☐	☐
Generation of project ideas/create new product concept……..….	☐	☐	☐	☐	☐	☐
Screening of project ideas………………………..………………	☐	☐	☐	☐	☐	☐
Engagement with project ……………………………..………….	☐	☐	☐	☐	☐	☐
Evaluate market opportunity……………………………………..….	☐	☐	☐	☐	☐	☐
Investigate legal / trade restrictions…………………………….…...	☐	☐	☐	☐	☐	☐
Search of patents and design registrations……………………..…….	☐	☐	☐	☐	☐	☐
Materials research…………………………………………………..…….	☐	☐	☐	☐	☐	☐
Manufacturing research…………………………………..……….	☐	☐	☐	☐	☐	☐
Ergonomics research……………………………………...……...	☐	☐	☐	☐	☐	☐
Evaluation of competitive product…………………………..…….	☐	☐	☐	☐	☐	☐
Screen information and assess relevance………………………...	☐	☐	☐	☐	☐	☐
Design questionnaires…………………..………………………..	☐	☐	☐	☐	☐	☐
Conduct user surveys…………………………..…………………	☐	☐	☐	☐	☐	☐
Market research…………………………………………………..….	☐	☐	☐	☐	☐	☐
Identify and liaise with industry sponsor…………………………..….	☐	☐	☐	☐	☐	☐
Develop design brief……………………………………………….….	☐	☐	☐	☐	☐	☐
Provision of a realistic time plan…………...…………………….	☐	☐	☐	☐	☐	☐

Table 4-1 Questionnaire section that considers issues associated with Management and Research

4.1.1.2 Conceptualisation

This section includes the conceptualisation phase that follows the research and the development of a design brief. In this area of the project, students must generate ideas for a product concept, assess and screen these ideas to arrive at a final proposal. The first question asks about *creative thinking.*, Is their approach to creative thinking unsatisfactory or excellent? This block of 14 questions will enable a picture to be constructed of the approach of students in the area of conceptualisation.

	unsatisfactory ← 1 2 3 4 5 → excellent	N/A
Creative thinking…………………………………………………….	☐☐☐☐☐	☐
Conceptualisation…………………………………………………..	☐☐☐☐☐	☐
Idea generation…………………………………………………….	☐☐☐☐☐	☐
Screening of ideas………………………………………………….	☐☐☐☐☐	☐
Application of brainstorming techniques………………………….	☐☐☐☐☐	☐
Application of bionics……………………………………………….	☐☐☐☐☐	☐
Application of synectics…………………………………………….	☐☐☐☐☐	☐
Ranking of design concept…………………………………………	☐☐☐☐☐	☐
Creative materials selection………………………………………..	☐☐☐☐☐	☐
Confidence in design decision-making…………………………….	☐☐☐☐☐	☐
Flexibility in considering/rejecting idea……………………………	☐☐☐☐☐	☐
Consideration of patents and design registrations………………..	☐☐☐☐☐	☐
Search for a visual language……………………………………….	☐☐☐☐☐	☐
Use of semantic space………………………………………………	☐☐☐☐☐	☐

Table 4-2 Section from the Questionnaire allocated to considerations associated with Conceptualisation

4.1.1.3 Resolution & Presentation

This section, of the questionnaire, includes the tasks associated with evaluating and refining the design, selecting materials, developing specifications, detailed design, determination of product and component costs, investment and bill of materials. An example of a question in this area is the general capability of students in relation to their ability to *evaluate and refine* their design. Many students are capable at generating concepts but their ability to evaluate and refine their own design is generally lacking. This is simply due to a lack of experience in "designing".

	unsatisfactory ← 1	2	3	4	excellent → 5	N/A
Evaluation and refinement of the design ….……………………….						
Detailed design …………………….……………………………..						
Appreciation of link between design and manufacturing…….…...…..						
Appreciation of the link between design and market…….……......….						
Documentation (engineering drawings/specifications)…...…..….….						
Materials selection…………………………………………......….						
Prototyping and models………………………………………......….						
Resolution of ergonomic issues………………………….….....….						
Resolution of assembly issue……………………………......….						
Resolution of issues associated with finish………….………...….						
Renderings …………………………………………………...….						
Graphics……………………………………………………...….						
Development of business plan…………………………...…..….….						
Evaluate investment involved in project……………………......….						
Financial/investment analysis……………………………….....….						
Estimation/determination of manufacturing costs………….......….						
Consideration/resolution of strength and structural issues……..….						

Table 4-3 Section from the Questionnaire allocated to considerations associated with Resolution & Presentation

4.1.1.4 Design Methods & Process

What design methods and/or tools are employed by students, in their final-year, major projects? The responses may range from 1 (least utilised) to 5 (highly utilised). The experience of the author suggests that, In the case of *anthroprometric analysis,* most students are generally proficient and seek the application of knowledge to ensure the product meets requirements. However, the teaching of *benchmarking* is not generally included in industrial design programs and whilst students are aware of benchmarking few have any knowledge of how to apply it.

In conclusion, responses to these four sections will enable a complete picture of the design methods and process situation with students: their capacity in managing their major projects; their ability to conceptualise; and resolve and present; and finally the extent to which they generally apply design methods.

Method	1	2	3	4	5	N/A
	least utilised ←				→ highly utilised	
Anthropometric analysis						
Benchmarking						
Bionics						
Brainstorming						
Brain-writing						
Computer-aided drafting						
Computer-aided design						
Computer-integrated manufacturing						
Concept selection (Pugh)						
Concurrent engineering						
Cost analysis						
Design catalogues						
Design-by-drawing						
Design drawings (engineering)						
Design for assembly (DFA)						
Design for disassembly (DFAD)						
Design for environment						
Design of experiments (Taguchi)						
Design for long life						
Design for manufacture and assembly						
Design review						
Design for service						
Design for serviceability						
Failure mode and effects analysis (FMEA)						
Fault tree analysis						
Features analysis						
Finite element analysis						
Function analysis						
Function-cost analysis						
Ergonomic analysis						
Integrated product development						
Literature searches						
Market research						
Morphological analysis						
Objectives trees						
Patent search						
Peeves analysis						
Performance Specification method						
Project time plan						
Prototypes						
Quality-function deployment						
Questionnaire						
Rapid prototyping						
Removing mental blocks						
Renderings						
Reverse engineering						
Solid modelling						
Specification checklists						
Statistical process control (SPC)						
SWOT analysis						
Synectics						
Total quality management (TQM)						
Trend studies						
User research						
User interview						
Value analysis (VA)						
Value engineering (VE)						

Table 4-4 Section from the Questionnaire allocated to considerations associated with Design Methods and Process

4.1.2 Mathematical and Statistical analysis applicable to this section of the research programme

The four surveys conducted in Part 1, the survey of industrial design academics, are identical in the manner of indication of the academics opinion, reflected in the enter of a score. Armstrong and Conrad (1995) describe a means by which numerical equivalents of 1,2, 3, 4, and 5 are indicated to determine the opinion of the academic with respect to a range from 1 = unsatisfactory to 5 = excellent.

According to Armstrong and Conrad a mean response of 3.0 indicates that, as many respondents agree with the statement as disagree with it, and as a consequence there is a situation of ambivalence, called the Likert mean. Therefore, a response at the mid point is not really a satisfactory indication of the student performance and in this experiment results above 3 are regarded as satisfactory or excellent. A mean response of 4 is indicating excellent performance and a result of 2 clearly unsatisfactory.

An additional category of response applies to “Not Applicable” and respondents were asked to record this response when students did not apply a particular approach or method. For example, it would be reasonable that many students would not use *Statistical Process Control* as a method.

The responses were taken from the questionnaire sheets and recorded in spreadsheets (refer Appendices 9 to 12) and the columns of data, set up to include summation of the respective category and calculation of *Mean* and *Standard Deviation*. These calculations were performed using the statistical analysis functions in Excel software.

Therefore across the sections of the questionnaire the means and standard deviations associated with the 33 responses in each case can be determined and equated to the criteria proposed by Armstrong and Conrad and the situation of each category established. For example, as part of the *Management and Research* aspect a mean determination for the category of *Time Management* (which is concerned with time-management efficiency and preparation of timelines) scored 2.2 with a standard deviation of 0.89. This suggests that the capability of students across a number of programmes was unsatisfactory.

The analysis of the data across the four categories of enquiry enabled a picture of the situation of students across a number of programmes and the results confirm or otherwise the situation at UNSW.

4.2 PART 2: SURVEY OF GRADUATES AND GRADUANDS

In Sections 3.6 and 3.7 the author proposed an MPD Model and an MPD System. The examination phase in Part 2 endeavoured to validate the effectiveness of the MPD System's influence on studio thinking and project outcomes. Two phases of examination and survey were conducted with the two groups of students as the respondents and these phases are described as follows:

Part 2: Phase 1: A survey of graduates[24] who executed their major projects during 2003. The survey took the form of a questionnaire (refer Appendix 2, page 259), which was mailed to graduates in January 2005.

Phase 2: A survey of graduands[25] who executed their major projects during 2004. The survey took the form of a questionnaire (refer Appendix 3, page 266), which was mailed to graduands in January 2005.

4.2.1 Research propositions

The research propositions that guide the research methods associated with Part 2 and Part 3 are shown in Table 4-5 and the relationships between the variables in the experimental programme are shown in Figure 4.2 below.

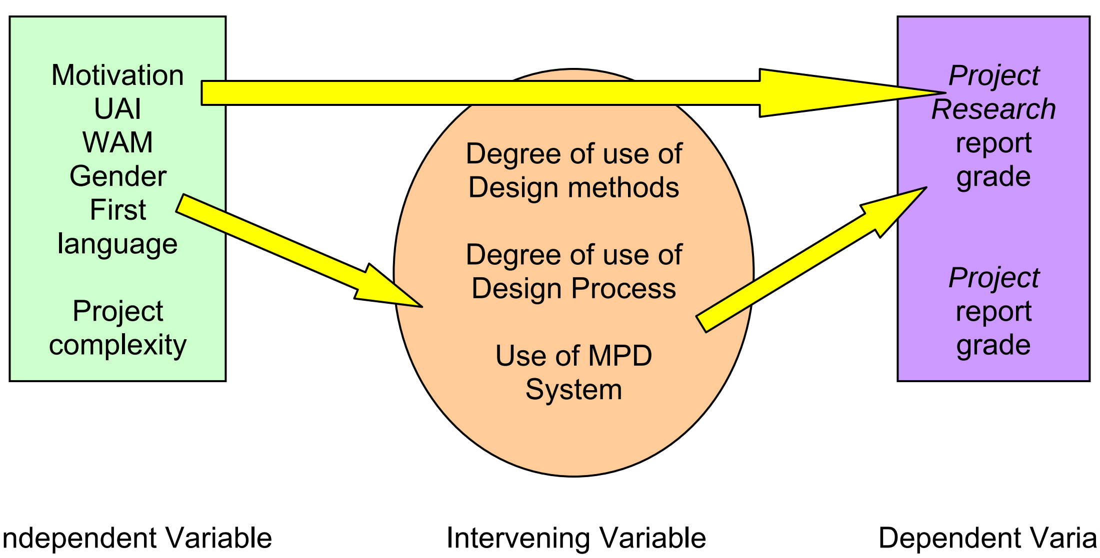


Figure 4.2 Model for the experimental investigation of the relationships of the research variables

[24] This cohort who carried out their major projects during 2003 graduated in April 2004.
[25] This cohort described as graduands carried out their major projects during 2003 and graduated in April 2005

1. Industrial design students engaged in final-year major projects do not include design methods and methodology to any significant extent in their project work and in their *Project Research* and *Project* reports.

2. Students trained in design methods, but additionally have access to a computer-integrated suite of design methods arranged around a Major Project Development Process (MPD System), incorporate design methods to a greater level in their *Project Research* and *Project* reports.

3. Students trained in the stages of the design and product-development processes, including the associated tasks, do not incorporate the stages and tasks, in their projects, to any significant extent.

4. Students trained in the stages of the design and product-development processes, including the associated tasks, but who have access to MPD System, are more likely to incorporate the stages and tasks in their projects.

5. There is a perceived need, by final year students, of a more comprehensive computer integrated selection of design methods, than that which is currently available.

6. Students who have used the MPD System claim that is of considerable assistance to them in their major project work.

7. The higher the motivation towards the major project the higher the use of various design methods.

8. The higher the UAI of the student the higher the use of design methods.

9. The higher the WAM of the student over the 4-year degree the higher the use of design methods.

10. A greater incidence of the use of design methods will lead to a higher quality project outcome.

11. Complex projects tend to incorporate a higher use of design methods.

Table 4-5 Research propositions associated with Part 2 and Part 3[26]

The research propositions arise from and are aligned with the aims and research questions noted in Chapter 1.

[26] UAI (Universities Admission Index) and WAM (Weighted Average Mark) described in Chapter 5.02

4.2.2 Part 2_ Questionnaire structure

The questionnaire development and construction has followed the total design method (TMD) devised by Dillman (1978). Visual aspects of the questionnaire were closely modeled on questionnaires used in two previous studies: *Emerging Exporters* (Australian Manufacturing Council & McKinsey and Company, 1993, 73 81) and *Leading the Way* (Australian Manufacturing Council & Manufacturing Advisory Group (NZ), 1994).

Each questionnaire was accompanied by a personally addressed and signed cover letter explaining the nature of the research, advising that the results would be available on request and reassuring the recipients of strict confidentiality.

Dillman advises that similar questions should "be placed together rather than intermingled with others" (p.124). Therefore the questionnaire was designed with two main sections: General Questions and Design Methods (see Figure 4.3). The questionnaire was of 4 pages length including the cover letter and title page. The questionnaire consisted of two main sections and a total of 14 questions (see Appendix 2 and 3).

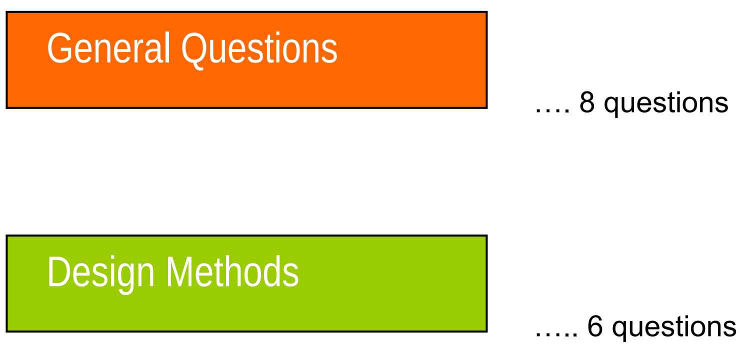


Figure 4.3 Two key sections of the questionnaire

4.2.2.1 General Questions

The general questions are described hereunder.

1. Concerning your motivation, with respect to execution of your final year project, please number the following descriptions that most accurately describes your particular motivation in order of importance. (Please number from 1 (= highest importance) to 5 (= lowest importance):

- to pass? .... ☐
- to gain the highest possible mark?............................ ☐
- to produce a high-quality project outcome? .... ☐
- to produce an outcome that was truly creative?......... ☐
- to showcase a broad range of skills? .... ☐

This question sought to measure the motivation of the respective student and relate this to their use of design methods and process in their reports. The research proposition that is associated with the above question is that:

7. the higher the motivation towards the major project the higher the use of various design methods.

The scoring that applied to the above question is shown in Table 4-6. Measurement of the extent of use of design methods would be determined from Question 9.

Motivation descriptor	Score
to pass	1
gain the highest possible mark	5
produce a high-quality project outcome	4
produce an outcome truly creative	3
showcase a broad range of skills	2

Table 4-6 Scoring for Question 1.

Q2. What was your TER or UAI result in the Higher School Certificate? ………………………..…… ☐

The proposition associated with question 2 is that:

8. *the higher the TER / UAI of the student the higher the use of design methods*

The extent of use of design methods is based on Question 9.

Q3. What was your result in Design Methodology IDES 2091 in 2001 (2003 cohort) or 2002 (2004 cohort)?………. ☐

The Design Methodology course IDES2091 occurs in Stage 2 of the industrial design programme. Students are introduced to design methods and the intention is that such methods may be helpful in their project work. The proposition associated with this question is that:

> 1. *Industrial design students engaged in final-year major projects although trained in design methods and methodology do not include these to any significant extent in their project work and in their project Research and Project reports.*

The basic argument is that even when students are trained in design methods the application of these can be cumbersome and does not encourage their use in major projects. However the mark is a reflection of the level of expertise achieved and it may prevail that a high level of expertise leads to a high incidence of use of design methods.

Q4. What was your Weighted Average Mark (WAM) over the 4 years of the program? …………………………… ☐

The proposition associated with question 4 is that:

> 9. *the higher the WAM (a mark based upon the student's average performance over the four years of the programme) of the student the higher the use of design methods"*

The extent of use of design methods is based on question 9.

Q5. Gender of respondent?………………………………… ☐ M ☐ F

Q6. First language of respondent?…………………………………………………..

This question is included to determine if there is any relationship between first language and the use of design methods.

Q7. What was the assessment given to your *Project Research* Report by the assessment panel in June 2003?…………… [ ]

Q8. What was the assessment given to your *Project* Report by the assessment panel in November 2003?……………… [ ]

The proposition associated with questions 7 and 8 is that:

> 10. A greater incidence of the use of design methods will lead to a higher quality project outcome".

The project outcome is measured by the assessed result as part of the normal assessment process described in Section 2.1.6.1.

4.2.2.2 Design Methods

This next section of the survey sought to determine the extent to which specific design methods and/or tools were employed in the project work and documentation. Forty-one methods was incorporated in the survey and the candidate and respondent recorded the use of a particular method. The propositions that apply to this question are:

> *1. Industrial design students engaged in final-year major projects do not include design methods and methodology to any significant extent in their project work and in their Project Research and Project reports.*

> *2. Students trained in design methods, but additionally have access to a computer-integrated suite of design methods arranged around a Major Project Development Process (MPD System), incorporate design methods to a greater extent in their Project Research and Project reports".*

Q9. Did you use the following design methods?
If Yes, please tick the box against each item.

	Use	*If Yes, was this method included in your reports?*
Anthropometric analysis?	☐ Yes	☐
Benchmarking?	☐ Yes	☐
Bionics?	☐ Yes	☐
Brainstorming?	☐ Yes	☐
Brain-writing?	☐ Yes	☐
Computer-aided drafting?	☐ Yes	☐
Computer-aided design?	☐ Yes	☐
Concept selection?	☐ Yes	☐
Cost determination?	☐ Yes	☐
Design catalogues?	☐ Yes	☐
Design-by-drawing?	☐ Yes	☐
Design drawings (engineering)?	☐ Yes	☐
Design for assembly (DFA)?	☐ Yes	☐
Design for disassembly (DFDA)?	☐ Yes	☐
Design for manufacture and assembly?	☐ Yes	☐
Design review?	☐ Yes	☐
Ergonomic analysis?	☐ Yes	☐
Fault tree analysis?	☐ Yes	☐
Features analysis?	☐ Yes	☐
Function analysis?	☐ Yes	☐
Function-cost analysis?	☐ Yes	☐
Life-cycle analysis?	☐ Yes	☐
Market research?	☐ Yes	☐
Morphological analysis?	☐ Yes	☐
Objectives trees?	☐ Yes	☐
Patent search?	☐ Yes	☐

Peeves analysis? .... ☐ Yes ☐

Performance specification method? .... ☐ Yes ☐

Project time plan?... ☐ Yes ☐

Prototypes? .... ☐ Yes ☐

Quality-function deployment?....................................... ☐ Yes ☐

Questionnaire? .... ☐ Yes ☐

Rapid prototyping? .... ☐ Yes ☐

Renderings? .... ☐ Yes ☐

Solid modelling? .... ☐ Yes ☐

Specification checklists? .... ☐ Yes ☐

SWOT analysis?... ☐ Yes ☐

Synectics? .... ☐ Yes ☐

Trend studies?.. ☐ Yes ☐

User research?... ☐ Yes ☐

Value analysis (VA)? .... ☐ Yes ☐

Q10. Do you feel the need for a more comprehensive computer-integrated selection of design methods than what is currently available?.............................. ☐ Yes ☐ No

- ◻ if Yes, go to Question 14
- ◻ if No, go to Question 15

Q10 sought to determine from the 2003 cohort if they feel a need for a more comprehensive computer-integrated system of design methods than what is currently available. These students have been trained in design methods however the candidate believes that such a system would enhance their understanding and potential for application of design methods to projects. The proposition that applies to this question is:

> *5. There is a perceived need, by final year students, of a more comprehensive, computer integrated selection of design methods, than that which is currently available.*

Q11. (for the 2004 questionnaire) The MPD System is based around seven stages of the Major Project Development Process. To what extent did the MPD System assist you in the seven stages?

	minimal ← 1 2 3 4 5 → considerable
□ **Product Planning** Strategic review of the market Competitor analysis Patent searching Identify opportunities for product development Planning and scheduling project	□□□□□
□ **Task Clarification** Setting design objectives; Materials research; Technology research; Human factors research; Development of a brief.	□□□□□
□ **Conceptualisation** Solution conjecture; Generation of ideas; Folio of concept sketches Simple models (mock-ups)	□□□□□
□ **Embodiment** Evaluation of concepts; Refined candidate solutions; Relevant technical information; Determination of preferred concept	□□□□□
□ **Detailed Design** Development of preferred concept Specification of materials Layout drawings Dimensional specifications	□□□□□
□ **Communication** Folio of presentation drawings Technical drawings Refined three-dimensional model Manufacturing information Financial information (ROI)	□□□□□
□ **Preparation for production** Analysis of costs Consideration of tooling Estimate production investment Consider DFA	□□□□□

Table 4-7 Question 11 (2004 cohort) asking to what extent the MPD System assisted in the major project

Q11 (2004 cohort) seeks to understand the contribution of the MPD System to the various stages of the MPDP. This question seeks the respondent's view as distinct from what was incorporated in the project reports.

Q12. Do you feel such a system would help you, in:

- □ planning? ....□ Yes
- □ identification of the steps in the process? ....□ Yes
- □ facilitation of idea generation?...................................□ Yes
- □ organization of creative proposals? ....□ Yes
- □ systematic classification of data and findings? ....□ Yes
- □ communication of project findings?............................□ Yes
- □ determination of product cost? ....□ Yes
- □ consideration of manufacturing issues?.....................□ Yes

Go to Question 14

Question 12 seeks to understand the potential contribution of the MPD System. The proposition that applies is:

> *6. Students who have used the MPD System claim that is of considerable assistance to them in their major project work".*

Q13. Why wouldn't such a system help you?

- □ too complicated?...□ Yes
- □ too time consuming? ....□ Yes
- □ did not understand how to use? ....□ Yes
- □ unnecessary? ....□ Yes
- □ ……..□ Yes
- □ ……..□ Yes
- □ ……..□ Yes

In question 13 the 2003 cohort is asked: why wouldn't such a comprehensive, computer-based system help you in the execution of the project. Conversely the 2004 cohort are asked why didn't the MPD System assist you in the execution of the project.

Q14. Please give suggestions as to how you could have executed the final-year, major project more effectively?

- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………
- □ ……………………………………………………………………………

In Q14 the respondent in the 2003 cohort is asked how the major project could have been executed more effectively. In contrast, the respondent in the 2004 cohort is asked in what ways the MPD System could be improved.

4.2.3 Mathematical and Statistical analysis applicable to this section of the research programme

The two surveys conducted in Part 2, *the survey of graduates and graduands*, have been explained in the previous section. The first section sought answers to general questions to establish the demographics of the respondents. These apply to motivation, TER/UAI result, assessed grade in Design Methodology, Weighted Average Mark (WAM), gender, first language and assessed results of the Project Research and Project. These data are recorded in spreadsheets (refer Appendix 29 and 30) and the respective means and standard deviation is calculated using the tools in Excel software. Responses to the categories of gender and first language are counted and summed manually. The determination of mean and standard deviation enables the demographics of the 2003 and 2004 cohorts to be compared and contrasted. Normal distributions of the data in each category, for example, UAI, WAM and IDES2091 (design methodology) as well as Project Research and Project results result are determined (refer Appendices 37 and 38).

The normal distributions were determined using Excel software and applying the criteria NORMDIST worksheet function which applies the equation:

$$F(z) = 1/ (2\pi)^{-2} . e [-z^2/2] \text{ where } \mu =0$$

And to standardise a set of scores where z= x - μ / (std devn). In each instance from the data the normal distributions were able to be determined (Schmuller, 2005).

The tests of correlations between the variables, as shown previously in Figure 4.2 and resulting from the research propositions shown in Table 4-5, are based on the relationships between the variables as shown in the table below and these have been tested using SPSS Software where the relationship between, for example, use of design methods and *Project Research* and *Project grade* is tested for correlation (using a Pearson correlation based on a significance of $p < 0.05$).

Independent variable	Intervening variable	Dependent variable
Motivation	Use of design methods	Project research and project grade
UAI	Use of design methods	Project research and project grade
WAM	Use of design methods	Project research and project grade
Gender	Use of design methods	Project research and project grade
Design methodology	Use of design methods	Project research and project grade

Other tests of correlation have included use of correlation worksheet functions in Excel software namely the PEARSON correlation worksheet which tested correlation between two arrays of data. In this case significance of data can be determined in the Excel worksheet using the TTEST worksheet which was used to test two arrays of data.

In the case of the determination of the extent of use of design methods respondents are asked "if a particular design method was used". In this situation the positive responses were summed and the percentage positive response of the cohort summed. For example, if 23 respondents out of 36 confirmed that features analysis was used as a design method then the percentage response is (23/36*100) = 63.8%. This means of examining the response enables comparison, method by method, across the determinants. This approach of summing the particular response and determining the percentage response occurs extensively in this study.

4.3 PART 3: EXAMINATION OF MAJOR PROJECT REPORTS

Part 3: Phase 1: An examination of 30 major-project reports produced in 2003 by a cohort of students with an understanding of design methods but with no access to the "MPD System"; and

Phase 2: An examination of 30 major-project reports each produced in 2004 by individuals' specifically educated and competent in both the "MPD Model" and "MPD System".

4.3.1 Examination to determine project tasks included in *Project Research* and *Project* reports

Q1. To what extent did the *Project Research* and *Project* reports include tasks normally associated with:

	minimal (=0) considerable (=10)
Product planning…….. ………………………………………..	
Task clarification ………..……………………………………..	
Concept generation …..………………………………………..	
Evaluation and refinement …………………………………….	
Detailed design of preferred concept ………………………..	
Communication of results …………………………………….	
Prepare for production ………………………………………..	

	minimal (=0) considerable (=10)
Q2. To what extent did the *Project Research* report follow the established tasks associated with the product-development process?……………………………	

In questions 1 and 2 the propositions that apply are:

> *3. Students trained in the stages of the design and product-development processes, including the associated tasks, do not incorporate the stages and tasks, in their projects, to any significant level"*

> *4. Students trained in the stages of the design and product-development processes, including the associated tasks, but who have access to The MPD Model and MPD System are more likely to incorporate the stages and tasks in their projects.*

This section involved the assessment of the tasks executed in the major project reports of the 2003 and the 2004 cohorts. In Chapter 3.6.4 the tasks contained in the MPD Model are proposed. The purpose of the assessment of the reports was to determine the extent to which these tasks have been incorporated in the project reports and the appropriateness of the tasks proposed in the model. A worksheet (earlier shown in Table 3-13) was developed that enabled this determination and is shown in Table 4-8 below.

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

Table 4-8 Respective tasks associated with the phases of the MPD Model

The relative effectiveness of the manner in which students applied themselves to 60 project reports has been determined by an independent assessor, namely Mr. Bob White a consulting engineer of considerable industrial and educational experience. His CV is included in Appendix 8.

4.3.2 Examination to determine the *Complexity* of reports

This section involved the assessment of the complexity executed in the major project reports of the 2003 and the 2004 cohorts. The purpose of the assessment of the reports was to determine the level of complexity of each project based on use of the complexity model.

simple (=0) complex (=10)

Q1. What is the degree of complexity of the project……………….. [ ]

The issue of complexity was discussed in Section 3.9 and a model describing complexity proposed in Section 3.9.1. In question 1 the proposition that applies is:

> *11. Complex projects tend to incorporate a higher use of design methods*

A worksheet was developed that enabled this determination and is shown in Table 4-9 below.

Student…………………………………………………………… Student number……………………………………….

Project…………………………………………………………….

Student name: **Complexity Worksheet**
Project:

#	Tasks	Weighting Factor	Score 0	1	2	3	4	5	6	7	8	9	10	Total Score	Total Possible
1	Complexity of the market	5													50
2	Scientific considerations	3													30
3	Regulatory issues	3													30
4	Ergonomic considerations	5													50
5	Health and safety considerations	3													30
6	High level of aesthetic requirements	5													50
7	Sustainability considerations	3													30
8	Manufacturing issues	3													30
9	Political/global/cultural/racial considerations	2													20
10	Engineering design considerations	3													30
													Sum………………		350

Table 4-9 Indicating factors which describe the complexity of the project

By consideration of the 60 project reports the relative complexity of each project were assessed, by the independent assessor, Mr. Bob White. Knowledge of the complexity of each project then enables the measurement of the extent of use of design methods as a function of the level of complexity.

In the next chapter of the thesis the experimental results obtained from the above surveys are documented and discussed. This will be cross-referenced to the research propositions and to the related aims of the thesis as noted in Chapter 1.0.

4.3.3 Mathematical and Statistical analysis applicable to this section of the research programme

In this section tests are conducted on the examined reports from the 2003 and 2004 cohorts. The basis of the examination has been explained in Chapter 4.3.1 (examination of tasks and 4.3.2 (examination of complexity). These two examinations produce a set of scores respectively for the 2003 and 2004 cohorts.

The tests involve the determination of correlation between the range of scores as well determination of significance and difference. The two sets of data are tested using Pearson's product moment correlation. Statistical tests using EXCEL software derives a *correlation coefficient*. A result of such a test will indicate +1 (a perfect, positive correlation where one goes up, the other goes up) or -1 (perfect, negative correlation where one goes up, the other goes down) or 0 where there is no relationship. In reality, correlations are unlikely to be perfect. Researchers generally regard any correlation coefficient between 0.3 and 0.7 (plus or minus) as demonstrating some reasonable correlation between two variables. 0.3 is reasonably weak, and 0.7 is reasonably strong (Denscombe, 2003). In determining the significance of the correlation a TTEST is applied where researchers take the null hypothesis as their starting point. If the probability is estimated to be greater than 1 in 20 that the results are a one-off (a fluke) the researcher will consider that the null hypothesis stands. Within the convention of statistics, it is held that where the probability is less than 1 in 20 (0.05) any association in the data may be treated as likely to be genuine and real. Therefore the categories of assessing probability are $p < 0.05$ (two tailed significance) and $p < 0.01$ (single tailed significance).

The formula for the TTest is:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The consideration of the data associated with the cohorts involves establishing the significance of the difference between the data. This is determined using the chi-squared test. It is expected that there will be a difference between findings associated with the 2003 cohort and the 2004 cohort. And this difference, between what was observed and what was expected is the key to the chi-squared test. The formula for the Chi-square test is:

$$\chi^2 = \frac{(N-1)s^2}{\sigma^2}$$

where N = the number of scores in the sample, s^2 = sample variance and $sigma^2$ = is the population variance under H_o (or the square of the standard deviation).

Again the criteria $p < 0.05$ specifies the probability of the difference between the respective range of data as being significant.

In all the above tests EXCEL provides the statistical subroutines for: correlation, using PEARSON; probability using TTEST; and significance of difference (Chi-squared) using CHITEST (Schmuller, 2005).

The normal distributions were determined using Excel software and applying the criteria NORMDIST worksheet function which applies the equation:

$$F(z) = 1/ (2\pi)^{-2} . e [-z^2/2] \text{ where } \mu = 0$$

And to standardise a set of scores where $z= x - \mu$ / (std devn). In each instance from the data the normal distributions were able to be determined.

4.4 EXPERIMENTAL PROGRAMME and ETHICS APPROVAL

This project was approved by the University of Canberra - Committee for Ethics in Human Research. The assigned Project Number is 04/85 established December 22, 2004. Approval followed a submission to the Committee in November, 2004 in which the research plan was described and the intentions with respect to the surveying of respondents clarified. A *Participant Information* form accompanied the submission and this form is located in Appendix 6. Similarly, an *Informed Consent* form is located in Appendix 7. All responses from the respective surveys are located in lever-arch files locked in the author's office at the University of New South Wales. The responses and the research data including the contents of this thesis do not identify the respective respondent. The data obtained in the respective surveys although securely stored is available for incorporation in future studies.

This concludes the explanation of the Research Methodology and Experimental Programme. The results and discussion arising from the research are included in the next chapter.

.

Chapter 5

Results and Discussion

This Chapter presents the results and analyses obtained from the experimental investigation based on the research methodology described in Chapter 4.

5.0 RESULTS and DISCUSSION

This chapter presents the results that were obtained in the experimental programme. The first part outlines results from the survey of academics in Australia and overseas. The second part presents results from the survey of graduates and graduands and the third part presents findings based on analysis of the student project reports. Recall that the three sections are more specifically described as:

Part 1: Results associated with a structured survey of academics, described in Chapter 4, Part 1, sought to gain the opinions of academics with respect to the quality of the major-project work and the extent to which design methods normally featured in student projects.

Part 2: A survey of graduates and graduands based on a questionnaire that sought their opinions with respect to their results, experience and process/methods employed in their final-year major projects.

Part 3: The evaluation of student final-year project reports with respect to the project development tasks incorporated into their project work and the determination of the comparative complexity of the respective projects.

5.0 Demographic Characteristics of Respondents

The three groups of respondents in this study were:

1. The Industrial Design academics;
2 2003 Graduate students of Industrial Design from UNSW;
3 2004 Graduand students of Industrial Design from UNSW.

5.0.1 The Industrial Design Academics

Thirty-three (33) academics were surveyed to reveal their perceptions/observations of approaches and design methods employed by students in their final-year projects. Twenty-three (23) were employed in seven Australian universities, six (6) from South Korean universities, three (3) from the National University of Singapore and one (1) from the University of Surry in the United Kingdom (see Table 5.1).

N=	Respondent No.	University	Country	Years teaching	Gender	Highest qualification
1	31309	Daebul University	Sth Korea	16-20	M	MFA
2	31291	International Design School	Sth Korea	6-10	M	PhD
3	31117	Dankook University	Sth Korea	6-10	M	MFA
4	31317	Woosong University	Sth Korea	6-10	M	MFA
5	31320	Ewha University	Sth Korea	11-15	M	MFA
6	31319	University of Newcastle	Australia	10-15	M	BAppSc,BA
7	31266	University of Canberra	Australia	35-40	M	PhD
8	31292	University of Canberra	Australia	16-20	M	MIndDes
9	31270	University of New South Wales	Australia	1-5	M	MIndDes
10	30979	University of New South Wales	Australia	6-10	F	BDes
11	30988	University of New South Wales	Australia	6-10	M	BA(IndDes)
12	31092	University of New South Wales	Australia	11-15	M	MSc
13	31296	University of New South Wales	Australia	11-15	M	MDes,MHEd
14	31294	University of New South Wales	Australia	11-15	F	BA(IndDes)
15	30971	University of New South Wales	Australia	11-15	F	PhD
16	30669	University of New South Wales	Australia	6-10	F	MDes
17	31286	University of New South Wales	Australia	6-10	M	PhD
18	31325	University of New South Wales	Australia	11-15	M	MA
19	31296	University of Western Sydney	Australia	6-10	M	BA(IndDes)
20	31029	University of Western Sydney	Australia	6-10	M	BDes(IndDes)
21	31289	University of Western Sydney	Australia	6-10	M	PhD
22	31305	University of Technology Sydney	Australia	21-25	M	MIndDes
23	31288	University of Technology Sydney	Australia	11-15	F	BA(IndDes)
24	31326	University of Sth Australia	Australia	21-25	M	MFA
25	31312	University of Sth Australia	Australia	21-25	F	MFA
26	31344	Monash University	Australia	6-10	M	MD
27	22523	Monash University	Australia	6-10	M	PhD
28	31331	National University of Singapore	Singapore	11-15	M	MSc
29	31269	National University of Singapore	Singapore	21-25	M	MSc
30	31266	National University of Singapore	Singapore	1-5	M	PhD
31	31274	University of Surry	UK	6-10	M	MSc
32	30878	Open Cyber University	Sth Korea	1-5	F	MFA
33	30250	Queensland University of Technology	Australia	21-25	F	PhD

Table 5-1 Demographics of academic respondents

Table 5-2 shows that twenty-five or 76% of academics were male and eight or 24% were female. Of eight female respondents, seven were from Australia and one from South Korea. This proportion of gender distribution is reflective of a still predominantly male-dominated career in Industrial Design teaching.

The majority of the respondents (18 only) held a Masters Degree, eight (8) have a PhD, and seven have Bachelor degrees in Industrial Design.

There is a significant wealth in teaching experience among the respondents with 11 (33%) having teaching experience from 11 to 20 years, 5 (15%) greater than 21 years and one (3%) with experience of more than 35 years.

Among those who held PhDs, two have 21+ years of experience in teaching design courses.

Seventeen (52%) of the respondents have had experience as Head of programme for a period greater than 3 years. All respondents have supervised students engaged in final-year projects.

Variable		N=33	**%**
Gender	Male	25	76
	Female	8	24
Highest Qualification	PhD	8	24
	Masters	18	55
	Bachelors	7	21
Country of University Employment	Australia	23	70
	Singapore	3	9
	South Korea	6	18
	United Kingdom	1	3
Years of Teaching Design Courses	1- 5 years	3	9
	6-10 years	13	39
	11-15 years	9	27
	16-20 years	2	6
	21+ years	6	18

Table 5-2 Demographic characteristics of academic respondents

Based on the above criteria describing the respondents, it can be concluded that: they represent a diverse group, as balanced as could be expected in gender; they have extensive experience in the teaching of industrial design and in the supervision of major projects; and they represent programmes in diverse regions and which have particular foci in terms of the nature of their programmes. Because of this, it is reasonable to assume the results associated with the survey will be considered and factual in relation to the approaches and methods employed by students.

5.0.2 2003 graduate students of industrial design at UNSW

A total of 53 students completed their final year projects during 2003. Of these, 46 have been successfully located while 7 graduates were unable to be found.

Forty-six (46) students were sent questionnaires and only five failed to respond. Table 5-3 lists the 41 students who responded.

Male students, twenty-six (26) only, dominated the 2003 cohort making up a little less than two-thirds (63%) of the total number of students. The 15 female graduates made up approximately one-third (37%) as shown in Table 5-4.

No.	Respondent Number	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language
1	8160.03	N/A	N/A	69	M	English
2	6735.03	75	68	65	M	Indonesian
3	6023.03	N/A	N/A	64	M	English
4	5284.03	90	60	58	M	English
5	7444.03	96	67	68	F	Chinese
6	7543.03	96	72	72	M	Chinese
7	3022.03	81	73	60	M	Chinese
8	7311.03	79	66	60	F	English
9	7058.03	92	72	67	F	Indonesian
10	7754.03	82	73	64	M	English
11	2114.03	73	67	50	F	Chinese
12	7336.03	82	65	65	F	English
13	7546.03	90	69	62	M	English
14	2509.03	52	67	71	M	English
15	3215.03	79	72	72	M	English
16	3027.03	90	75	60	F	Korean
17	7409.03	87	70	70	M	English
18	2485.03	N/A	76	59	F	Korean
19	6742.03	78	66	58	F	Indonesian
20	944.03	76	72	58	M	English
21	7685.03	N/A	65	70	M	Chinese
22	7373.03	89	70	62	M	Chinese
23	7959.03	78	67	58	M	Chinese
24	2871.03	79	69	57	F	Chinese
25	7249.03	91	63	76	M	English
26	5153.03	80	85	67	M	English
27	7462.03	84	73	61	M	English
28	3022.03	N/A	59	58	M	English
29	2184.03	87	68	59	M	English
30	7557.03	88	67	72	M	English
31	2476.03	N/A	69	69	M	English
32	2956.03	80	71	54	F	English
33	2424.03	95	65	64	M	English
34	7347.03	90	67	67	M	English
35	7741.03	86	56	57	M	English
36	7423.03	91	68	69	F	Chinese
37	7324.03	85	68	68	F	Chinese
38	6738.03	97	71	62	F	Indonesian
39	3031.03	74	70	52	F	Chinese
40	7515.03	82	63	59	F	Chinese
41	5364.03	N/A	62	61	M	Indonesian
41	Means…..	84	68	63	26M : 15F	
	Std Dev'n…	8.8	5.1	6.0		

Table 5-3 Demographics of the 2003 cohort respondents

The 2003 final-year cohort attracted students from diverse cultural backgrounds. More than one half of the cohort (54%) indicated their first language as English. The number of students whose first language was not English comprised 46%, made up of Chinese (29%), Indonesian (12%) and Korean (5%). All of the students were proficient in English having met the university's entrance requirements and age ranged from 22 to 29 years.

Three sources of school and course grades of the respondents were used to substantiate the level of academic performance of the respondents. These were, the University Admission Index (UAI), a specific course in Design Methodology, course code (IDES2091) and the Weighted Average Mark (WAM).

Students wishing to undertake university courses in the state of New South Wales are required to sit for the Higher School Certificate Examination and the resultant grade equated to a ranking, the UAI, which is used to regulate admission to various programmes. The high school results of students from other states and overseas are equated to the UAI by criteria used by the University of New South Wales. The UAI requirement for a particular course changes every year and in 2000, when most of the 2003 graduates would have been admitted, the UAI prerequisite was 70.

Variable		Mark	No.	%
UAI attainment…………………..………	highest	97		
	mean	84		
	lowest	52		
Design Methodology (IDES2091)….	highest	85		
	mean	68		
	lowest	56		
Weighted Average Mark (WAM)	highest	72		
	mean	63		
	lowest	50		
Gender ……………..…………..…..	Male		26	63
……………………….. ….	Female		15	37
First language ……………………..	English		22	54
……………………..	Chinese		12	29
	Indonesian		5	12
	Korean		2	5

Table 5-4 Summary, demographics, 2003 Cohort

Twenty-four students (58.5%) had a UAI score of 80 and above. Eleven students (27%) had a score of 90 and above with four among them having a score of 95 and above. Of the 13 students who had a score of 80 to 89, six had a UAI score of 85-89. Only eight students had a UAI of 70 to 79, with seven 75 to 79. The highest UAI was 97 while the lowest was 50. Seven students (recorded as N/A) did not have UAI results, and these gained alternate entry based on their achievement in Diploma-level programmes overseas. The results converted to a normal distribution show a curve slightly skewed to the right (refer Appendix 37, Figure A1).

The Design Methodology course (IDES2091) is a core subject that provides essential knowledge in the industrial design process. One student achieved a high distinction of 85 and two students received a grade of Distinction with scores 75 and 76. More than one-half of the 2003 cohort, received a grade of Credit from 65 to 74 and only two received a Pass grade of 59 and 56. When the results were converted to a normal distribution the resultant curve was normal as shown in Appendix 37, Figure A-3.

The Weighted Average Mark (WAM) is the grade achieved by the student over the four years of the programme and this grade reflects the over-all achievement of the student in the Industrial Design Course. One half of the students (27) achieved a Credit grade between 65 and 74. The normal distribution of the WAM results of the 2003 cohort is centrally located. Overall, the performance of the 2003 cohort on the three categories consistently showed the normal curve pattern. Comparative analysis of individual students, however, showed no relationship between the three categories in terms of individual achievements. The student who achieved the highest score of 97 in UAI received a Credit grade of 71 in Design Methodology subject and a grade of 62 in the WAM.

Meanwhile, a student who received the lowest UAI score of 73 also received the lowest WAM score of 50 but received a Credit mark in Design Methodology subject with a grade of 67. The student who received the highest WAM score of 76 (Distinction) was not in the top five highest UAI score and received only 63 in the Design Methodology course, a grade lower than what the lowest WAM scorer received.

5.0.3 2004 graduate students of industrial design at UNSW

A total of 36 students completed their final year projects during 2004. All students were sent questionnaires and 100% response was received.

The 2004 graduates consisted of 25 males (69.5%) and 11 females (30.5%). A little over one-half (53%) of the population indicated English as their first language while 47% came from a Non-English speaking background and consisted of 14 Chinese, 1 Spanish, 2 Norwegian and 1 Malay. All the students were proficient in English and age ranged from 22 to 31 years.

The Universities Admission Index (UAI) admission requirement for the Industrial Design programme in 2001 (when the 2004 cohort enrolled) was 70. The Industrial Design course attracted students with high UAI with two students having a score of 99. The lowest UAI score for this group was 74. There were a total of ten students with 90 and above, fourteen scored 80 and above and six a score of 74 to 79. Overall, the 2004 students have a high average UAI more than two-thirds of students scoring 80 and above. Six (6) students were admitted to the programme based on their achievement in Diploma-level courses.

No.	Respondent Number	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language
1	2275.04	92	63	70	M	English
2	2288.04	81	65	60	F	Chinese
3	2446.04	85	66	61	M	Chinese
4	2363.04	96	73	67	F	English
5	8744.04	78	65	61	F	Chinese
6	1573.04	N/A	68	65	M	Chinese
7	9130.04	77	73	52	M	English
8	2300.04	85	60	68	M	Chinese
9	7345.04	94	67	71	M	English
10	2285.04	74	70	64	F	Chinese
11	7330.04	84	65	64	M	English
12	1574.04	N/A	59	60	M	Spanish
13	7259.04	91	75	66	F	English
14	2379.04	92	77	67	F	English
15	1208.04	80	67	70	M	Norwegian
16	2818.04	84	69	65	F	Chinese
17	4128.04	97	68	61	F	Chinese
18	7403.04	80	67	58.7	F	Chinese
19	8282.04	N/A	58	61	M	Norwegian
20	2308.04	99	69	75	M	English
21	4016.04	N/A	67	71	M	English
22	5244.04	86	60	56	M	English
23	2397.04	82	67	60	M	Chinese
24	4017.04	N/A	51	62	M	Malay
25	7487.04	88	67	51	F	English
26	2278.04	99	72	75	M	English
27	5240.04	89	68	61	M	English
28	7762.04	89	61	64	M	English
29	7373.04	79	65	61	M	English
30	2272.04	92	67	74	M	English
31	2544.04	78	69	66	M	Chinese
32	0745.04	N/A	N/A	76	M	Chinese
33	2350.04	90	62	63	M	English
34	2345.04	82	61	63	M	English
35	2424.04	76	63	56	M	English
36	4009.04	85	68	64	F	Chinese

36	Means…	86	66	64	25M : 11F
	Std Dev'n..	7.0	5.1	6.0	

Table 5-5 Demographics of the 2004 cohort respondents

The highest result in Design Methodology (IDES2091) was 77 and the lowest 51. Of the five students who received a grade of more than 70, four students were almost top UAI scorers. No High Distinction (85 and above) was achieved by this cohort and only two received a Distinction (75-84). Thirty (30) students received a grade of Credit and only three received a Pass grade.

Variable		Mark	No.	%
UAI attainment……………….………	highest	99		
	mean	86		
	lowest	74		
Design Methodology (IDES2091)…….	highest	77		
	mean	66		
	lowest	51		
Weighted Average Mark (WAM)	highest	76		
	mean	64		
	lowest	51		
Gender …………….…………..…..	Male		25	69.5
……………………….. ….	Female		11	30.5
First language ……………………..	English		19	53
……………………..	Chinese		13	36
	Spanish		1	2.8
	Norwegian		2	5.5
	Malaysian		1	2.8

Table 5-6 Summary, demographics, 2004 Cohort

Grades received by students on the Weighted Average Mark (WAM), showed that of the four students who received a distinction (75 above) three students were also the top UAI scorers.

5.0.4 A comparative demography of 2003 and 2004 students

The comparative mean data associated with the two groups are summarised in Table 5-7.

The respective final years were comprised of 41 (89%) respondents from the 2003 cohort and 36 (100%) respondents from the 2004 cohort.

There was very little difference in the level of UAI scores between the 2003 and 2004 cohorts with a mean of 84 (standard deviation 8.8) for the 2003 cohort and 86 (standard deviation 7.0) respectively for the 2004 cohort. This measure, determined at the commencement of their programmes, indicates that the relative student performance of the two groups was similar.

The results for the Design Methodology (IDES2091) course are similar, the mean scores 68 (standard deviation 5.1) for the 2003 cohort and 66 (standard deviation 5.1) for the 2004 cohort.

Demographics	No.	UAI	IDES-2091	WAM	Gender		First language						
					Male %	Female %	Eng %	Chin %	Ind %	Kor %	Span %	Malay	Norw %
2003 cohort	41	84	68	63	63.5	36.5	54	29	12	5			
2004 cohort	36	86	66	64	69.5	30.5	53	36			2.8	2.8	5.5

Table 5-7 Demographic comparison of the 2003 and 2004 cohorts

The mean score for the WAM was almost the same with the 2003 cohort achieving 63 (standard deviation 6.0) and the 2004 cohort 64 (standard deviation 6.0).

There was very little difference in gender and first language demographics. Both classes were male-dominated with almost two-thirds male and one-third female. Similarly for both classes, almost one-half of the population was from Non-English-speaking background (46% and 47% respectively). Among the non-English first-language students, Chinese language speakers ranked high (29% and 36% respectively).

Overall, comparison of the demography of the two groups reveals that the UAI, Design Methodology capability and WAM are similar. Therefore it is safe to conclude that the two groups have similar academic performance abilities. In addition, the two groups have similar gender representation, their first-language proportions are similar and their age range is comparable. Therefore the principal finding associated with the demographic comparison is that the design performance and in their major project work of the two cohorts can be compared and that the results associated with their survey, explained in the next Chapter, is valid.

5.1 PART 1: SURVEY OF INDUSTRIAL DESIGN ACADEMICS

This questionnaire (refer Appendix 1) was sent to thirty-three academics (described in Chapter 5.0.1) employed in industrial design programmes in a number of universities in Australia and overseas as indicated in Table 5-1. Thirty-three responses (100%) were obtained. The survey questionnaire included four categories of consideration:

1. Management and Research
2. Conceptualisation
3. Resolution and Presentation
4. Design Methods and Process

The questionnaire data obtained from the survey of academics in the above categories have been analysed in accordance with the methodology recommended by Armstrong and Conrad (1995). This methodology includes important guidelines for interpretation of the data as below:

> "The mean score for each item is derived from the numerical equivalents of 1, 2, 3, 4 and 5 allocated to the responses Strongly Agree, Agree, Uncertain, Disagree, and Strongly Disagree respectively. A mean of 3.0 indicates that as many respondents disagree with the statement as agree with it; a mean of 2.0 means that, on average, the respondents agree with the statement; and a mean of 4.0 indicates that, on average, the respondents disagree with the statement. If the statements to which the students respond are positive rather than negative, those items with a mean score higher than 3.0 generally indicate problem areas that are giving students some cause for concern or complaint" (Armstrong and Conrad, 1995, p.134).

These guidelines are clear in terms of how the response data are to be interpreted. However, the response item "Uncertain" (U) is more open to interpretation. In this regard, Armstrong and Conrad have suggested the following approach:

> It may mean simply that the respondent doesn't feel strongly enough about the statement to make a judgment on it - in one case it might really mean "Not applicable" or "Not relevant" or "Doesn't worry me". In other cases responses may indicate a mild level of dissatisfaction with the aspect of the subject. In still other cases, a large number of U responses may mean that the question was ambiguous" (Armstrong and Conrad, 1995, p.134-135)

In this thesis the data have been analysed to arrive at a mean score from the numerical equivalents 1, 2, 3, 4, and 5. In this case 1= *Unsatisfactory* and 5= *Excellent*. A mean of 3.0, defined as the Likert midpoint, indicates an ambivalent result, neither unsatisfactory nor satisfactory. A mean of 2.0 indicates an *unsatisfactory* result and a mean of 4.0, the respondents agree that the outcome is approaching *excellent*.

In many instances a significant number of responses have indicated "Not Applicable" (N/A) and these are clearly shown in the tables. In this situation the N/A responses generally indicate that the process/activity/method is not employed by those particular students.

5.1.1 Management and Research

This section sought to determine the attitude and approach of students to the overall management (project coordination, time management, engagement, identification and liaison with industry sponsors) and the research work (identification of product opportunity, market, competitor, and user studies) associated with project management and design research aspects of their project work.

Appendix 9 contains findings from the raw data and Table 5-8 below, summarises these. This research identified 18 determinants, for example, *time management*, *generation of project ideas*, among sixteen others. The 33 academic respondents indicated that only two activities exceeded the Likert mid point of 3.0, namely: *engagement with project* (3.2), and *ergonomics research* (3.4). The remaining 16 determinants, namely *time management* (2.2), *screening of project ideas* (2.5), *evaluate market opportunity* (2.6), *legal/trade restrictions* (1.5) and so on, all are indicated as equal to or less than the Likert mid point of 3.0.

unsatisfactory 1 2 3 4 5 excellent

Activity	Mean Score	N/A	Std Dev.
Time management	2.2	0	0.89
Generation of project ideas	3.0	0	0.73
Screening of project ideas	2.5	0	0.87
Engagement with project	3.2	0	0.87
Evaluate market opportunity	2.6	0	0.99
Legal / trade restrictions	1.5	2	0.62
Patent/ design registrations	1.8	0	0.98
Materials research	2.6	0	1.00
Manufacturing research	2.5	0	0.97
Ergonomics research	3.4	0	0.93
Evaluate competitive products	3.0	0	0.95
Screen information	2.5	0	0.90
Design questionnaires	2.6	0	1.14
Conduct user surveys	2.8	0	1.29
Market research	3.0	0	0.88
Identify industry sponsor	2.6	0	1.12
Develop design brief	2.9	0	1.02
Provide realistic time plan	2.5	0	0.83

Table 5-8 Mean responses to questionnaire (management and research) by industria l design academics. (Overall mean response across the eighteen categories = 2.6).

The findings are important and alarming in that they suggest students in general embrace activities associated with *management and research* to a level that is unsatisfactory. The overall-all mean of all the 18 activities is determined as 2.6, highlighting the overall unsatisfactory level of application. For the activity of *legal/trade restrictions,* two respondents (6%) indicated this activity "not applicable" to an industrial design major project.

5.1.2 Conceptualisation

This section sought to determine the approach of students to the phase of *conceptualisation*. In a project, students must generate ideas for a product concept, assess and screen those ideas to arrive at a final proposal. A number of focused activities assist the process of conceptualisation and these form the determinants expressed below.

Activity	unsatisfactory (1) … excellent (5)	Mean Score	N/A	Std. Dev.
Creative thinking		2.8	0	0.87
Conceptualisation		2.7	0	0.92
Idea generation		2.9	0	0.8
Screening of ideas		2.4	0	0.86
Application of brainstorming techniques		2.5	1	0.94
Application of bionics		1.5	12	0.80
Application of synectics		1.4	14	0.75
Ranking of design concepts		2.4	0	1.06
Creative materials selection		2.6	0	0.94
Confidence in design decision making		2.4	0	0.96
Flexibility in considering/rejecting ideas		2.5	0	0.94
Consideration of patents/design registrations		1.5	3	0.67
Search for a visual language		2.8	0	0.73
Use of semantic space		2.4	2	0.96

Table 5-9 Mean responses to questionnaire (conceptualisation) by industrial design academics (overall mean across the fourteen categories = 2.3). *N=33*

Appendix 10 contains the findings from the raw data and Table 5-9 above, summarises these findings. This research identified 14 determinants, for example, *creative thinking*, *conceptualisation*, among twelve others. The 33 academic respondents indicated that no activities exceeded the Likert mid point of 3.0. The 14 determinants, namely *creative thinking* (2.8), *conceptualisation* (2.7), *idea generation* (2.9), *screening of ideas* (2.4) and so on, all are indicated as less than the Likert mid point of 3.0.

The overall-all mean of all activities is 2.3, considerably less than the mid-point of 3.0. Twelve responses (36%) considered the *application of bionics,* 14 responses (42%) considered the *application of synectics* and 3 responses (9%) considered *patents / design registrations*, 2 responses considered *use of semantic space* as "not applicable" to the *conceptualisation* phase of industrial design projects.

Again these findings are serious and suggest that, in the critical area of industrial design *conceptual* activity, students are not engaging and their application is extremely unsatisfactory.

5.1.3 Resolution and Presentation

This section sought to determine the attitude and approach of students to the tasks associated with *resolution and presentation*, namely evaluating and refining the design, selecting materials, developing specifications, detailed design, determination of product and component costs, investment and bill of materials and communication of the design using prototypes and graphics.

Activity	Mean Score	N/A	Std. Dev.
Evaluation and refinement of the design	2.7	0	0.73
Detailed design	2.4	0	0.83
Appreciation of link design and manufacturing	2.5	0	1.06
Appreciation of the link design and marketing	2.9	1	0.9
Documentation (engineering drgs/spec'ns)	2.4	1	0.87
Materials selection	2.5	0	0.75
Prototyping and models	3.5	0	0.87
Resolution of ergonomic issues	3.1	0	0.72
Resolution of assembly issues	2.2	0	0.73
Resolution of issues associated with finish	2.5	0	0.97
Renderings	3.9	0	0.66
Graphics	3.5	1	1.15
Development of business plan	1.8	6	0.82
Evaluate investment involved in project	1.5	5	0.56
Financial/investment analysis	1.3	6	0.53
Estimation of manufacturing costs	1.7	4	0.69
Consideration strength and structural issues	1.8	4	0.75

Table 5-10 Mean responses to questionnaire (resolution and presentation) by industrial design academics(Overall mean across the seventeen categories = 2.5).

Appendix 11 contains the findings from the raw data and Table 5-10 above, summarises these findings. This research identified 17 determinants, for example, *evaluation and refinement of the design*, *detailed design*, among fifteen others. The 33 academic respondents indicated that only three activities exceeded the Likert mid point of 3.0, namely: *prototyping and models* (3.5), *resolution of ergonomic issues* (3.1), *renderings* (3.9) and *graphics* (3.5). The remaining 13 determinants, namely *evaluation and refinement of the design* (2.7), *detailed design* (2.4), *appreciation of the link between design and manufacturing* (2.5), *financial /investment analysis* (1.3) and so on, all are indicated as less than the Likert mid point of 3.0.

The overall-all mean of all activities is 2.5, less than the Likert mid-point of 3.0. The *link between design and marketing, documentation* and *graphics*, each received one (1) response as "not applicable". Six responses (18%) considered the *business plan* and five responses (15%) considered *evaluate investment*, six responses (18%) considered *financial/investment analysis,* four responses each (12%) considered *estimation of manufacturing costs* and *strength/structural issues* as “not applicable” to the *resolution/ presentation* phase of industrial design projects.

Summarising the findings associated with Chapters 5.1.1 to 5.1.3 reveal firstly, where student application, is considered by the academics surveyed, ranges from satisfactory to excellent based upon the recorded scores. These determinants considered as satisfactory to excellent are:

- engaging with projects
- conducting ergonomics research
- carry out prototyping and modelling
- resolving ergonomic issues
- creating graphics presentations
- rendering images.

The above six determinants arose from the list of 49. However, the remaining 43 determinants are considered by the academics as unsatisfactory performance. These determinants are listed below:

- managing time
- generating project ideas
- screening project ideas
- evaluating market opportunities
- determining legal/trade restrictions
- determining patent/design issues
- researching the market
- carry out materials research
- conducting manufacturing research
- evaluation of competitive products
- screening information
- designing questionnaire
- conducting user surveys
- carrying out market research
- identifying industry sponsors
- developing a design brief
- providing a realistic time plan
- creative thinking
- engaging with conceptualisation
- generating ideas
- screening ideas
- applying brainstorming
- applying bionics
- applying synectics
- ranking design concepts
- selecting materials creatively
- making design decisions
- flexible in considering/rejecting ideas
- considering patents/registrations
- searching for a visual language
- using a semantic space
- evaluating and refining the design
- design detailing
- linking design and manufacturing
- linking design and marketing
- documenting design work
- selecting materials
- resolving assembly issues
- resolving finish
- developing business plan
- evaluating investment
- analysing financial investment
- estimating manufacturing costs
- considering structural issues

It is conceded that the standard deviation can influence the score for a particular determinant. For example, *managing time* had a *score of* 2.2 and a standard deviation of

0.89. This can realise a score of either 3.09 or 1.31. Therefore the score can range over the Likert mid point or considerably below (1.31). In this discussion, the considerations have been based on the mean. The overall conclusion is inescapable in that student performance as indicated by the respondent academics is unsatisfactory. Clearly, more work has to be done within industrial design programmes to arrive at a more comprehensive attainment in terms of expertise.

5.1.4 Design Methods and Process

In this section respondents indicated the design methods employed by students, in their final-year major projects. The extent to which these methods are employed in their project work and documentation is rated as 1 (least utilised) to 5 (highly utilised). Alternatively, where students would generally not use a method, respondents indicated *not applicable* (N/A).

Appendix 12 contains the raw data and Table 5-11 summarises the findings. This research identified 57 determinants, for example, *anthropometric analysis*, *benchmarking*, bionics, among fifty-four others. The 33 academic respondents indicated that only fourteen activities exceeded the Likert mid point of 3.0. Examples are: *anthropometric analysis* (3.3), *brainstorming* (3.1), *computer-aided drafting* (3.9) among eleven others. The list of activities that exceed the midpoint of 3.0 are included in the right-hand column of Table 5-12. The remaining 43 determinants, namely *benchmarking* (2.1), *bionics* (1.4), *brain-writing* (1.5), *computer-integrated manufacturing* (1.4) and so on, are all indicated as less than the Likert mid point of 3.0. These are included in Table 5-12 in the left-hand column.

The list shown in Table 5-11 includes a large number of “not applicable” (N/A) responses. For example, 19 respondents (57.5%) considered *statistical process control*, 19 (57.5%) *total quality management*, 12 respondents (36%) *bionics, and so on,* methods “not applicable” to industrial design projects. Again, these findings are disturbing and reveal that many lecturers confirm their students are not employing these, for example, *morphological analysis, quality-function deployment, reverse engineering* and others shown in the Table as “not applicable”.

Table 5-12 presents a summary of Table 5-11 and categorises the findings into two columns. The left-hand column shows those methods which in terms of their application are equal to, or less than, the Likert mid point of three. The right-hand column includes those activities where the mid point of three is exceeded. The left hand column includes 43 methods arranged in descending order from *project time plan* (3.0) to *total quality*

Design Method	Mean Score	N/A Resp.	Std. Dev.
Anthropometric analysis	3.3	0	0.88
Benchmarking	2.1	2	1.07
Bionics	1.4	12	0.71
Brainstorming	3.1	1	1.09
Brain-writing	1.5	10	0.79
Computer-aided drafting	3.9	0	0.88
Computer-aided design	3.9	1	0.98
Computer-integrated manufacturing	1.4	11	0.61
Concept selection (Pugh)	1.6	6	0.87
Concurrent engineering	1.4	10	0.70
Cost analysis	1.7	3	0.78
Design catalogues	3.0	1	1.05
Design-by-drawing	3.5	0	0.87
Design drawings (engineering)	2.8	0	0.73
Design for assembly (DFA)	2.0	1	0.77
Design for disassembly (DFAD)	1.8	3	0.87
Design for environment	2.8	2	0.95
Design of experiments (Taguchi)	1.4	10	0.61
Design for long life	2.1	3	1.00
Design for manufacture and assembly	2.4	0	0.75
Design review	2.2	4	1.14
Design for service	1.7	5	0.85
Design for serviceability	1.7	3	0.69
Failure mode and effects analysis (FMEA)	1.2	13	0.44
Fault tree analysis	1.1	14	0.33
Features analysis	1.6	8	0.86
Finite element analysis	1.1	15	0.42
Function analysis	2.1	3	1.20
Function-cost analysis	1.3	7	0.60
Ergonomic analysis	3.1	0	1.01
Integrated product development	1.7	8	0.89
Literature searches	3.5	1	1.00
Market research	3.1	1	1.02
Morphological analysis	1.8	10	1.17
Objectives trees	1.6	7	0.79
Patent search	2.0	6	1.07
Peeves analysis	1.2	15	0.44
Performance Specification method	1.6	13	0.79
Project time plan	3.0	0	1.07
Prototypes	3.4	0	1.14
Quality-function deployment	1.4	16	0.86
Questionnaire	3.2	0	1.15
Rapid prototyping	2.4	5	1.39
Removing mental blocks	1.6	8	1.06
Renderings	4.2	0	0.71
Reverse engineering	1.6	11	1.00
Solid modelling	3.9	0	0.86
Specification checklists	2.3	7	1.28
Statistical process control (SPC)	1.1	19	0.42
SWOT analysis	3.0	0	1.53
Synectics	1.4	12	0.65
Total quality management (TQM)	1.1	19	0.24
Trend studies	2.6	5	1.27
User research	3.3	0	0.91
User interview	3.3	0	0.88
Value analysis (VA)	1.5	5	0.76
Value engineering (VE)	1.2	9	0.55

Table 5-11 Mean responses to questionnaire (design methods and process) by industrial design academics

Design Methods with low utilisation score (<or = 3.0)			
Design Method	Utilisation Score	Std Dev	No. of N/A responses
Project time plan	3.0	1.1	0
SWOT	3.0	1.5	0
Design drawings (engineering)	2.8	0.7	0
Design for environment	2.8	1.0	2
Trend studies	2.6	1.3	5
Design for manufacture and assembly	2.4	0.8	0
Rapid prototyping	2.4	1.4	5
Specification checklists	2.3	1.3	7
Design review	2.2	1.1	4
Benchmarking	2.1	1.1	2
Design for long life	2.1	1.0	3
Function analysis	2.1	1.2	3
Design for assembly	2.0	0.8	1
Patent search	2.0	1.1	6
Design for assembly and disassembly	1.8	0.9	3
Morphological analysis	1.8	1.2	10
Cost analysis	1.7	0.8	3
Design catalogues	1.7	1.1	1
Design for service	1.7	0.9	5
Design for serviceability	1.7	0.7	3
Integrated product development	1.7	0.9	8
Concept selection	1.6	0.9	6
Features analysis	1.6	0.9	8
Objectives trees	1.6	0.8	7
Performance Specification method	1.6	0.8	13
Removing mental blocks	1.6	1.1	8
Reverse engineering	1.6	1.0	11
Brain-writing	1.5	0.8	10
Value analysis (VA)	1.5	0.8	5
Bionics	1.4	0.6	12
Computer-integrated manufacturing	1.4	0.6	11
Concurrent engineering	1.4	0.7	10
Design of experiments (Taguchi)	1.4	0.6	10
Quality-function deployment	1.4	0.9	16
Synectics	1.4	0.7	12
Function-cost analysis	1.3	0.6	7
Failure mode and effects analysis (FMEA)	1.2	0.4	13
Peeves analysis	1.2	0.4	15
Value engineering (VE)	1.2	0.6	9
Fault tree analysis	1.1	0.3	14
Finite element analysis	1.1	0.4	15
Statistical process control (SPC)	1.1	0.4	19
Total quality management (TQM)	1.1	0.2	19
Mean Scores	1.8	0.8	7.5

Design Methods with high utilisation score (> 3.0)			
Design Method	Utilisation score	Std Dev	No. of N/A responses
Renderings	4.2	0.7	0
Computer-aided drafting	3.9	0.9	0
Computer-aided design	3.9	1.0	1
Solid modelling	3.9	0.9	0
Design by drawing	3.5	0.9	0
Literature searches	3.5	1.0	1
Prototypes	3.4	1.1	0
Anthropometric analysis	3.3	0.9	0
User research	3.3	0.9	0
User interview	3.3	0.9	0
Questionnaires	3.2	1.2	0
Brainstorming	3.1	1.1	1
Ergonomic analysis	3.1	1.0	0
Market research	3.1	1.0	1
Mean scores	3.5	1.0	0.3

Table 5-12 A summary of the highly utilized and not-applicable design methods

management (1.1). The mean of this list was determined as 1.8 and standard deviation 0.8. The right-hand column of Table 5-12 includes 14 methods arranged in descending order from *renderings* (4.2) to *market research* (3.1). The mean of this list was determined as 3.5 and standard deviation 1.0. The column includes methods traditionally used in industrial design, namely rendering (4.2), computer-aided drafting, and computer-aided design (3.9) solid modeling (3.9) and design-by-drawing (3.5). In contrast the left-hand column includes methods, such as *failure-mode effects analysis* (1.2), *morphological analysis* (1.7) and *features analysis* (1.6), which respondents did not consider were applied by industrial design students. These listed design methods although not generally taught and applied in industrial design programmes are nonetheless important in product design. The major proportion of design work done by industrial design consultancies in Australia is concerned with product design. Therefore it can be argued that most industrial design programmes neglect product design teaching.

The traditional methods such as rendering, design-by-drawing, computer-aided drafting and design, and solid modeling are included as used by students. However, increasingly effective methods such as value analysis, quality-function deployment, benchmarking, among many others are accepted as essential in major projects. Clearly, design methods are not employed to any significant extent by students in major projects and the findings outlined in Chapters 5.1.1 to 5.1.4 are very significant indeed.

In summary, the research findings in Chapter 5.1 showed in the four categories considered the application, by students, to the various sub-categories was disappointing and unsatisfactory. In addition, the large number of "not applicable" responses by lecturers indicated that many activities and design methods were considered not used by industrial design students.

In the category of design methods and process only 14 methods could be classed as *highly utilised* and all of these are "traditional" to industrial design practice. Of the 43 design methods classed as *least utilised* many of these are fundamentally important to design research, for example, morphological analysis, objectives trees, value analysis, quality function deployment, function analysis, design for manufacture and assembly among others.

In Chapter 2.6 the author, based upon 12 years teaching and supervising major projects, listed areas where students have significant problems and these were stated as:

- Poor time management
- Inadequate creative thinking
- A tendency to regard industrial design as a skill and not an integration of disciplines
- Lack of confidence in design decision-making
- Insufficient engagement with the project
- Insufficient appreciation of the link between design and manufacturing
- Inability to make the connections between the learning arising from courses in other faculties, namely marketing, commerce, engineering, science and manufacturing
- A fixation with the product as compared to an understanding of the need
- A capacity to evaluate alternative concepts is lacking

The results of the structured survey confirmed the above problematic issues and highlighted a serious situation in industrial design teaching and learning. Clearly, more work needs to be done to introduce models and systems of teaching that enable students to broaden their capacities and applications to major projects. These results have confirmed the need for the MPD Model and justified the development of the computer-based, suite of design methods, namely the MPD System.

5.2 PART 2: SURVEY OF GRADUATES AND GRADUANDS

This part of the experimental programme included two phases:

Phase 1: A survey of graduates who executed their final-year major projects during 2003. The survey took the form of a questionnaire (refer Appendix 2), mailed to 46 graduates. Forty-one (41) responses were obtained.

Phase 2: A survey of graduands who executed their final-year major projects during 2004. The survey took the form of a questionnaire (refer Appendix 3), mailed to 36 graduands. Thirty-six (36) responses were obtained.

5.2.1 Phase 1 - Survey of graduates: major projects in 2003

Questions 1 to 8 of the survey sought to determine general information about the graduates. Some of these findings have been previously discussed in Section 5.0.2. The full summary of the raw data is shown in Appendix 29 and a condensed version in Table 5-13.

The second column in Table 5-13 includes code numbers used to conceal the identity of respondents. For example, the numbers 8160.03 and 6735.03 identify the respondents. The third column relates to the individual motivation of the student as determined by a method described in Chapter 4.2.2.1. The individual ratings of motivation are listed in table 5-13 and the average is 48 (standard deviation 4.6). These results are tested against the use of design methods later in this chapter.

The fourth column lists the UAI of students when they entered the programme and these results have been discussed in Section 5.0.2 together with the results in columns 5, 6, 7, and 8. These are further tested in following sections.

The 9th and 10th columns are the assessed results of courses IDES4301 (Project Research) and IDES4352 (Project). These results are based on continuous assessment of student work as described in Section 2.1.7.1 and are contrasted with Motivation, UAI, IDES2091 (Design Methodology) and the WAM in Section 5.2.1.1.

Column 11, averages the results from Project Research (column 9) and Project (column 10), and represent the students' overall achievement in the year-long major project.

No.	Respondent Number	Motivation (3)	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language	Proj Resch (9)	Project (10)	Av. Proj Rsrch & Project
1	8160.03	52	N/A	N/A	69	M	English	77	59	68
2	6735.03	48	75	68	65	M	Indonesian	74	86	80
3	6023.03	50	N/A	N/A	64	M	English	75	56	66
4	5284.03	49	90	60	58	M	English	70	63	67
5	7444.03	49	96	67	68	F	Chinese	80	70	75
6	7543.03	46	96	72	72	M	Chinese	64	65	65
7	3022.03	43	81	73	60	M	Chinese	50	69	60
8	7311.03	51	79	66	60	F	English	60	72	66
9	7058.03	51	92	72	67	F	Indonesian	75	62	69
10	7754.03	47	82	73	64	M	English	50	67	59
11	2114.03	48	73	67	50	F	Chinese	78	59	69
12	7336.03	50	82	65	65	F	English	80	83	82
13	7546.03	51	90	69	62	M	English	66	62	64
14	2509.03	36	52	67	71	M	English	60	90	75
15	3215.03	48	79	72	72	M	English	67	58	63
16	3027.03	54	90	75	60	F	Korean	70	67	69
17	7409.03	48	87	70	70	M	English	75	76	76
18	2485.03	48	N/A	76	59	F	Korean	58	76	67
19	6742.03	48	78	66	58	F	Indonesian	55	55	55
20	944.03	51	76	72	58	M	English	75	59	67
21	7685.03	48	N/A	65	70	M	Chinese	58	68	63
22	7373.03	52	89	70	62	M	Chinese	50	60	55
23	7959.03	35	78	67	58	M	Chinese	62	54	58
24	2871.03	46	79	69	57	F	Chinese	55	50	53
25	7249.03	52	91	63	76	M	English	89	87	88
26	5153.03	50	80	85	67	M	English	65	65	65
27	7462.03	46	84	73	61	M	English	74	58	66
28	3022.03	48	N/A	59	58	M	English	50	75	63
29	2184.03	46	87	68	59	M	English	61	50	56
30	7557.03	48	88	67	72	M	English	72	85	79
31	2476.03	52	N/A	69	69	M	English	87	80	84
32	2956.03	44	80	71	54	F	English	67	55	61
33	2424.03	45	95	65	64	M	English	75	79	77
34	7347.03	38	90	67	67	M	English	60	60	60
35	7741.03	49	86	56	57	M	English	54	69	62
36	7423.03	39	91	68	69	F	Chinese	83	57	70
37	7324.03	52	85	68	68	F	Chinese	68	71	70
38	6738.03	48	97	71	62	F	Indonesian	60	60	60
39	3031.03	41	74	70	52	F	Chinese	75	71	73
40	7515.03	51	82	63	59	F	Chinese	65	52	59
41	5364.03	55	N/A	62	61	M	Indonesian	65	55	60
41	Means…..	48	84	68	63	26M : 15F		67	66	67
	Std Dev'n…	4.6	8.8	5.1	6.0			10.3	10.8	8.3

Table 5-13 Response to Questions 1-8 by the 2003 cohort

5.2.1.1 Testing of the data in Table 5-13, the responses to Questions 1-8

Table 5-14 summarises statistical tests applied between independent and dependent variables. The full results from the analysis are shown in Appendix 27. In this analysis of the responses to Questions 1-8 of the survey, of the 2003 cohort, the independent variables, namely Motivation, UAI, IDES 2091, WAM, gender and first language have been tested against assessed results in Project Research, Project and the average of these.

i) The determination of the *motivation* of the students was tested against the assessed results of Project Research, Project and the average of these. The outcome is shown in Table 5-14 and the conclusion is there was no correlation (0.178) between Project

Research, no correlation with the average result (0.121) and no correlation with Project (0.016).

		Project Research	Project	Average of Proj Rsrch & Proj
Motivation	Pearson Correlation	0.178	0.016	0.121
	Sig. (2-tailed)	0.267	0.919	0.452
	N	41	41	41
UAI	Pearson Correlation	0.039	-0.066	-0.019
	Sig. (2-tailed)	0.809	0.68	0.907
	N	41	41	41
IDES2091	Pearson Correlation	-0.184	0.139	-0.024
	Sig. (2-tailed)	0.249	0.386	0.88
	N	41	41	41
WAM	Pearson Correlation	.322(*)	.440(**)	.484(**)
	Sig. (2-tailed)	0.04	0.004	0.001
	N	41	41	41
Gender	Pearson Correlation	0.106	-0.158	-0.036
	Sig. (2-tailed)	0.508	0.323	0.821
	N	41	41	41
First Language	Pearson Correlation	-0.148	-0.18	-0.208
	Sig. (2-tailed)	0.357	0.261	0.192
	N	41	41	41
Proj_Resch	Pearson Correlation	1	0.247	.779(**)
	Sig. (2-tailed)		0.119	0
	N	41	41	41
Project	Pearson Correlation	0.247	1	.800(**)
	Sig. (2-tailed)	0.119		0
	N	41	41	41
Average Project Res/Proj	Pearson Correlation	.779(**)	.800(**)	1
	Sig. (2-tailed)	0	0	
	N	41	41	41

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5-14 A summary of the correlations between selected independent and dependent variables

ii) UAI was tested against the assessed results obtained in Project Research, and Project and there is no significant correlation. This means that the level student performance as measured the by UAI has no relation to final results achieved in major projects.

iii) The results obtained in the Design Methodology course (IDES 2091) were tested against the results achieved in Project Research (-0.184), Project (0.139) and the average of these (-0.024) and there is no significant correlation which suggests that expertise in design methods is not leading to an enhanced final outcome in the major project.

iv) The Weighted Average Mark (WAM) was tested to assess its correlation to the assessed results and it was found that there was significant correlation. For example, Project Research (0.322, p=0.04), Project (0.44, p=0.004) and the average (0.484, p=0.001). Clearly, consistent performance over the period of the programme has a significant bearing on the quality of outcome in the final project.

v) The test of *Gender* indicated that there was no correlation and similarly no correlation with respect to *First Language*.

5.2.1.2 Determination of the design methods used by the 2003 cohort of students in final-year projects and project reports

Appendices 13 and 14 contain the raw data from Questions 9a and 9b of the survey of the 2003 cohort. A portion of the spreadsheet that typically shows the form of the data is shown (for convenience) in Table 5-15 in which 11 methods out of 41 are shown. The responses from the 2003 cohort indicate:

a) the extent to which a specific design method was used in the major project (refer Appendix 13); and
b) the extent to which a specific design method was included in the major project report (refer Appendix14).

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain-writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing
8160.03	2	2	2	1	2	1	2	1	2	2	1
6735.03	1	1	2	1	2	1	1	1	1	2	1
6023.03	1	1	2	1	1	1	1	1	1	1	1
5284.03	1	1	2	1	2	1	1	1	1	1	1
7444.03	2	2	2	1	2	1	1	1	1	2	1
7543.03	1	2	2	1	2	1	1	1	1	2	1
3022.03	1	1	1	2	2	1	1	1	1	2	1
7311.03	1	2	2	1	2	1	1	1	1	2	1
7058.03	1	1	2	1	2	2	2	1	1	1	2
7754.03	2	2	2	1	2	1	1	2	2	2	1
2114.03	2	2	2	1	2	1	1	1	1	1	1
7336.03	2	2	2	1	2	2	1	1	1	2	1
7546.04	1	2	2	1	2	1	1	1	1	1	1
2509.03	1	1	2	1	2	1	2	1	1	1	1
3215.03	2	2	2	1	1	2	1	1	1	2	1
3027.03	2	2	2	1	1	1	1	1	1	1	1
7409.03	2	1	2	1	2	1	1	1	1	2	1
2485.03	2	2	2	1	2	2	1	1	1	2	1
6742.03	2	2	2	1	1	1	1	1	1	1	1
0944.03	1	2	2	1	2	1	1	1	1	2	1
7685.03	2	2	2	1	2	1	1	2	2	2	1
7373.03	1	2	2	1	2	2	1	1	1	2	1
7959.03	2	2	2	2	2	2	2	2	1	2	1
2871.03	2	2	2	1	2	1	2	1	1	1	1
7249.03	1	2	2	1	2	2	1	1	1	2	2
5153.03	1	1	2	1	2	1	1	1	2	2	1
7462.03	2	2	2	1	2	2	1	1	2	2	2
3022.03	1	2	2	1	2	1	1	1	1	1	1
2184.03	1	2	2	1	2	1	1	1	2	2	2
7557.03	2	2	2	1	2	2	1	1	1	2	1
2476.04	1	1	2	1	2	2	1	1	1	2	1
2956.03	1	2	2	1	2	1	1	1	2	2	1
7504.03	1	1	1	1	2	1	1	1	1	2	1
7347.03	1	2	2	1	2	1	1	1	1	2	2
7741.03	1	2	2	1	2	1	1	1	1	2	1
7423.03	2	2	2	2	2	1	1	2	2	2	1
7324.03	1	1	2	1	2	1	1	1	1	1	1
6738.03	1	2	2	1	2	2	1	1	1	2	1
3031.03	2	2	2	1	2	1	1	1	1	2	1
7515.03	2	2	2	1	2	2	1	1	1	2	1
5364.03	1	2	2	1	2	2	1	1	1	1	2
Yes responses	23	11	2	38	4	28	36	37	33	11	35
%	56%	27%	5%	93%	10%	68%	88%	90%	80%	27%	85%

Table 5-15 A portion of spreadsheet from Appendix 13 which shows raw data associated with Q9a, (the responses with respect to methods used in major project.(N=41, 1=Yes, 2=No).

In Table 5-15 the design methods, for example *anthropometric analysis*, *benchmarking*, and *bionics* (41 in total) are arranged in columns across the spreadsheet. Responses to the question by each respondent include 1=Yes, 2=No. The *Yes* responses are summed and the percentage of *Yes* responses stated at the base of the spreadsheet. The percentage responses, as a proportion of the cohort, are then transferred to Tables 5-16a and 5-16b.

Tables 5-16a and 5-16b classify the 41 design methods included in the survey into the respective stages of the MPD Model, namely *Product Planning*, *Task Clarification*, *Concept Generation* and so on. The Table is shown in two sections, 5-16a and 5-16b

Design Method		Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100) — %
PRODUCT PLANNING		
Features analysis?	….in their project work?	61
	…..in their report?	32
Benchmarking	.. in their project work?	27
	…..in their report?	22
Patent search?		56
	…..included in report?	29
SWOT analysis?		61
	…..included in report?	41
Peeves analysis?		24
		12
Project time plan?		90
		78
Market research?		95
		78
Trend studies?		51
		44
User research?		63
		59
TASK CLARIFICATION		
Anthropometric analysis...used in project work?		56
	……included in report?	44
Objectives trees?		12
		2
Function analysis?		61
		41
Function-cost analysis?		29
		17
Questionnaire?		93
		78
CONCEPT GENERATION		
Brainstorming?		93
		56
Brain-writing?		10
		7
Concept selection?		90
		73
Bionics?		5
		7
Synectics?		0
		2
Design catalogues?		27
		15
Morphological analysis?		5
		0

Table 5-16a A summary of responses to the use in project work and in project reports of a range of design methods by the 2003 cohort.

simply because it cannot be clearly shown on a single page. The percentage "Yes" response is shown in the table in the two categories corresponding to a) and b) on page 163. The percentage of students who applied a particular method in their project work is shown in *Red* and the percentage of students who included the method in their project report is shown in *Green*. In Table 5-16a, corresponding to *Product Planning,* 61% of students used Features Analysis in their project work and 32% included this method in their project reports. Similarly 90% of students employed a Project Time Plan but 78% only, included the plan in their project reports.

Design Method	Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100)	%
EVALUATION & REFINEMENT		
Quality-function deployment?		12
		7
Computer-aided design?		88
		76
Ergonomic analysis?		85
		68
Design review?		29
		20
Performance specification method?		12
		2
Design-by-drawing?		85
		51
DETAILED DESIGN		
Fault tree analysis?		2
		5
Life-cycle analysis?		17
		5
Cost determination?		80
		73
Design drawings (engineering)?		71
		56
Value analysis (VA)?		22
		15
Computer-aided drafting?		68
		59
Specification checklists?		20
		12
COMMUNICATION OF RESULTS		
Rapid prototyping?		7
		7
Renderings?		98
		71
Solid modelling?		63
		51
Prototypes?		76
		56
PREPARE FOR PRODUCTION		
Design for assembly (DFA)?		83
		56
Design for disassembly (DFDA)?		44
		22
Design for manufacture and assembly?		80
		59

Table 5-16b A summary of responses to the use in project work and in project reports of a range of design methods by the2003 cohort.

Table 5-17 summarises the findings from Tables 5-16a and 5-16b and shows the average of the percentage responses grouped into the stages of the MPD Model. For example, the average percentage of students who used various methods in the *Product Planning* phase is 59% and the average percentage of students who included those methods in the project reports as 44%.

Design Method	Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100)	%	%
PRODUCT PLANNING.....in their project work		59	
.....in their reports			44
TASK CLARIFICATION		50	
			36
CONCEPT GENERATION		33	
			23
EVALUATION and REFINEMENT		52	
			37
DETAILED DESIGN		40	
			32
COMMUNICATION of RESULTS		61	
			46
PREPARATION for PRODUCTION		69	
			46
	Sum..	52	38

Table 5-17 An overall summary of responses grouped in the phases of the MPD Model for the 2003 cohort.

In the *Concept Generation* phase the percentage of students who used the range of methods was 33% and 23% included such methods in their project reports. If the percentage responses over the phases of Table 5-17 are summed and averaged this leads to an overall "Yes" response of 52%. The percentage responses of students, who included these in their project reports, came to an overall average of 38%.

In summary, the determinations of Table 5-17 indicate that an overall average of 52% of students positively indicated their use of the range of design methods and 38% indicated the inclusion of those methods in their project reports.

5.2.2 Phase 2 - Survey of graduands: major projects in 2004

Questions 1 to 8 of the survey sought to determine general information about the graduands. Some of these findings have been discussed in Chapter 5.0.3. The full summary of the results is shown in Appendix 30 and in condensed form in Table 5-18. The discussion on page 160 concerning Questions 1-8 and which describes the information listed in the respective columns for the 2003 graduates also applies to Table 5-18, the 2004 graduands.

No.	Respondent Number	Motivation (3)	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language	Project Research (9)	Project (10)	Av. Proj Rsrch & Project
1	2275.04	49	92	63	70	M	English	74	85	80
2	2288.04	51	81	65	60	F	Chinese	71	58	65
3	2446.04	46	85	66	61	M	Chinese	53	57	55
4	2363.04	48	96	73	67	F	English	70	68	69
5	8744.04	51	78	65	61	F	Chinese	64	53	59
6	1573.04	46	N/A	68	65	M	Chinese	58	68	63
7	9130.04	49	77	73	52	M	English	70	52	61
8	2300.04	51	85	60	68	M	Chinese	80	77	79
9	7345.04	42	94	67	71	M	English	77	65	71
10	2285.04	37	74	70	64	F	Chinese	50	62	56
11	7330.04	52	84	65	64	M	English	78	52	65
12	1574.04	52	N/A	59	60	M	Spanish	61	62	62
13	7259.04	48	91	75	66	F	English	65	66	66
14	2379.04	48	92	77	67	F	English	68	56	62
15	1208.04	46	80	67	70	M	Norwegian	67	70	69
16	2818.04	46	84	69	65	F	Chinese	75	80	78
17	4128.04	48	97	68	61	F	Chinese	51	35	43
18	7403.04	48	80	67	58.7	F	Chinese	54	72	63
19	8282.04	46	N/A	58	61	M	Norwegian	66	61	64
20	2308.04	48	99	69	75	M	English	74	90	82
21	4016.04	54	N/A	67	71	M	English	62	76	69
22	5244.04	48	86	60	56	M	English	78	57	68
23	2397.04	42	82	67	60	M	Chinese	51	63	57
24	4017.04	46	N/A	51	62	M	Malay	59	55	57
25	7487.04	46	88	67	51	F	English	55	75	65
26	2278.04	51	99	72	75	M	English	80	89	85
27	5240.04	54	89	68	61	M	English	62	36	49
28	7762.04	51	89	61	64	M	English	60	73	67
29	7373.04	44	79	65	61	M	English	74	57	66
30	2272.04	49	92	67	74	M	English	69	93	81
31	2544.04	49	78	69	66	M	Chinese	80	60	70
32	0745.04	48	N/A	N/A	76	M	Chinese	81	73	77
33	2350.04	54	90	62	63	M	English	57	53	55
34	2345.04	46	82	61	63	M	English	50	62	56
35	2424.04	49	76	63	56	M	English	56	34	45
36	4009.04	55	85	68	64	F	Chinese	51	53	52
36	Means…	48	86	66	64	25M : 11F		65	64	65
	Std Dev'n..	3.7	7.0	5.1	6.0			10.1	14.3	10.2

Table 5-18 Response to Questions 1-8 by the 2004 cohort

5.2.2.1 Testing of the data in Table 5-18, the responses to Questions 1-8

Table 5-19 presents a summary of statistical tests, based on the use of SPSS software, applied between the independent and dependent variables. The full results from the analysis are shown in Appendix 28. In this analysis of the responses to Questions 1-8 of the survey of the 2004 cohort, the independent variables, namely Motivation, UAI, IDES 2091, WAM, gender and first language are tested against the assessed results in Project Research, Project and the average of these.

i) The determination of the *motivation* of the students are tested against the assessed results of Project Research, project and the average of these. The outcome is shown in Table 5-19. No significant correlation exists between Project Research (0.138), similarly with Project (-0.098) and the average of these (-0.001).

ii) UAI was tested against the assessed results obtained in Project Research, Project and the average of these. There is no significant correlation which means that the level of student performance as measured the UAI has no relation to final results achieved in major projects.

		Project Research	Project	Average Proj Resrch & Proj
Motivation	Pearson Correlation	0.138	-0.098	-0.001
	Sig. (2-tailed)	0.422	0.568	0.998
	N	36	36	36
UAI	Pearson Correlation	0.076	0.006	0.042
	Sig. (2-tailed)	0.658	0.972	0.807
	N	36	36	36
IDES2091	Pearson Correlation	-0.199	-0.054	-0.137
	Sig. (2-tailed)	0.245	0.754	0.427
	N	36	36	36
WAM	Pearson Correlation	.459(**)	.613(**)	.658(**)
	Sig. (2-tailed)	0.005	0	0
	N	36	36	36
Gender	Pearson Correlation	-0.269	-0.104	-0.206
	Sig. (2-tailed)	0.113	0.547	0.228
	N	36	36	36
First language	Pearson Correlation	-0.152	-0.072	-0.126
	Sig. (2-tailed)	0.376	0.675	0.463
	N	36	36	36
Project Research	Pearson Correlation	1	.376(*)	.760(**)
	Sig. (2-tailed)		0.024	0
	N	36	36	36
Project	Pearson Correlation	.376(*)	1	.888(**)
	Sig. (2-tailed)	0.024		0
	N	36	36	36
Average Project Research	Pearson Correlation	.760(**)	.888(**)	1
	Sig. (2-tailed)	0	0	
	N	36	36	36

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5-19 A summary of the correlations between selected independent and dependent variables.

iii) The results obtained in the Design Methodology course (IDES 2091) were tested against the results achieved in Project Research, Project and the average of these and there is no significant correlation.

iv) The Weighted Average Mark (WAM) was tested to assess its correlation to the assessed results and it was found that there is significant correlation with *Project Research* (0.459, p=0.005) and *Project* (0.613, p=0). Clearly, consistent performance over the period of the programme has a significant bearing on the quality of outcome in the final project.

v) The test of *gender* indicated that there was no correlation and similarly no correlation with respect to *first language*.

These results for the 2004 cohort are consistent with those obtained for the 2003 cohort.

5.2.2.2 Determination of the design methods used by the 2004 cohort of students in final-year projects and project reports

Appendices 15, 16 and 17 contain the raw data from Questions 9a, 9b and 9c. Thirty-six responses from the 2004 cohort were received and these provided answers to the questions, indicating:

a) if a specific design method was used in the major project (Appendix 15);
b) if that design method was included in the major project report (Appendix 16); and
c) if the MPD System was used to facilitate the design method (Appendix 17).

The responses to the questions concerning the use of design methods are recorded in appendices 15, 16 and 17 together with the summed percentage "Yes" responses. The respective determinations have been transferred to Tables 5-20a, 5-20b and 5-20c.

Design Method		Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100)	%
PRODUCT PLANNING			
Features analysis?	….in their project work?		83
	…..in their report?		69
	…..was MPD System used?		72
Benchmarking	.. in their project work?		47
	…..in their report?		39
	…..was MPD System used?		25
Patent search?			64
			47
			42
SWOT analysis?			81
			81
			67
Peeves analysis?			67
			50
			53
Project time plan?			83
			78
			69
Market research?			69
			64
			25
Trend studies?			56
			36
			8
User research?			64
			61
			19
TASK CLARIFICATION			
Anthropometric analysis...	used in project work?		61
	……included in report?		47
			8
Objectives trees?			50
			44
			42
Function analysis?			72
			61
			44
Function-cost analysis?			36
			28
			25
Questionnaire?			61
			42
			19

Table 5-20a A summary of responses to the use in project work and in project reports of a range of design methods by the 2004 cohort

Table 5-20 arranges the methods into the stages of the MPD Model, namely *Product Planning*, *Task Clarification*, *Concept Generation* and so on. In this situation, the 2004 graduands, who used Features Analysis in their project work, amounted to 83% shown in Red, and 69% of the students included the method in their reports, shown in Green. In addition, 72% of the students used the MPD System for this method, shown in Yellow.

Design Method	Percentage of students who applied this method (%)
CONCEPT GENERATION	
Brainstorming?	92
	72
	53
Brain-writing?	14
	14
	6
Concept selection?	78
	81
	36
Bionics?	39
	31
	31
Synectics?	28
	22
	25
Design catalogues?	33
	11
	6
Morphological analysis?	25
	22
	17
EVALUATION & REFINEMENT	
Quality-function deployment? ...in project work	11
	8
…was MPD System used?	8
Computer-aided design?	92
	100
	22
Ergonomic analysis?	83
	75
	11
Design review?	33
	25
	3
Performance specification method?	11
	8
	3
Design-by-drawing?	94
	83
	33
DETAILED DESIGN	
Fault tree analysis?	6
	0
	0
Life-cycle analysis?	19
	8
	14
Cost determination?	75
	75
	56
Design drawings (engineering)?	78
	64
	17
Value analysis (VA)?	17
	8
	11
Computer-aided drafting?	83
	83
	17
Specification checklists?	22
	14
	14

Table 5-20b A summary of responses to the use of a range of design methods in project reports and use of the MPD System by the 2004 cohort

Design Method	Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100)	%
COMMUNICATION OF RESULTS		
Rapid prototyping?		8
		8
		8
Renderings?		94
		78
		17
Solid modelling?		83
		75
		19
Prototypes?		69
		58
		22
PREPARE FOR PRODUCTION		
Design for assembly (DFA)?		53
		42
		14
Design for disassembly (DFDA)?		28
		14
		8
Design for manufacture and assembly?		53
		28
		11

Table 5-20c A summary of responses to the use in project work and in project reports of a range of design methods by the 2004 cohort

Table 5-21 summarises the findings from Tables 5-20a, 5-20b and 5-20c and shows the averages of the percentage responses grouped into the stages of the MPD Model. For example, the average percentage of students who used various methods in the *Product Planning* stage was 68%; the average percentage of students who included those methods in the project reports as 58% and the mean percentage using the MPD System was 42%.

Design Method	Percentage of students who applied this method (10 20 30 40 50 60 70 80 90 100)	%	%	%
PRODUCT PLANNING…..in their project work		68		
…..in their reports			58	
…..by use of the MPD System				42
TASK CLARIFICATION		56		
			47	
				28
CONCEPT GENERATION		44		
			36	
				25
EVALUATION and REFINEMENT		54		
			50	
				13
DETAILED DESIGN		43		
			36	
				18
COMMUNICATION of RESULTS		64		
			55	
				17
PREPARATION for PRODUCTION		45		
			28	
				11
		54	44	22

Table 5-21 An overall summary of responses grouped in the stages of the MPD Model for the 2004 cohort. (Note average 54% over Q9a)

If the percentage responses over the stages of Table 5-21 are summed and averaged and this leads to an overall percentage response of 54%. The percentage responses of students who both used specific methods and included these in their projects report came to an average of 44%. The percentage of responses of students who used specific methods from the MPD System, as an aid, came to an overall average of 22%.

In summary, the determinations of Table 5-21 indicate that an overall average of 54% of students positively indicated their use of the range of design methods, 44% indicated the inclusion of these methods in their project reports and 22% used the MPD System to aid their project work.

5.2.2.3 A comparison of the 2003 and 2004 cohorts in relation to the design methods used in their projects.

Table 5-22 summarises the findings from Table 5-16 (the 2003 cohort) and Table 5-20 (the 2004 cohort). The purpose is to distinguish the response of the respective cohorts. Table 5-22 groups the design methods into the stages of the MPD Model and shows the percentage of students using a particular method; the 2003 cohort shown in Red and the 2004 cohort in Green.

Of the 41 design methods listed, the 2004 cohort, in the extent of their usage of the methods, exceeded the 2003 cohort's usage in 27 instances. For example, consideration of *Features Analysis* reveals 83% of the students in the 2004 cohort used the method compared to 61% of the 2003 cohort.

If this process of comparison is continued over the 41 design methods, included in Table 5-22, the use of the design methods by the 2003 cohort averages 52% (as earlier determined in Chapter 5.2.1.2). Similarly, use of the design methods by the 2004 cohort averages 54% (determined in Chapter 5.2.2.2). This suggests a modest difference between the cohorts, in their use of design methods, however when specific methods are studied, the 2004 cohort has a significantly higher use of a specific method when the MPD System presents a methodology for that specific method. For example, the MPD System has a very effective methodology for *Features Analysis.* In this instance, the 2004 cohort scored 83% versus 61%. Similarly *Benchmarking* scored 47% (2004 cohort) versus 27% (2003 cohort), as can be seen in Table 5-22.

The MPD System does not provide methodologies for all the methods listed in Table 5-22 however it is clear that when a methodology is presented the use by the cohort is higher.

Design Method	Percentage of students who applied this method
PRODUCT PLANNING	
Features analysis? ….2003 cohort	61
…..2004 cohort	83
Benchmarking .. 2003 cohort	27
…..2004 cohort	47
Patent search? ….2003 cohort	56
…..2004 cohort	64
SWOT analysis? ….2003 cohort	61
…..2004 cohort	81
Peeves analysis?	24
	67
Project time plan?	90
	83
Market research?	95
	69
Trend studies?	51
	56
User research?	63
	59
TASK CLARIFICATION	
Anthropometric analysis…2003 cohort	56
……2004 cohort	61
Objectives trees?	12
	50
Function analysis?	61
	72
Function-cost analysis?	29
	36
Questionnaire?	93
	61
CONCEPT GENERATION	
Brainstorming?	93
	92
Brain-writing?	10
	14
Concept selection?	90
	78
Bionics?	5
	39
Synectics?	0
	28
Design catalogues?	27
	33
Morphological analysis?	5
	25
EVALUATION & REFINEMENT	
Quality-function deployment?	12
	11
Computer-aided design?	88
	92
Ergonomic analysis?	85
	83
Design review?	29
	33
Performance specification method?	12
	11
Design-by-drawing?	85
	94
DETAILED DESIGN	
Fault tree analysis?	2
	6
Life-cycle analysis?	17
	19
Cost determination?	80
	75
Design drawings (engineering)?	71
	78
Value analysis (VA)?	22
	17
Computer-aided drafting?	68
	83
Specification checklists?	20
	22
COMMUNICATION OF RESULTS	
Rapid prototyping?	7
	8
Renderings?	98
	94
Solid modelling?	63
	83
Prototypes?	76
	69
PREPARE FOR PRODUCTION	
Design for assembly (DFA)?	83
	53
Design for disassembly (DFDA)?	44
	28
Design for manufacture and assembly?	80
	53

Table 5-22 An overall comparison of the 2003 and 2004 cohorts in their use of specific design methods in the final-year projects.

This issue is confirmed when the first three phases are studied, that is, the *Product Planning*, *Task Clarification* and *Conceptualisation* phases. The MPD System is more focused in these phases, for example, presenting methods such as features analysis, brainstorming, benchmarking, bionics, synectics among 16 others. If the percentage use of design methods is calculated from the data shown in Table 5-22, over the first three stages (21 design methods), then the respective use of design methods are:

1. 2003 cohort, mean use = 48%, and standard deviation = 33%.
2. 2004 cohort, mean use = 57%, and standard deviation = 22%

This is a more representative indication of the increased use of the design methods in the first three phases by the 2004 cohort. The difference was tested using TTest and Chi squared analysis to confirm that the difference between these was significant and not a chance difference. The associated calculations ofmeans, standard deviation and statistical testing is included in Appendix 42 and summarised as: TTest = 0.0427, two tailed where p =0.0427 and Chi-squared, where p= 3.31E-29. Both these findings confirm that the difference is indeed significant and that the 2004 cohort has achieved a considerably higher use of methods in these first three phases.

A further picture of the use of design methods by the respective cohorts is shown in Table 5-23 which contrasts the use of specific methods. In many instances the use of methods by the 2004 cohort well exceeds the 2003 cohort. Examples are, features analysis, benchmarking, patent search, SWOT analysis, objectives trees, bionics, synectics among others. It is believed that this is due to the MPD System having specific sections that include these methods as has been demonstrated above.

The subdivisions of methods used by both the 2003 and 2004 cohorts shown in Table 5-23 are classified into responses of less than or equal to (<=) 50% and more than (>) 50%.

Comparison of Tables 5-23 and 5-12 reveals that the cohorts at UNSW use more design methods than the students in other programmes (indicated by academics in the structured survey). However, there are many areas of agreement, for example, brainstorming, anthropometric analysis, design-by-drawing, computer-aided design, prototypes, to name a few. In contrast, those methods not commonly used included benchmarking, bionics, fault-tree analysis, morphological analysis, life-cycle analysis and value analysis, among others. Table 5-23 shows a wide usage of design methods however there are a significant number of methods poorly utilised by both cohorts.

Design Methods with low utilisation by cohorts(<or =50%)	
Design Method	Utilisation Score (%)
2003 COHORT	
Design for disassembly	44
Design review	29
Function-cost analysis	29
Benchmarking	27
Design catalogues	27
Peeves analysis	24
Value analysis (VA)	22
Specification checklists	20
Life-cycle analysis	17
Objectives trees	12
Performance Specification method	12
Quality-function deployment	12
Brain-writing	10
Rapid prototyping	7
Bionics	5
Morphological analysis	5
Fault tree analysis	2
Synectics	0
Mean….	17
2004 COHORT	
Objectives trees	50
Benchmarking	47
Bionics	39
Function-cost analysis	36
Design catalogues	33
Design review	33
Design for disassembly	28
Synectics	28
Morphological analysis	25
Specification checklists	22
Life-cycle analysis	19
Value analysis (VA)	17
Brain-writing	14
Performance Specification method	11
Quality-function deployment	11
Rapid prototyping	8
Fault tree analysis	6
Mean….	25

Design Methods with high utilisation by cohorts (> 50%)	
Design Method	Utilisation score (%)
2003 COHORT	
Renderings	98
Market research	95
Brainstorming	93
Questionnaires	93
Concept selection	90
Project time plan	90
Computer-aided design	88
Design by drawing	85
Ergonomic analysis	85
Design for assembly	83
Cost determination	80
Design for manufacture and assembly	80
Prototypes	76
Design drawings (engineering)	71
Computer-aided drafting	68
Solid modelling	63
User research	63
Features analysis	61
Function analysis	61
SWOT	61
Anthropometric analysis	56
Patent search	56
Trend studies	51
Mean….	76
2004 COHORT	
Design by drawing	94
Renderings	94
Brainstorming	92
Computer-aided design	92
Computer-aided drafting	83
Ergonomic analysis	83
Features analysis	83
Project time plan	83
Solid modelling	83
SWOT	81
Concept selection	78
Design drawings (engineering)	78
Cost determination	75
Function analysis	72
Market research	69
Prototypes	69
Peeves analysis	67
Patent search	64
User research	64
Anthropometric analysis	61
Questionnaires	61
Trend studies	56
Design for assembly	53
Design for manufacture and assembly	53
Mean...	75

Table 5-23 The design methods with low utilisation (<50%) and high utilisation (>50%) used by the 2003 and 2004 cohorts

Clearly, a great deal more work has to be done by industrial design programmes to provide more structure into the studio process and to consider how a greater provision of design methods can be introduced to achieve more effective teaching and learning in the studio.

5.2.3 The extent to which the MPD System contributed to the stages of the 2004 cohort's major project

This chapter assesses both the need for, and the contribution of, the MPD System to major projects. Firstly, the responses from the 2003 cohort record their perception of the need for a more comprehensive, computer-integrated system of design methods (note that this cohort had no knowledge of the MPD System). Secondly, responses from the 2004 cohort record their experience in using the MPD System. The research proposition that applies to this section is:

> 6. Students who have used the MPD System claim it is of considerable assistance in their major project work.

The raw data from Question 10 of the 2003 cohort survey is included in Appendix 18. The question asked respondents "do you feel the need for a more comprehensive, computer-integrated system of design methods". The possible answers were 1=Yes, 2=No and 3=Not sure. A summary of these responses is shown in Table 5-24. The table shows that 31 respondents out of 41 (75.6%) believed there was a need for a computer-integrated system of design methods. Eight respondents (19.5%) felt that such a system was unnecessary and two (4.8%) were unsure.

Respondents who felt the need for a more comprehensive computer-integrated system of design methods	Respondents who did not feel a need for a compehensive computer-integrated system of design methods	Respondents who were not sure about such a need.
31	**8**	**2**

Table 5-24 The opinions of the 2003 cohort of students as to their perception of the need for a more comprehensive, computer-integrated system of design methods than is currently available

Question 11 in the survey of the 2004 cohort asked the same question however in this instance this cohort had experience of a comprehensive, computer-integrated system of

Respondents who felt the need for a more comprehensive computer-integrated system of design methods, namely the MPD System	Respondents who did not feel a need for a compehensive computer-integrated system of design methods, namely the MPD System	Respondents who were not sure about such a need.
29	**6**	**1**

Table 5-25 The opinions of the 2004 cohort of students as to their perception of the need for a more comprehensive, computer-integrated system of design methods, namely the MPD System.

design methods, namely the MPD System. The raw data of responses is shown in Appendix 19 and summarised in Table 5-25 which shows that 29 respondents out of 36 (80.5%) believed there was a need for a computer-integrated system of design methods. Six respondents (16.6%) felt that such a system was unnecessary and one (2.7%) was unsure.

	Minimal (1) – Considerable (5)	Mean Score
PRODUCT PLANNING		3.3
TASK VERIFICATION		3.6
CONCEPT GENERATION		3.2
EVALUATION & REFINEMENT		3.2
DETAILED DESIGN		3.3
COMMUNICATION of RESULTS		3.0
PREPARATION for PRODUCTION		3.3

Table 5-26 Opinions of 2004 cohort of students as to the extent that the MPD System contributed to the various defined stages of their major project

Respondents from the 2004 cohort were further asked “to what extent the MPD System contributed to their major project work”. The question included a range of possible responses from *minimal* = 1 to *considerable* = 5. The raw data associated with the responses is shown in Appendix 20.

Table 5-26 summarises these responses and shows that a mean score of 3.3 for the *Product Planning* stage which indicates a belief that the MPD System has positively contributed to major project work. This order of response similarly applies to the other stages, namely *Task Verification*, *Concept Generation* and so on. The 2003 cohort was not asked this question because they have not experienced the MPD System. In each instance the response to each phase exceeded the Likert midpoint of 3.0. Therefore there is a unanimous response that the MPD System’s contribution to their project work approached a level of ”considerable” assistance.

Question 11 to the 2003 cohort sought their opinion “as to how and in what areas of the major project a computer-integrated system might help in project work”. Appendix 21 contains the raw data from this question and Table 5-27 summarises this data in responses that range from “Yes” it would be of help; “No”, it would not be of help; “Not sure” and “Not Applicable”. The Not Applicable responses resulted from Question 10 and were those responses that did not consider a computer-integrated system necessary in a major project.

	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
Yes…….	28	30	14	21	28	26	26	22
No……..	1	1	9	6	1	4	5	6
Not sure..	4	2	10	6	4	3	2	5
N/A……..	8	8	8	8	8	8	8	8

Table 5-27 The opinions of the 2003 cohort with respect to the extent to which a comprehensive, computer-integrated selection of design methods might help in various areas of their project work.

In areas of *Planning*, 28 respondents (68.3%) felt a computer-integrated system would help in *Planning* associated with the project. Thirty (30) respondents (73%) believed that the system would help in the *identification of the steps in the process* and so on with each category clearly indicating a belief in the value of a computer-integrated system.

	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
Yes…..	27	21	10	19	25	24	23	25
No…….	1	6	14	6	0	4	3	1
Not sure…	1	2	5	4	4	1	3	3
N/A……..	7	7	7	7	7	7	7	7

Table 5-28 The opinions of the 2004 cohort with respect to the extent to which the MPD System helped in various areas of their project work.

Similarly the 2004 cohort were asked "how and in what areas the MPD System had helped in project work". Appendix 22 contains the raw data and Table 5-28 summarises the responses. In *Planning* 27 respondents (75%) confirmed the MPD System's value. Twenty-one respondents (58%) confirmed that the System had helped *in the Identification of the steps of the process*.

Design Method	Percentage of students (10 20 30 40 50 60 70 80 90 100)	Yes %	No %	N/S %	N/A %
PLANNING …..2003 cohort		68	3	10	20
….2004 cohort		75	3	3	20
IDENTIFICATION OF STEPS IN PROCESS		73	2	5	20
		58	17	6	19
FACILATE IDEA GENERATION		34	22	24	20
		28	39	14	19
ORGANISATION OF CREATIVE PROPOSALS		51	15	15	20
		53	17	11	19
SYSTEMATIC CLASSIFICATION OF DATA		68	2	10	20
		69	0	11	19
COMMUNICATION OF PROJECT FINDINGS		63	10	7	20
		67	11	3	19
DETERMINATION OF PRODUCT COST		63	12	5	20
		64	8	8	19
CONSIDERATION OF MANUFACTURING		54	15	12	20
		69	3	8	19

Table 5-29 The opinions of the 2003 and 2004 cohorts with respect to the extent to which a comprehensive, computer-integrated selection of design methods might help in various areas of their project work.

The responses of both cohorts expressed in Tables 5-27 and 5-28 are combined and included in Table 5-29. This shows (aligned with PLANNING) the percentage of respondents from the 2003 cohort (violet = yes response, red = No + N/S + N/A) and for the 2004 cohort (dark green = yes response, and light green = No + N/S+ N/A).

Clearly, the results indicate that there is a:

1. perceived need for a computer-integrated system; and
2. confirmed belief that the MPD System is valued towards project work.

Question 12 of the 2003 cohort sought to understand impressions of the extent to which a computer-integrated system of design methods could assist in the phases listed in Table 5-29, namely in *planning*, *identification of the steps in the process*, *facilitate idea generation* and so on. This was an optional question resulting from the earlier question 10 the responses to which are listed in Table 5-24. The results are listed in Table 5-30 where a number of students, for example: 4 out of 41 (10%) believed such a system would be too complicated. In contrast, 37 respondents (90%) believed such a system was not too complicated. Three (7.3%) believed the system too time consuming however 38 (92.6%) believed the system was not too time consuming and so on.

Response	too complicated	time consuming	did not understand	unnecessary
Yes……….	4	3	3	5
No…………	0	0	0	1
Not applicable..	37	38	38	35

Table 5-30 The opinions of the 2003 cohort with respect to the extent to which a comprehensive, computer-integrated selection of design methods might not help in various areas of their project work.

Question 13 of the 2004 cohort asked a similar question but in this instance the cohort was specifically asked: In what ways did the MPD System fail to help in phases of the project, such as, *planning*, *identification of the steps in the process*, *facilitate idea generation* and so on as listed in Table 5-29. The results are listed in Table 5-31 where a number of students, for example, one out of 36 (2.7%) believed the system too complicated, 3 (8.3%) too time consuming, and 2 (5.5%) unnecessary.

	too complicated	too time consuming	did not understand	Unnecessary
Yes……….	1	3	0	2
No………..	2	1	2	1
Not applicable..	33	32	34	33

Table 5-31 The opinions of the 2004 cohort with respect to the extent to which the MPD System did not help in various areas of their project work.

The responses *No* and *Not Applicable* combine to suggest that a computer-integrated system or the MPD System was not too complicated, too time consuming, was understandable and necessary. For example, 35 (97.2%) believed it was not too complicated, 33 (91.6%) believed the system understandable, and 34 (94.4%) believed the system necessary.

In summary, the findings reveal that there is an overwhelming belief that the MPD System is valued highly in its contribution to project work and that, amongst both cohorts, there is a conviction that a system of computer-integrated design methods is needed to aid project work. These findings repudiate the long-held belief, by many teaching staff in particular, that systematic approaches are unnecessary and impede creative potential. Clearly, the students feel that some structure and support in the form of design methods is essential towards more effective studio work. The findings in this section of the results are significant because no research of this specific type has addressed the effectiveness of student application and the use of methods and process in the studio.

5.2.4 Open-ended question posed to the 2003 and 2004 cohorts

i) Question 13 of the questionnaire, directed to the 2003 cohort, asked the respondents to indicate “how could they have executed the project more effectively”. The responses are listed in Appendix 25. Samples of the responses are as follows:

- Incorporate methods in Studio 3 and 4 making it part of design process
- Planning time important, need to stress, generate time plan each week.
- Use other methods to generate ideas, for example, morphological analysis.
- Better decision-making at critical stages
- Structured phases in design process (knowing the next step)
- Employ systematic design methods
- Introduce instruction booklet/software that outlines the different methods available
- Better time planning and response to systematic checkpoints / criteria
- Mentors to encourage use of design methods
- More effective time planning
- Incorporate more consideration of cost in execution of product
- Provide a more concrete structure for the development process
- Provide some type of checklist system that can be tailored for each project.
- Milestones specified for the whole process
- More thorough pre-process plan
- More time on methodology selection
- Better understanding of exactly what design methodology is.
- The provision of a more structured planning procedure
- Relating more of the techniques that were learnt during the course.
- More time should be spent on Project Planning

- Could have incorporated more design methodologies into the project, for example, Objectives Trees, Peeves Analysis, SWOT Analysis. Such methodologies might have substantiated the research.
- Using computer-integrated system could have helped with initial research and the collation/interpretation of initial results.
- Could have prepared more before start of project to understand the steps and prepare information.
- Establish an effective time plan.
- Better project management planning.
- More detailed time plan
- Seek more understanding of the design process.
- More hands-on approach to manufacturing.
- Stricter adherence to schedule
- Meticulous listing of tasks

These responses clearly suggest that students need a more structured approach and it is noted that these students did not have awareness of or exposure to the MPD System. The belief held by many staff in the teaching of industrial design that design methods are not central to the studio process is not shared by the students of the 2003 cohort.

ii) Question 14 of the questionnaire, directed to the 2004 cohort, asked the respondents to provide suggestions as to "how the MPD System could be improved". The responses are listed in Appendix 26. Samples of the responses are as follows:

- Break up the MPD System into sections that might equate to specific types of projects, for example furniture or a hand-held electronic device
- Provide a larger variety of examples/case studies
- Complete set of examples of each step of a real life product and explain how each step contributes to the product development process
- Direction to where more information on manufacturing, ie. Contacts for suppliers, contacts for metal casting etc.
- Make the examples in the in the various stages consistent with respect to one type of product.
- Categorise the methodologies to suit different approaches ie., innovative design, improving an existing product, etc.
- Apply MPD System in the studio but select projects that demand selected methodologies so that students can experience the range of methods.
- Commence application of the MPD System from year 1. This is the only way to consolidate expertise.
- It is believed the taxonomy is very helpful in product planning and task verification but not so much in conceptualisation. If the taxonomy could trigger creative thought through images, examples of innovations, these might interest students more.
- I think the MPD System is great however time allowed for Project does not allow enough time to pursue.
- Make MPD System in PDF form for printing out.
- More examples of cost determination.
- More help on manufacturing
- Guide to calculate cost
- The MPD System should be demonstrated in a "walk through" manner prior to embarking on the final-year project.

- Insisting that the MPD System is used throughout the Planning and development stages.
- The MPD System is a way of thinking and therefore one must adopt a certain disposition for it to be of value. Must be used from the first as a form of mental discipline.
- The MPD System's importance in certain areas of the project should be stressed to students.
- Such areas are cost determination, manufacturing and planning.
- By completing the sections where the software states "awaiting content". More importantly start integrating it earlier than year 4. Stress the importance to students.
- Could be made even more comprehensive which would save users a great deal of time.
- Provide a checklist to be able to see what stage you are up to and be aware of the next step.
- Provide links to supplement the more complicated areas
- Provide more clear examples.
- Make methodology examples less complicated and more understandable
- Conduct the Design Methods earlier in the program so that students are more aware of design methods
- Incorporate methods into the studio
- Set the MPD System as part of studio projects to determine how it can introduce a more holistic approach.
- More focus on the first two stages of the MPD System (Project Planning and Task Verification).
- To provide the capability for users to post and thus share useful web-links etc.
- Simplify the MPD System to make it less overwhelming.
- Emphasise certain steps in the MPD System.

These responses indicate an extremely positive view of the MPD System and point to areas where its application and content could be improved. Consistently recurring suggestions apply to the introduction of the MPD System into studio projects much earlier in the degree programme. Other responses apply to the provision of examples and structuring the System towards specific product groups.

The next chapter is concerned with the rigorous examination of student project reports to determine the tasks carried out in the project reports and the overall complexity of the projects.

5.3 PART 3: EVALUATION OF FINAL-YEAR PROJECT REPORTS

In this part of the thesis, the reports have been examined by an independent assessor. The purpose was to understand the tasks accomplished and the complexity of each report. The phases of the examination process were as follows:

Phase 1: An examination of 30 major-project reports produced in 2003 by a cohort of students with an understanding of design methods but with no access to the "MPD System"; and

Phase 2: An examination of 30 major-project reports each produced in 2004 by individuals' specifically educated and competent in both the "MPD Model" and "MPD System".

Thirty *project research* and *project* reports from the 2003 cohort were selected at random from the 46 available. Similarly, thirty *project research* and *project* reports from the 2004 cohort were selected at random from the 36 available. These sixty *project research* and *project* reports were studied over a period of six weeks. The report pairs were selected on a random basis and assessment in each instance proceeded without knowledge of the student or cohort. The assessment was carried out by Mr. Robert White whose *Curriculum Vitae* is shown in Appendix 8.

5.3.1 Examination of 30 project reports from the 2003 cohort

The basis of the examination and the assessment instrument used has been explained in Section 4.3.1, and the assessment instrument shown in Table 4-8.

Table 5-32 lists the results of the examination. The columns 2-8 are assessments of the projects in sections that equate to the stages of the MPD Model. For example, in column 2 the various tasks associated with *Product Planning* have been assessed, that is, the extent to which these tasks have been included, in the project reports, has been assessed out of 10. In the case of the student, code no. 8160.03, the assessment of the tasks that have been carried out is 2.6 (column 2, *Product Planning*). The mean of the results achieved by the cohort of students in Product Planning is 3.9 out of 10. The respective results that apply over the stages of the MPD Model are shown in the summary of the means and standard deviations in columns 2-8.

Column 9 summarises the results over the seven stages and produces an over-all assessment out of 10. In the case of the student 8160.03 the average result is 4.1, and the mean for the cohort is 3.9. The overall score (out of 1270) shown in column 10 results from the computation of all the tasks using the assessment instrument presented in Table 4-8. The score achieved in column 10 indicates a spread ranging from the highest, 963 to the lowest, 180. The mean of the range is 498 (standard deviation 222.6). These outcomes define the extent to which various tasks have been accomplished in the project and are compared to a maximum possible score of 1270. Therefore the mean of 498 represents a score (498/1270=39%) which is considered unsatisfactory. The final column shows an overall assessment of the two reports and is a considered evaluation by the independent assessor. The average assessment of the 30 *Project Research* and *Project* reports, produced by the 2003 cohort, is 47 out of 100 (with a standard deviation of 19.1).

1	2	3	4	5	6	7	8	9	10	11
Code No.	Product Planning /10	Task Clarification /10	Concept Generation /10	Evaluation Refinement /10	Detailed Design /10	Communication /10	Prepare production /10	Overall Score /10	Overall Score /1270	Over all assessment /100
8160.03	2.6	3.1	6.0	5.3	6.0	3.9	1.2	4.1	525	45
6735.03	4.4	5.5	4.5	4.4	5.9	5.4	5.8	5.0	640	55
6023.03	4.7	4.9	5.5	4.8	5.8	5.5	3.8	5.1	644	55
5013.03	1.7	1.6	1.5	1.5	0.3	1.8	1.1	1.4	180	20
7444.03	1.7	3.2	4.0	3.1	3.4	3.8	1.8	3.0	386	40
3022.03	3.6	3.1	4.0	3.5	4.0	3.8	3.0	3.6	455	45
7058.03	6.4	7.1	7.0	6.7	7.0	7.4	6.2	6.9	873	75
2114.03	3.4	3.9	4.8	3.1	4.2	4.1	2.0	3.7	474	40
7336.03	3.7	2.9	2.5	2.3	3.9	4.2	3.5	3.3	414	45
7546.03	5.5	1.7	0.0	0.2	0.0	0.5	1.7	1.5	189	15
2509.03	5.5	7.1	6.8	6.5	6.5	7.3	5.0	6.4	819	75
3215.03	3.3	5.6	5.8	5.5	4.8	4.8	3.5	4.8	612	55
3027.03	6.1	6.9	7.3	7.3	7.1	6.1	1.9	6.4	811	70
7409.03	6.2	7.5	8.5	8.3	8.0	8.3	5.7	7.6	963	85
2485.03	4.0	5.5	6.0	5.1	4.1	5.3	4.1	4.9	623	55
6742.03	3.5	3.0	2.0	2.5	3.2	3.3	1.1	2.8	355	30
7685.03	4.0	3.9	5.3	4.5	2.8	4.2	3.0	4.1	517	55
7958.03	1.7	3.0	2.8	2.6	1.7	3.2	2.0	2.4	311	30
7318.03	3.6	4.3	4.8	5.2	3.6	4.6	3.6	4.3	544	60
7249.03	3.7	4.4	5.3	4.6	6.3	5.1	2.4	4.6	587	55
7462.03	2.9	3.6	0.8	1.6	1.3	1.5	0.9	1.9	241	20
7557.03	1.7	1.4	3.3	2.3	3.3	4.4	1.6	2.6	332	40
6737.03	2.8	2.6	1.5	1.7	1.3	1.0	0.9	1.8	227	20
7149.03	4.1	3.8	2.8	3.2	3.1	2.0	2.7	3.1	399	45
2476.03	6.7	7.7	7.5	8.3	8.6	8.1	5.6	7.6	963	75
2956.03	4.8	4.6	2.3	1.6	3.9	3.6	2.5	3.4	431	60
7347.03	4.1	2.0	2.8	1.7	1.1	1.6	0.8	2.2	276	20
7423.03	3.3	3.7	1.8	1.6	1.3	0.2	0.8	1.9	244	25
7324.03	3.4	3.6	4.0	3.1	1.9	2.7	1.7	3.0	387	30
7515.03	3.0	4.1	5.3	5.2	2.5	3.9	4.1	4.0	511	55
Means..	3.9	4.2	4.2	3.9	3.9	4.0	2.8	3.9	498	47
Std. Dev.	1.4	1.8	2.2	2.1	2.3	2.1	1.6	1.8	222.6	19.1

Table 5-32 Results from the study of 30 major project reports from the 2003 cohort

Figure 5.1 presents the scores from column 10 and arranges these in descending order. The average score of the group (N=30) is 498 (the average of column 10). The figure clearly shows the considerable spread of these results. The distribution of the scores is normal, slightly skewed to the right in the normal distribution shown in Appendix 37, Figure A-5.

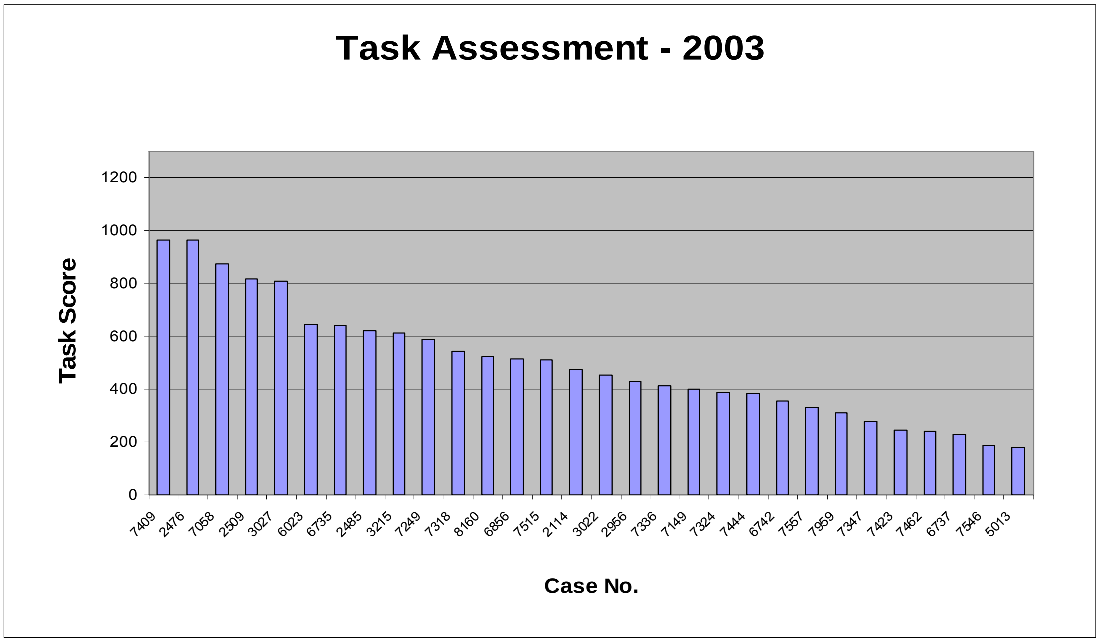


Figure 5.1 Assessment of the tasks and structure included in the 2003 cohort reports

5.3.2 Examination of 30 project reports from the 2004 cohort

Thirty *Project Research* and the companion *Project* reports were selected at random from the 36 reports produced by the 2004 cohort. The basis of the examination is identical to that previously described in 5.3.1.

Table 5-33 lists the results of the examination. The columns 2-8 are assessments of the projects in sections that equate to the stages of the MPD Model. For example, in Column 2 the various tasks that are associated with *Product Planning* have been assessed and the extent to which these tasks have been addressed, in the project reports, has been assessed out of 10. In the case of the student, code no. 2275.04, the assessment of the tasks that have been carried out within the *Product Planning* stage is 7.0. The average of the results achieved by the cohort of students in Product Planning is 5.5 out of 10. The respective results that apply over the stages of the MPD Model is shown in the mean summary of the means and standard deviations for columns 2-8.

1	2	3	4	5	6	7	8	9	10	11
Case No.	Product Planning /10	Task Clarification /10	Concept Generation /10	Evaluation Refinement /10	Detailed Design /10	Communication /10	Prepare production /10	Overall Score /10	Overall Score /1270	Over all assessment /100
2275.04	7.0	6.8	8.5	7.8	7.9	7.2	3.9	7.2	919	85
2288.04	7.0	6.6	7.5	5.3	6.6	7.1	1.3	6.1	777	40
2446.04	6.3	6.3	7.3	6.7	7.4	7.2	6.0	6.8	860	75
2363.04	5.5	6.7	7.3	6.3	4.8	5.8	3.3	5.8	743	70
8744.04	5.6	7.5	7.3	7.5	7.6	7.6	4.8	6.9	876	75
1573.04	7.0	5.9	7.5	8.0	7.6	8.9	7.2	7.5	947	83
9130.04	5.7	5.0	5.3	4.5	3.3	4.0	2.2	4.5	571	55
2300.04	4.5	5.2	6.8	6.1	4.8	6.5	2.6	5.3	675	60
7345.04	5.1	7.0	6.8	7.5	7.1	6.8	2.6	6.3	802	75
2285.04	4.6	6.1	7.0	6.3	6.3	6.6	3.4	5.8	736	60
7330.04	2.6	5.7	4.5	4.8	4.4	3.6	3.6	4.1	526	55
1574.04	5.4	5.3	4.5	4.5	2.2	2.8	1.8	4.0	508	50
7259.04	5.6	5.6	5.3	5.0	5.3	4.8	2.8	5.1	642	50
2818.04	5.5	5.4	6.8	5.2	6.1	4.8	0.0	5.2	656	65
7403.04	4.5	5.8	7.5	7.7	5.9	6.1	2.6	5.9	753	75
2308.04	7.3	8.2	8.7	8.8	8.8	7.5	5.0	7.9	1005	85
4016.04	6.3	6.5	7.0	5.6	6.2	6.1	3.3	6.1	769	75
5244.04	4.7	7.2	6.8	7.0	7.3	8.0	5.2	6.6	842	78
2397.04	5.1	7.6	7.8	7.8	6.1	7.9	5.2	6.9	873	75
4017.04	3.7	5.1	4.3	4.2	3.5	3.7	0.2	3.8	477	45
7487.04	5.0	5.5	4.5	4.8	3.8	3.7	4.1	4.5	575	60
2278.04	6.0	7.0	8.5	8.3	7.4	7.7	4.9	7.2	919	95
7762.04	6.7	5.2	5.5	6.3	4.4	1.2	1.1	4.6	583	55
7373.04	5.5	5.7	6.5	6.3	5.4	4.8	1.9	5.4	685	65
2272.04	7.5	8.4	8.0	8.1	8.3	8.2	6.6	7.9	1007	85
2544.04	5.0	5.4	5.8	5.5	6.3	6.4	4.4	5.4	691	68
0745.04	3.3	5.3	6.0	5.0	4.3	3.2	0.8	4.2	530	65
2350.04	4.2	5.1	4.5	5.7	5.3	5.1	0.3	4.6	584	60
2345.04	5.7	7.0	7.3	6.7	4.5	5.1	3.1	5.8	742	75
4009.04	5.9	5.9	6.8	7.0	7.5	6.3	4.8	6.4	810	70
Means..	5.5	6.2	6.6	6.3	5.9	5.8	3.3	5.8	736	68
Std. Dev.	1.17	0.96	1.29	1.31	1.64	1.86	1.90	1.19	151.33	13.16

Table 5-33 Results from the study of 30 major project reports from the 2004 cohort

Column 9 summarises the results over the seven stages and produces an over-all assessment out of 10. In the case of the student 2275.04 the mean result is 7.2, and the mean for the cohort is 5.8. The overall score (out of 1270) shown in column 10 results from the computation of all the tasks and this method was the basis of the assessment of the reports. Table 4-8 shows the instrument used to compute the score and sub-scores. The final column shows an overall assessment of the reports and is a considered evaluation by the assessor. The average of the 30 assessed *Project Research* and *Project* reports, produced by the 2004 cohort, is 68 out of 100. Figure 5.2 presents the scores from column 10 and arranges these in descending order. The highest score 1007, the lowest 477 and the average of the scores shown on the graph 736 (the average of column 10).

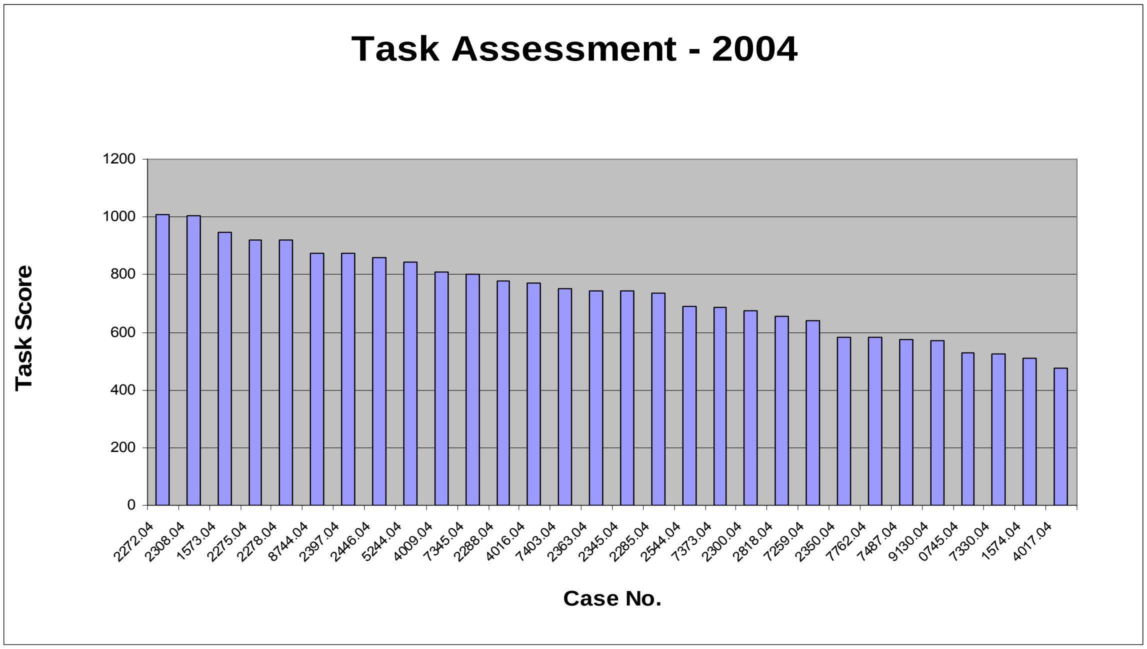


Figure 5.2 Assessment of the tasks and structure included in the 2004 cohort reports

The figure displays the spread in the scores from the highest, 1007 to the lowest, 477. Testing the distribution of the results from column 10 produces a normally distributed curve as shown in Appendix 38, Figure A-5.

5.3.3 A comparison of 30 project reports respectively from the 2003 and 2004 cohorts

Table 5-34 summarises the results from the 2003 and 2004 cohorts. In each category the 2004 cohort has achieved considerably higher assessments than the 2003 cohort. In *Product Planning* the 2003 executed tasks to an assessed level of 3.9 and correspondingly the 2004 cohort achieved 5.5, a significant difference. In terms of the over-all assessment of the tasks carried out shown in column 9 the respective scores are 3.9 and 5.8. The over-all assessment shown in column 11 shows a mark of 47 for the 2003 cohort and 68 for the 2004 cohort.

1	2	3	4	5	6	7	8	9	10	11
Mean results	Product Planning /10	Task Clarification /10	Concept Generation /10	Evaluation Refinement /10	Detailed Design /10	Communication /10	Prepare production /10	Overall Score /10	Overall Score /1270	Over all assessment /100
2003..mean	3.9	4.2	4.2	3.9	3.9	4.0	2.8	3.9	498	47
... .std dev	1.4	1.8	2.2	2.1	2.3	2.1	1.6	1.8	222.6	19.1
2004..mean	5.5	6.2	6.6	6.3	5.9	5.8	3.3	5.8	736	68
...std dev	1.2	1.0	1.3	1.3	1.6	1.9	1.9	1.2	151.3	13.2

Table 5-34 A summary of the average results from the study of 30 major project reports from the 2003 and 2004 cohorts.

This overall assessment is the examiners mark for the thesis and results from the study of the tasks employed, methods used and the overall quality of the project reports. This assessment appears at some variance to the assessment given by staff at the end of the course and this aspect is discussed in Section 6.5f.

Figure 5.3 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. 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.

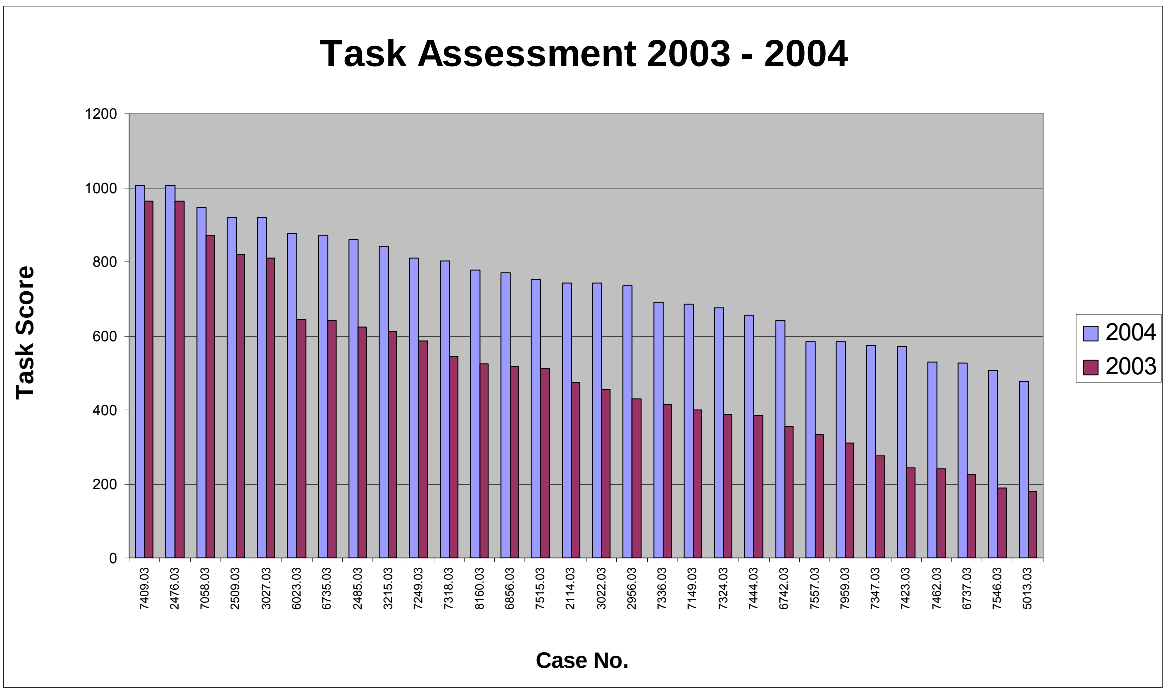


Figure 5.3 Bar chart contrasting the scores associated with the assessment of tasks included in the 2003 and 2004 cohort reports

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 (refer column 10 Tables 5-32 and 5-33) 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 (analysis located in Appendix 43) confirm a significant difference between the two cohorts.

Because the two cohorts are similar academically (refer Chapter 5.04), 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. 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.

5.3.4 Examination of the *Complexity* of 30 project reports from the 2003 cohort

Thirty *Project Research* and the companion *Project* reports were selected at random from the 46 reports produced by the 2003 cohort. These reports were the same as studied in the previous chapter, namely 5.3.1. The basis of the examination and the assessment instrument used has been explained in Chapter 4.3.2.

1	2	3	4	5
Case No.	Degree of Complexity /10	Degree of Complexity /350	Complexity Design Research /160	Complexity Project Research /200
8160.03	5.0	174	95	79
6735.03	5.8	203	95	108
6023.03	5.3	185	79	106
5013.03	1.8	63	24	39
7444.03	2.5	86	22	64
3022.03	4.6	160	66	94
7058.03	6.7	234	108	126
2114.03	3.7	130	52	78
7336.03	3.0	104	31	73
7546.03	4.3	149	64	85
2509.03	8.1	282	117	165
3215.03	4.3	149	70	79
3027.03	6.1	214	82	132
7409.03	7.0	244	101	143
2485.03	4.7	166	65	101
6742.03	4.0	139	52	87
6856.03	4.9	172	63	109
7959.03	2.5	88	28	60
7318.03	4.1	145	58	87
7249.03	4.9	172	67	105
7462.03	3.5	124	51	73
7557.03	2.5	87	24	63
6737.03	2.5	88	33	55
7149.03	3.2	111	45	66
2476.03	7.0	246	106	140
2956.03	4.4	155	66	89
7347.03	3.7	128	59	69
7423.03	3.6	125	50	75
7324.03	3.8	134	61	73
7515.03	3.5	123	64	59
Means…	4.4	153	63	89
Std.Dev.	1.53	53.39	26.12	29.31

Table 5-35 Results from the assessment of the 2003 Project Research and Project reports with respect to their Complexity

Table 5-35 lists the results of the examination where the respective projects were assessed based upon use of the instrument shown in Table 4.9. Column 3 presents the score associated with assessment, out of 350. For example, the first student code no. 8160.03 has scored 174 out of 350. The average of the range of scores for the 2003 cohort with respect to 30 projects is shown at the bottom of Column 3 and is 153 and standard deviation 53.4. This group of scores is presented graphically using a vertical bar chart to demonstrate the relationship between the projects (refer Figure 5.4 below). Column 2 presents a score out of 10 and is derived by interpolating the score in column 3 (out of 350) to a score out of 10. The mean score for this cohort is 4.4.

Figure 5.4 presents the results of the *Complexity* determination for the 30 *Project Research* and *Project* reports arranged in descending order. These indicate a range from the highest, 282 to the lowest 63, with a mean of 153.

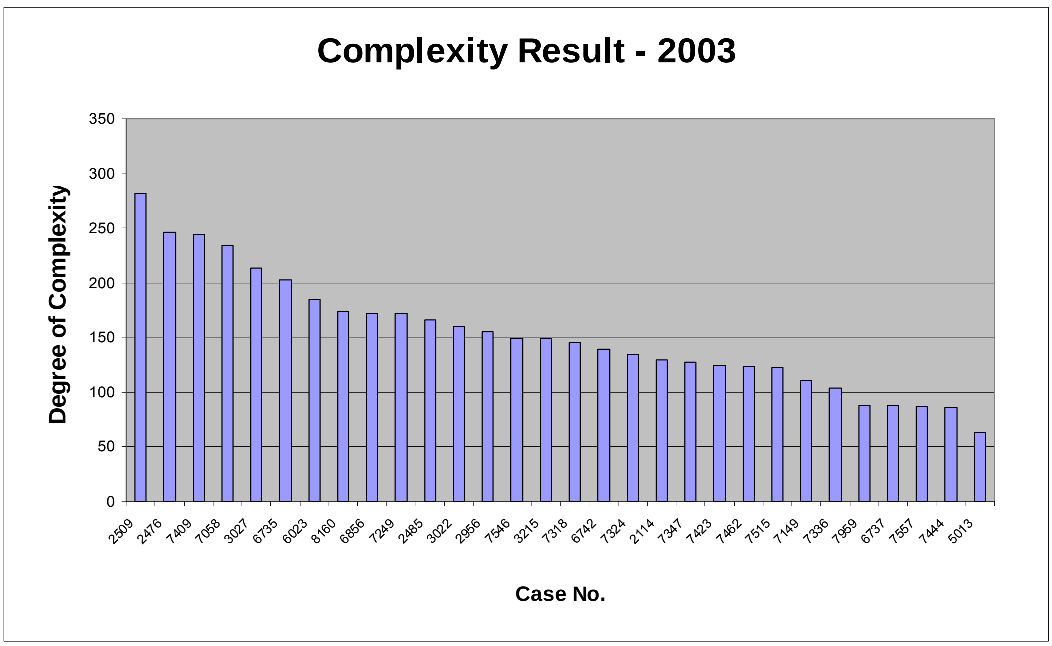


Figure 5.4 Bar chart showing the assessment of the 2003 Project Research and Project reports, with respect to Complexity, arranged in descending order.

The mean result of 153 represents a score (153/350=43.7%) which suggests that the group of projects are not overly complex. This is evident when the projects are considered because there has been a tendency in recent years for students to select relatively simple projects with limited challenge and this is clearly showing up in the results.

Testing the distribution of the results in column 3 produces a normally distributed curve as shown in Appendix 37, Figure A-6.

Alternatively the data is presented in matrix form and that is the purpose of columns 4 and 5 in Table 5-35. By arranging the scores on two coordinates a matrix can be constructed and is presented in matrix form as shown in Figure 5.5.

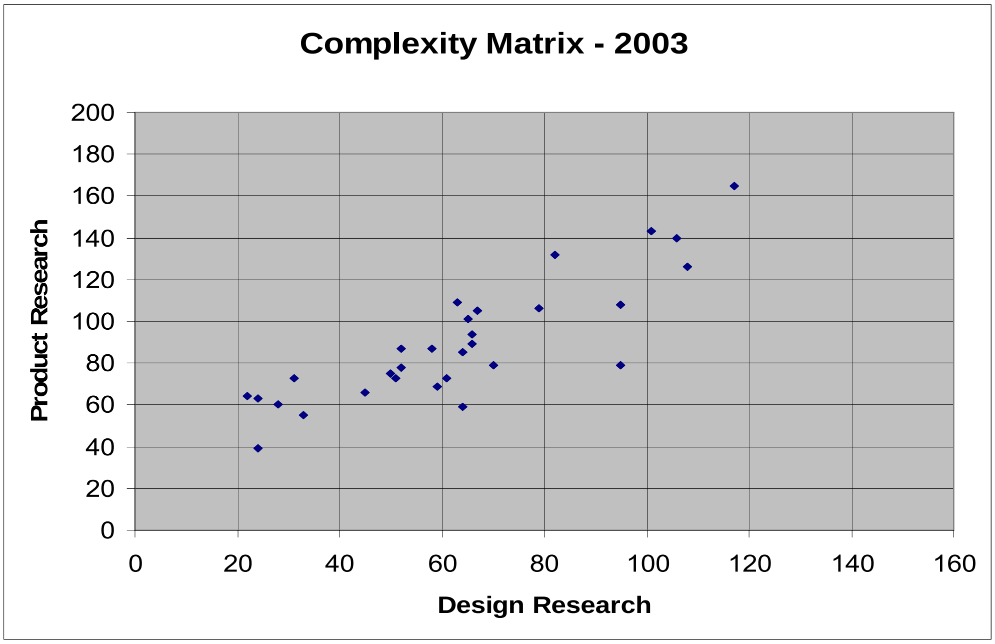


Figure 5.5 Complexity matrix for the 2003 cohort reports (average coordinate position of Product Research = 89, Design Research = 63).

The scores are plotted respectively against Product Research and Design Research as described in Section 3.9.3. The projects are scattered over the matrix with a resultant average coordinate position of Project Research = 89 and Design Research = 63.

The relationship between the variables Product Research and Design Research was statistically tested, that is, the data in columns 4 and 5 of Table 5-35. A positive Pearson correlation (0.855)[27], the result tested by TTEST, p=0.000571 (refer Appendix 45) which confirms the significance of the correlation, where in this situation, a positive increase in Product Research leads to a positive increase in Design Research.

5.3.5 Examination of the *Complexity* of 30 project reports from the 2004 cohort

Thirty *Project Research* and the companion *Project* reports were selected at random from the 36 reports (refer Section 5.2.2) produced by the 2004 cohort. These reports were the same as studied in the previous section, namely 5.3.2. The basis of the examination and the assessment instrument used has been explained in Section 4.3.2.

[27] Pearson correlation, significance 0.05 two tailed

Table 5-36 lists the results of the examination where the respective projects were assessed based upon use of the instrument shown in Table 4.9. Column 3 presents the score associated with assessment, out of 350. For example, the first student code no. 2275.04 has scored 209 out of 350. The mean of the range of scores for the 2004 cohort with respect to 30 projects is shown at the bottom of Column 3 and is 192. This group of scores can be presented graphically using a vertical bar chart to demonstrate the relationship between the projects. Alternatively column 2 presents a score out of 10 and is derived by interpolating the score in column 3 (out of 350) to a score out of 10. The mean score for this cohort is 5.5 (refer column 2).

1	2	3	4	5
Case No.	Degree of Complexity /10	Degree of Complexity /350	Complexity Design Research /160	Complexity Project Research /200
2275.04	6.0	209	82	127
2288.04	4.9	173	70	103
2446.04	5.3	187	82	105
2363.04	5.7	200	79	121
8744.04	6.1	215	84	131
1573.04	5.2	182	89	93
9130.04	4.6	162	66	96
2300.04	4.1	143	50	93
7345.04	5.8	202	80	122
2285.04	5.6	195	73	122
7330.04	4.9	171	73	98
1574.04	3.9	135	49	86
7259.04	5.8	203	86	117
2818.04	4.1	144	41	103
7403.04	6.0	210	86	124
2308.04	7.0	246	103	143
4016.04	4.5	157	73	84
5244.04	6.5	227	95	132
2397.04	6.9	242	105	137
4017.04	5.1	179	75	104
7487.04	6.0	209	82	127
2278.04	7.4	258	109	149
7762.04	6.1	215	82	133
7373.04	4.9	170	72	98
2272.04	6.7	235	101	134
2544.04	5.3	184	66	118
0745.04	5.0	176	66	110
2350.04	4.4	154	78	76
2345.04	6.0	209	80	129
4009.04	4.9	172	69	103
Means…	5.5	192	78	114
Std.Dev.	0.90	31.74	15.74	18.79

Table 5-36 Results from the assessment of the 2004 cohort's Project Research and Project reports with respect to their Complexity

Figure 5.6 presents the results of the complexity determination for 30 *Project Research* and *Project* reports arranged in descending order. These indicate a range from the highest, 258 to the lowest 135, with a mean of 192.

The mean result of 192 represents a score (192/350=54.8%) which is acceptable and represents an outcome 25% higher than the mean of the 2003 cohort. The only difference between the two cohorts is access to the MPD System by the 2004 cohort which enabled the group to explore a wider consideration of issues which showed up in being recognised as *Complexity*.

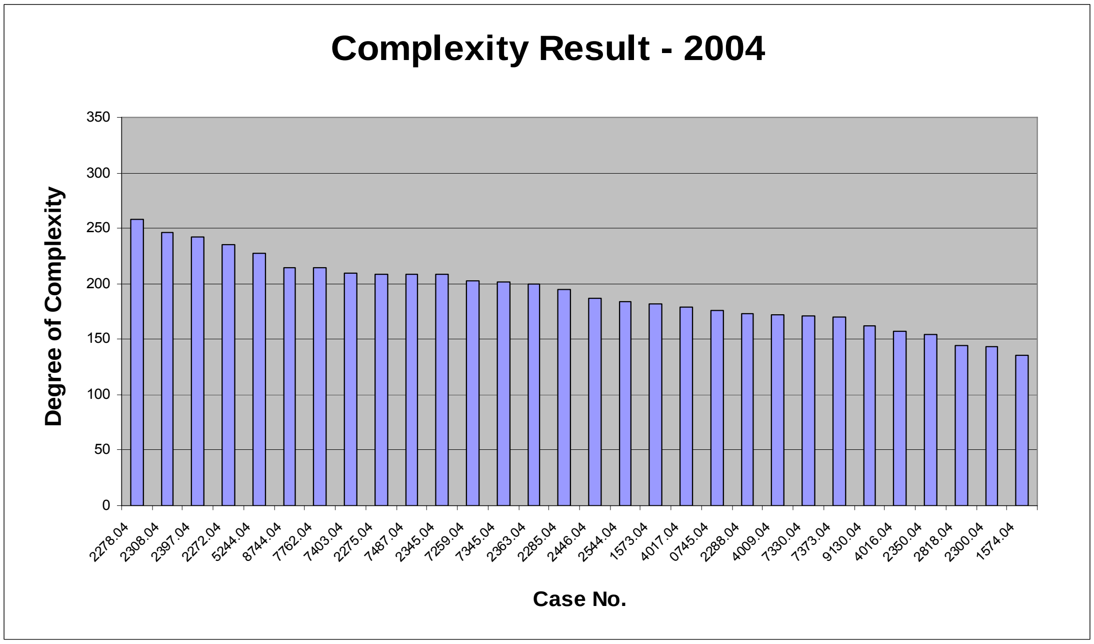


Figure 5.6 Bar chart showing the assessment of the 2004 Project Research and Project reports, with respect to Complexity, arranged in descending order.

Creating a normal distribution from the results in column 3 produces a normal distribution shown in Appendix 38, Figure A-7.

Alternatively the data is presented in matrix form and that is the purpose of columns 4 and 5 in Table 5-36. By arranging the scores on two coordinates a matrix can be constructed and is presented in graphical form as shown in Figure 5.7.

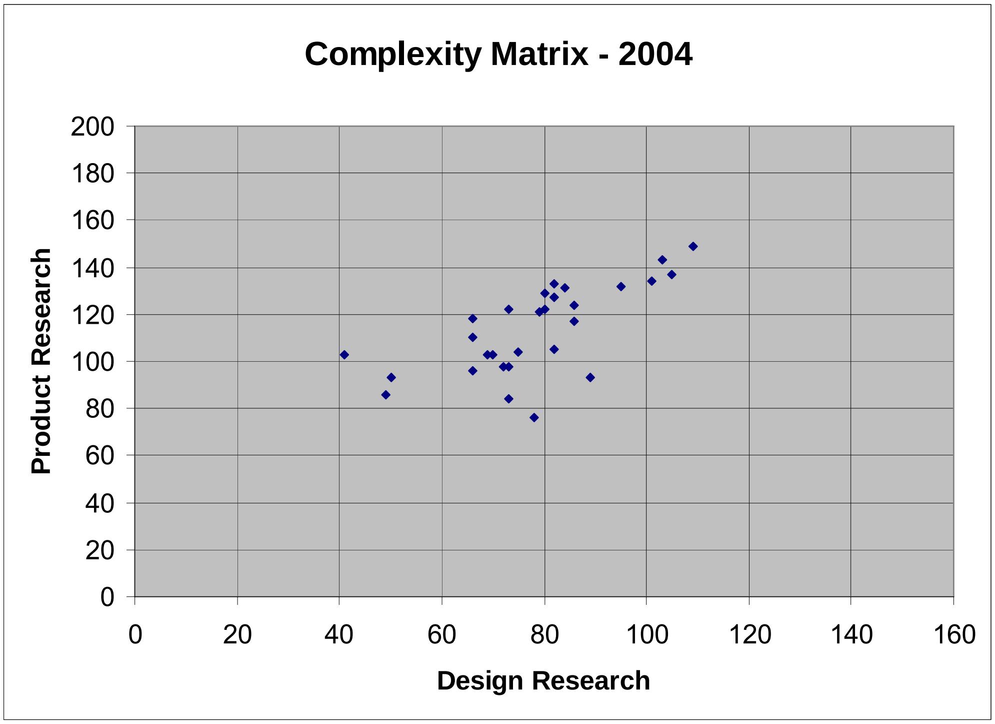


Figure 5.7 Complexity matrix for the 2004 cohort reports(average coordinate position, Product Research = 114, Design Research = 78).

The scores from column 4 (Design Research) and column 5 (Project Research) are plotted respectively. The projects are scattered over a matrix with an average coordinate position of: Product Research = 114; and Design Research = 78.

The relationship between the variables Product Research and Design Research was tested for correlation, that is, the data in columns 4 and 5 of Table 5-36. A positive correlation (0.688)[28], the result tested by TTEST, p=6.47E-11 (refer Appendix 46) which confirms the significance of the correlation, where in this situation, a positive increase in Product Research leads to a positive increase in Design Research.

5.3.6 A comparison of the complexity of 30 project reports respectively from the 2003 and 2004 cohorts

Table 5-37 summarises the results from the 2003 and 2004 cohorts. In each category, (columns 1 to 5), the 2004 cohort has achieved considerably higher assessments of *Complexity* than the 2003 cohort. The second column presents the degree of complexity out of 10; the 2003 cohort of projects being assessed as 4.4 and the 2004 cohort of projects assessed as 5.5.

[28] Pearson correlation, significance 0.05 two tailed

1	2	3	4	5
Mean results	Degree of Complexity /10	Degree of Complexity /350	Complexity Design Research /160	Complexity Project Research /200
2003..mean	4.4	153	63	89
...std dev	1.5	53.4	26.1	29.3
2004..mean	5.5	192	78	114
...std dev	0.9	31.7	15.7	18.8

Table 5-37 A summary of the results from the study of the relative complexity of 30 major project reports from the 2003 and 2004 cohorts.

The relative complexity scores for the projects of the 2003 and 2004 cohorts are contrasted in Figure 5.8. This clearly shows that the average complexity of the projects produced by the 2003 cohort was qualitatively less than the average produced by the 2004 cohort. Table 5-37 compares the two cohorts and in each instance of measurement the 2004 cohort's project are more complex by an average 20%.

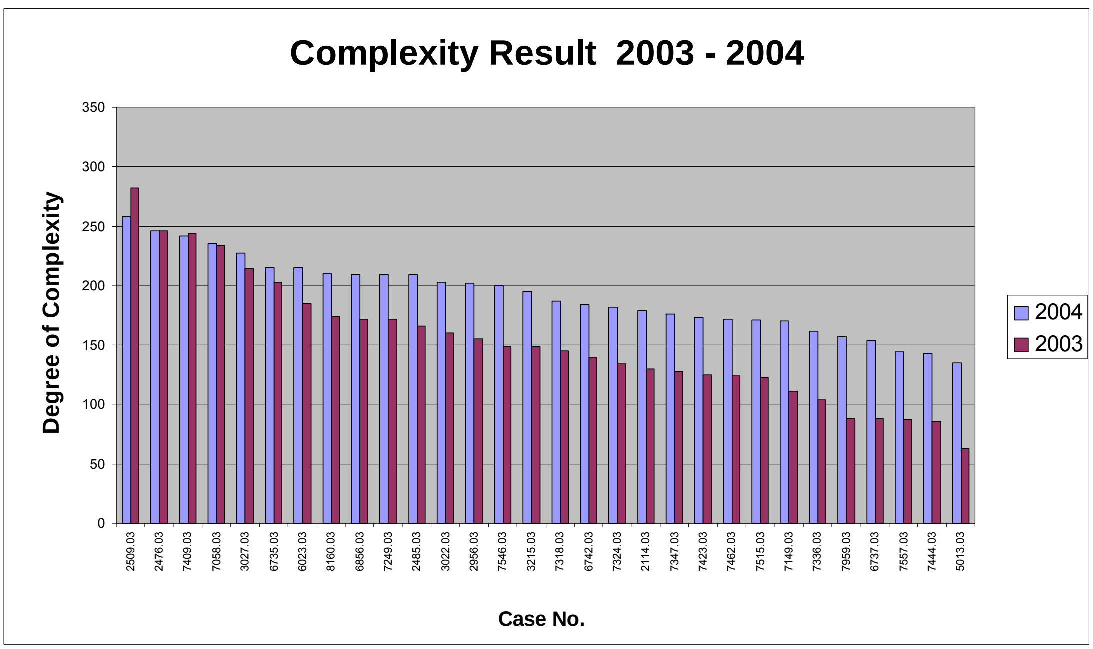


Figure 5.8 Bar chart showing the scores associated with the assessment of the complexity of the 2003 and 2004 cohort projects.

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 (refer column 3, Tables 5-35 and 5-36) were tested using EXCEL function analysis software firstly by TTEST resulting in the determination of p= 0.000544 and similarly Chi-square = 0. These results (analysis located Appendix 44) confirm a significant difference between the two cohorts.

Figure 5.9 presents the findings for the 2003 and 2004 cohorts in matrix form. The matrix clearly contrasts the scatter of both cohorts. The coordinate positions of the respective averages are compared in Table 5-37, for example: 2003 Design Research = 63, and Project Research = 89 whereas 2004 Design research = 78 and Project Research = 114.

These results clearly indicate that the method of determining complexity is feasible and there is a clear distinction in the level of projects between the 2003 and 2004 cohorts. This distinction was achieved using the Complexity model presented in Table 3-14 and analysis carried out using the instrument shown in Figure 4-9.The validation of this model clearly is a significant development in this thesis. The principles can be adopted and integrated into the assessment process to arrive at a more comprehensive evaluation of student application in major projects.

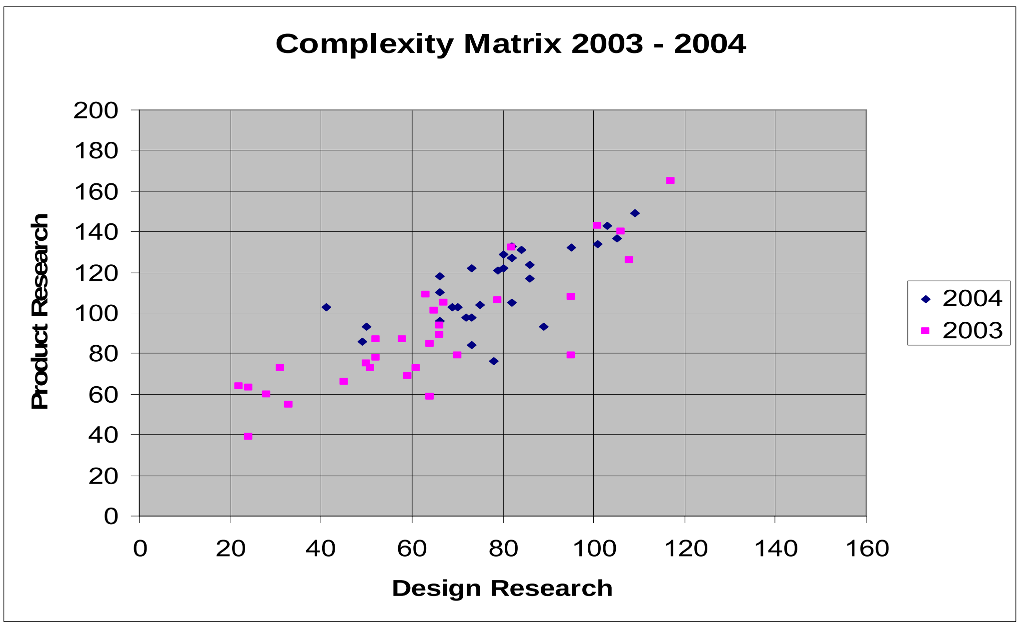


Figure 5.9 Matrix showing the thirty 2003 cohort projects contrasted with thirty 2004 cohort projects.

5.4 EXAMINATION OF THE EXTENT OF THE USE OF DESIGN METHODS; inclusion of tasks and structure; and independent assessment of the quality of projects

In this chapter, the use of design methods established from the survey of students from the 2003 and 2004 cohorts is examined and contrasted with the findings, associated with the inclusion of tasks and structure in the reports, determined by the independent assessor. These findings are further contrasted with the various measures of project quality, namely the assessed results of the projects by staff.

5.4.1 The extent of use of design methods and the effect on project quality

In Chapter 5.2.1.2 responses to the use of design methods were determined from Question 9a) of the survey of the 41 graduates in the 2003 cohort. The responses were listed in a spreadsheet shown in Appendix 13 and which is shown in partial form (for convenience) in Table 5-15. These spreadsheets list the "Yes" responses (where "Yes" admits to use of a particular design method).

Similarly Section 5.2.2.2 determined responses to the use of design methods from Question 9a) of the 36 graduands in the 2004 cohort. The responses were listed in a spreadsheet shown in Appendix 15 which listed the "Yes" responses.

		Project Research	Project	Average of Proj Rsrch & Proj	Yes Responses
Proj_Resch	Pearson Correlation	1	0.247	.779(**)	-0.127
	Sig. (2-tailed)		0.119	0	0.428
	N	41	41	41	41
Project	Pearson Correlation	0.247	1	.800(**)	-0.028
	Sig. (2-tailed)	0.119		0	0.861
	N	41	41	41	41
Average Project Res/ Project	Pearson Correlation	.779(**)	.800(**)	1	-0.097
	Sig. (2-tailed)	0	0		0.546
	N	41	41	41	41

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5-38 Statistical tests associated with the 2003 cohort.

The "Yes" responses were tested against the assessed Project Research, Project and the average of these using SPSS Software the results of which are shown in Appendix 27 (2003 Cohort) and Appendix 28 (2004 Cohort). These findings, that test the 2003 cohort, are included in Table 5-38 above for convenience.

The results indicate no significant correlation between the level of use of design methods (based on the "Yes" response) and the quality of the project as defined by the assessed level of Project research (-0.127), Project (-0.028) and the combined average of these (-0.097).

The “Yes” responses (from the 2004 cohort) were tested against the assessed Project Research, Project and the average of these also using SPSS Software and the results shown in Appendix 28 and Table 5-39. The results indicate no significant correlation between the level of use of design methods and the quality of the project as defined by the assessed results. In this regard the results from the 2003 cohort and 2004 cohort are similar.

		Project Research	Project	Average Proj Resrch & Proj	Yes Reponses
Project Research	Pearson Correlation	1	.376(*)	.760(**)	-0.234
	Sig. (2-tailed)		0.024	0	0.17
	N	36	36	36	36
Project	Pearson Correlation	.376(*)	1	.888(**)	0.062
	Sig. (2-tailed)	0.024		0	0.719
	N	36	36	36	36
Average Project Resrch	Pearson Correlation	.760(**)	.888(**)	1	-0.072
	Sig. (2-tailed)	0	0		0.675
	N	36	36	36	36

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5-39 Statistical correlations associated with the 2004 cohort.

A possible explanation for this result is the method used at UNSW to assess the major project, by the industrial design staff, earlier described in Chapter 2.1.6.1. This method is based on six stages of continuous assessment over the course of the year and where significant emphasis is placed on an end of each session final 10-minute presentation before a panel comprised of two academics and a representative from the design industry. Very little emphasis is placed on rigorous assessment of the project reports and as a consequence the issues associated with design research are not examined. For example, the embodiment and detailed design of the product itself, as clarified in the engineering drawings, is not sufficiently evaluated.

5.4.2 The inclusion of tasks and structure, independent assessment and the effect on project quality

In Part 3, Section 5.3, thirty only projects from both the 2003 and 2004 cohorts were evaluated by an independent assessor. The results, of this assessment of both cohorts, were discussed in Sections 5.3.1 and 5.3.2. In addition to the determination of the inclusion of tasks and structure the project reports were given an overall assessment.

		OA Assessment	Yes Responses	Task Score
Project Resch	Pearson Correlation	0.164	-0.214	0.21
	Sig. (2-tailed)	0.433	0.305	0.313
	N	25	25	25
Project	Pearson Correlation	.414(*)	-0.068	.411(*)
	Sig. (2-tailed)	0.04	0.748	0.041
	N	25	25	25
Combined Result	Pearson Correlation	0.381	-0.172	.406(*)
	Sig. (2-tailed)	0.06	0.412	0.044
	N	25	25	25
OA Assessment	Pearson Correlation	1	0.201	.946(**)
	Sig. (2-tailed)		0.335	0
	N	25	25	25
Yes Responses	Pearson Correlation	0.201	1	0.328
	Sig. (2-tailed)	0.335		0.11
	N	25	25	25
Task Score	Pearson Correlation	.946(**)	0.328	1
	Sig. (2-tailed)	0	0.11	
	N	25	25	25

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 5-40 Statistical tests associated with the examined reports of the 2003 cohort.

Appendix 31 and Table 5-32 show data associated with the 25 project reports (5 of the 30 reports were done by students that could not be surveyed) from the 2003 cohort and Appendix 32 and Table 5-33 show data associated with the 30 project reports from the 2004 cohort.

		OA Assessment	Yes Responses	Task Score
Proj_Resch	Pearson Correlation	0.1	-0.186	-0.047
	Sig. (2-tailed)	0.6	0.325	0.805
	N	30	30	30
Project	Pearson Correlation	.521(**)	0.185	0.317
	Sig. (2-tailed)	0.003	0.327	0.088
	N	30	30	30
Combined Result	Pearson Correlation	.404(*)	0.015	0.184
	Sig. (2-tailed)	0.027	0.937	0.331
	N	30	30	30
OA Assessment	Pearson Correlation	1	0.06	.604(**)
	Sig. (2-tailed)		0.751	0
	N	30	30	30
Yes Responses	Pearson Correlation	0.06	1	0.162
	Sig. (2-tailed)	0.751		0.393
	N	30	30	30
Task Score	Pearson Correlation	.604(**)	0.162	1
	Sig. (2-tailed)	0	0.393	
	N	30	30	30

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 5-41 Statistical tests associated with the examined reports of the 2004 cohort.

Statistical analysis was carried out on both cohorts, using SPSS Software, the findings for the 2003 cohort shown in Appendix 33 (reproduced in Table 5-40 for convenience) and the 2004 cohort shown in Appendix 34 (reproduced in Table 5-41). The results for the examined reports of the 2003 cohort indicate:

i) significant correlation (0.946) between the task score and the overall assessment.
ii) some correlation (0.328) between the task score and the “Yes” response (the level of use of design methods).
iii) significant correlation (0.406) between the task score and the combined result of the Project Research and Project reports.
iv) no correlation between the “Yes” response and both the task score (0.328) and the overall assessment (0.201).

The results for the examined theses of the 2004 cohort indicate:

i) a significant correlation (0.604) between the task score and the overall assessment.
ii) no correlation (0.162) between the task score and the “Yes” response (the level of use of design methods).
iii) no significant correlation (0.184) between task score and the combined result of the Project research and Project reports.
iv) no significant correlation between the “Yes” response and both the task score (o.162) and the overall assessment (0.06).

The results of the independent assessment support the argument that there are some problems in the UNSW assessment process with respect to the determination of project quality. It is believed that the “yes” response, associated with students use of a particular design method, has some problems because a response to, “do you employ features analysis?” might be based on the students use of an informal approach rather than a formal method.

The findings reveal that the instrument of assessment determined the level of tasks and structure in a project, when employed by the independent assessor. A high level of correlation was found between the level of use of design methods and tasks and the ultimate quality of the report.

The findings confirm there are issues associated with the assessment of projects by staff. The absence of rigorous assessment of the project reports in favour of aural and visual presentations by students (and where a rigorous assessment procedure or instrument is not used) does not lead to a balanced assessment and this has been confirmed in findings particularly arising out of Chapter 5.3.

5.5 COMPLEX PROJECTS AND THE EXTENT TO WHICH THESE:
include a higher use of design methods, tasks and structure

In Chapters 5.3.1 and 5.3.2 project reports from the 2003 and 2004 cohorts were examined by an independent assessor. The results of this assessment were shown in Appendices 31 and 32. A portion of Appendix 31, (Results from the examination of the 2003 cohorts examined theses), is reproduced below for convenience.

1	2	3	4	5	6	7	8	9
No.	Respondent Number	Proj Resch	Project	Combined Result	O/A Assessment	Yes Responses	Task Score	Complexity Score
1	8160.03	77	59	68	45	14	41	50
2	6735.03	74	86	80	55	24	50	58
3	6023.03	75	56	66	55	35	51	53
5	7444.03	80	70	75	40	19	30	25
7	3022.03	50	69	60	45	24	36	46
9	7058.03	75	62	69	75	21	69	67
11	2114.03	78	59	69	40	25	37	37
12	7336.03	80	83	82	45	16	33	30
13	7546.03	66	62	64	15	24	15	43
14	2509.03	60	90	75	75	23	64	81
16	3027.03	70	67	69	70	28	64	61
17	7409.03	75	76	76	85	19	76	70
18	2485.03	58	76	67	55	20	49	47
19	6742.03	55	55	55	30	33	28	40
21	7685.03	58	68	63	55	15	41	49
23	7959.03	62	54	58	30	8	24	25
25	7249.03	89	87	88	55	13	46	49
27	7462.03	74	58	66	20	14	19	35
30	7557.03	72	85	79	40	10	26	25
31	2476.03	87	80	84	75	25	76	70
32	2956.03	67	55	61	60	20	34	44
34	7347.03	60	60	60	20	20	22	37
36	7423.03	83	57	70	25	9	19	36
37	7324.03	68	71	70	30	26	30	38
40	7515.03	65	52	59	55	17	40	35
25	Means…	70	68	69	48	20	41	46
	Std devn..	10.1	11.9	8.7	19.2	6.9	17.8	15.1

Table 5-42 A portion of Appendix 31 showing results of the examined reports.

Column (3) lists the results achieved by the student in the *Project Research* section of the major project. This result was based on examination by staff (refer Chapter 5.2.1). Column (4) lists results for the *Project* section of the major project (refer Chapter 5.2.2) and Column (5), the combined result, is the average of columns 3 and 4.

Column (6) lists the overall assessment of the project reports based on examination by the independent assessor (refer Chapter 5.3) and Column (7) lists the responses by students that indicated their use of design methods (refer Chapters 5.2.1.2 and 5.2.2.2).

Column 8 lists the scores obtained by students derived from examination by the independent assessor (refer Chapter 5.3) and Column (9) lists the complexity score for the project reports also provided by the external assessor.

In this section the results presented in Appendix 31 were tested in order to determine the extent to which *Complex* projects include more extensive use of design methods, task and structure. This examination was done using SPSS Software and the results are included in Appendix 35 and a portion of those results is shown below in Tables 5-43 for convenience.

		Complexity Score
Project Resch	Pearson Correlation	0.049
	Sig. (2-tailed)	0.815
	N	25
Project	Pearson Correlation	0.363
	Sig. (2-tailed)	0.074
	N	25
Combined Result	Pearson Correlation	0.279
	Sig. (2-tailed)	0.177
	N	25
OA Assessment	Pearson Correlation	0.779
	Sig. (2-tailed)	0.000
	N	25
Yes Responses	Pearson Correlation	0.404
	Sig. (2-tailed)	0.045
	N	25
Task Score	Pearson Correlation	0.864
	Sig. (2-tailed)	0.000
	N	25
Complexity Score	Pearson Correlation	1
	Sig. (2-tailed)	
	N	25
*	Correlation is significant at the 0.05 level (2-tailed).	
**	Correlation is significant at the 0.01 level (2-tailed).	

Table 5-43 Experimental evidence associated with the 2003 cohort's examined project reports

For the 2003 cohort, the results indicate:

i) some correlation (0.404) between the level of complexity of the project and the use of design methods based upon the "Yes responses" which suggests that design methods are of benefit when involved in complex projects..

ii) significant correlation (0.864) between the task score and the level of complexity of the project. The correlation between the task score and the complexity of the project confirms that students who are scoring highly with tasks are able to do complex projects.

iii) significant correlation (0.779) between the overall assessment and the level of complexity of the project. This confirms that higher performing students tackle complex projects.

These findings for the 2003 cohort indicate a positive relationship between the complexity of the project and the use of design methods.

Similarly the results presented in Appendix 32 were tested in order to determine the extent to which *Complex* projects include more extensive use of design methods, task and structure. This examination was done using SPSS Software and the results are included in Appendix 36 and a portion of those results is shown below in Table 5-44.

		Complexity Score
Proj_Resch	Pearson Correlation	-0.026
	Sig. (2-tailed)	0.890
	N	30
Project	Pearson Correlation	0.405
	Sig. (2-tailed)	0.027
	N	30
Combined Result	Pearson Correlation	0.254
	Sig. (2-tailed)	0.176
	N	30
OA Assessment	Pearson Correlation	0.605
	Sig. (2-tailed)	0.000
	N	30
Yes Responses	Pearson Correlation	-0.259
	Sig. (2-tailed)	0.168
	N	30
Task Score	Pearson Correlation	0.444
	Sig. (2-tailed)	0.014
	N	30
Complexity Score	Pearson Correlation	1
	Sig. (2-tailed)	
	N	30

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5-44 Experimental evidence associated with the 2004 cohort's examined project reports

For the 2004 cohort, the results indicate:

i) a negative correlation (-0.259) between the level of complexity of the project and the use of design methods based upon the "Yes responses". This suggests there is no correlation between the use of methods indicated by the students of the 2004 cohort and the level of complexity of the project.

ii) a correlation (0.444) between the task score and the level of complexity of the project. The correlation between the task score and the complexity of the project confirms that students who are scoring highly with tasks are able to do complex projects.

iii) significant correlation (0.605) between the overall assessment and the level of complexity of the project. This confirms that higher performing students tackle complex projects.

These findings from examination of the 2004 cohort's projects reveal some conflict in the results. There is a negative correlation of a low order between the "Yes" responses and the level of complexity. However there is a positive correlation between the task score and the overall assessment. It is concluded that the detailed examination of the "tasks" within each project report is the more reliable determinant of the extent of use of design methods. Therefore, in the above examination, it is concluded that students who are able to perform well in the tasks associated with a major project are also able to engage with complex projects. And similarly, higher-performing students, tackle complex projects.

The next chapter summarises the research project and presents the findings and conclusions.

Chapter 6

Findings and Conclusions

Discusses the results of the respective tests concerning validation of the research propositions in the light of the aims of the thesis.

6.0 FINDINGS and CONCLUSIONS

6.1 Introduction

In this thesis the industrial design studio has been investigated with particular reference to final-year industrial design major projects. The theoretical and experimental work was set in the context of final-year undergraduate degree programme in industrial design, in the School of the Built Environment, The University of New South Wales. From a critical review of the literature concerning the history of the studio, the nature of industrial design, models of teaching applicable in the industrial design studio and findings from a structured survey of academics, an understanding of the role of the studio in major projects is established and fundamental problems identified. A theoretical framework has been employed in the specification of a model that defines the phases and tasks associated with final-year, major projects from inception to completion. The model is enhanced by the addition of selected design methods aligned with the phases of the model. This enhanced model is entitled the Major Project Development Model or "MPD Model". An additional aspect of the research focused on the relative complexity of projects and a model proposed that was used to determine the complexity of student projects. The application of the model formed a part of the experimental work and analyses in this project.

The operational phases, associated tasks and methods in the MPD Model guided the development of a suite of computer-based methods designed and developed as part of this investigation. The computer-based system of methods called the "MPD System" is intended to serve as an instrument that encourages systematic activities within the creative culture of the studio. The entire suite of methods that comprises the "MPD System" is contained on a compact disc (CD) and located in Appendix 47.

The experimental work and analyses reported in this thesis have utilised the MPD Model applicable to final-year major projects. The experimental data available for analysis includes qualitative and quantitative information on tasks executed in major project reports, as well as the extent of use of design methods. The author developed questionnaires that enabled the collection of data associated with the project reports for successive cohorts of students in years 2003 and 2004. The findings and conclusions drawn from the theoretical and experimental work documented in this thesis will now be summarised and their significance discussed. This will be followed by recommendations for future research.

6.2 CHARACTERISTICS OF THE INDUSTRIAL DESIGN STUDIO

6.2a Summary

Chapter 2 has considered: the history and characteristics of the industrial design studio: teaching and learning in the studio; the nature of industrial design; design methodology and design methods; the process of designing; the author's observations; and clarification of fundamental problems associated with studio teaching. All have been examined and interpreted in relation to published reports as well as from the relatively sparse industrial design literature. The findings listed below are relevant to gaining an understanding of the studio and how its role can be enhanced.

6.2b Findings

1. The following are found to adequately describe the historical development of the design studio and its main characteristics.

i) The architectural studio emerged as a special form of education within the E'cole *des Beaux* Arts and concurrent with the program offered by the E'cole was part-time study of individual subjects, supplemented by employment, in the manner of the old *atelier* system of indentures and articles (Bingham, 1993)

ii) The Bauhaus was a teaching institution founded at Weimer in Germany in 1919. The early years of the Bauhaus were focused on uniting art and craft and the objective was to train a new kind of collaborator, for industry and the crafts, who had an equal command of both technology and form (Heskett, 1999).

iii) In the United States, industrial-design education formally started at Carnegie Technical College (later to become Carnegie-Mellon University) in 1935-36 followed by the Pratt Institute of Art in New York and these developments together with those occurring in industry served to establish the industrial design profession. (Kaufman, 1999). Around this time in the United States designers came to prominence establishing studios to cater for a wide variety of products.

iv) The New Bauhaus, founded in Chicago, was the immediate successor to the Bauhaus, which was dissolved in 1933. In the 1950s the New Bauhaus merged with the Illinois Institute of Technology, which is still prominent in Chicago and rates as a highly respected and professionally oriented school of design.

v) The industrial design studio of the 80s did not differ significantly from the models exemplified by the Bauhaus and the American schools. They were essentially an amalgamation of art and craft.

vi) The industrial design studio of the 90s became a place where art, design, culture, manufacture, sustainability and usability were integrated into the design process however the central visual preoccupation remained.

vii) In the 21st Century industrial design will emphasise the experience of a product and user needs and modern technology will be employed to rapidly provide models for evaluation.

viii) The findings in i) to vii) support the conclusion that the characteristic of the industrial design studio has evolved in a unique way to incorporate a mode of thinking in the studio described as random, intuitive, holistic, synthesising, and subjective; all belonging to the fields of art, creativity and the skills associated with imagination and synthesis. This manner of thinking does not accommodate or lead to rigorous definition, planning, management and evaluation of projects.

2) Research findings associated with teaching and learning in the studio are described by the following:

i) The setting of ill-defined problems or projects is the essence of design teaching and learning in the studio. Other disciplines employ problem-based learning but the industrial design studio emphasises ill-defined, real-world problems or projects and it this aspect that distinguishes the studio approach.

ii) A certain tension exists between proponents of the studio process where intuition and reflection, processes critical to imaginative problem solving, are in some conflict with scientific application. It was found that this can lead to problems in the assessment of project work.

iii) Despite the rapid developments in technology and the breadth of considerations within typical projects, the studio remains a place where art and craft are blended in a process of intuition and reflection. It is a place that, to a large degree, has not embraced scientific and systematic thinking and much research needs to be done to broaden the considerations within the studio, yet retain the unique creative focus.

iv) Many students are not able to *make-the-connections* between the supporting disciplines, for example, mechanics, materials science, manufacturing and marketing and their relationship to the design process, in many cases because the relevant tools or design methods have not been taught in their programs.

v) The studio cannot function in isolation and depends on the sequence of learning and the interaction between the classroom and studio which sums to a stage that students attain, namely prior learning. The philosophy of learning associated with the studio is based on increasing complexity in projects over the duration of the programme and this cannot happen without the linkage between the classroom and the studio and the cycle of learning that occurs between.

vi) The findings expressed in i) to v) highlight the characteristics of the studio, but allude to a problem, in that the studio does not readily accommodate systematic thinking and this is significant where large projects are involved. Major projects can span a whole academic year and require a blend of systematic and intuitive approaches and many students struggle within a studio culture that does not readily accommodate systematic and analytical thinking. An issue addressed in this thesis.

3) Knowledge of the nature of industrial design and the skills expected of industrial designers is a prerequisite to the design of models that describe the design process. The features and general nature of the industrial, the product and the engineering professions have been identified from the literature and key findings are as follows:

i) Industrial design is the professional service of creating and developing concepts and specifications that optimise the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer (IDSA, 1996).

ii) Industrial design may also be defined as the: ideation, specification, and development of functions, properties and concepts of industrially manufactured products and systems, mainly regarding aspects of user-product interaction, aesthetics and identity considering a totality of ergonomic, usability, technical, economic and social factors (Warell, 1999).

iii) Product design may be defined as: those activities involving the design of products and which include the activities of engineering design and industrial design (Warell, 1999).

iv) Engineering design may be stated as: design with particular emphasis on the technical aspects of a product and includes activities of analysis as well as synthesis.

v) Designers juggle variables, reconcile conflicting values and maneuver around constraints - a process in which, although some design outcomes are superior to others there are no unique right answers.

vi) Findings and definitions expressed in i) to v) highlight the breadth of issues associated with product development. In particular, the *closeness* of industrial and product design is not reflected in industrial design teaching, where the emphasis is on visual and human issues, at some expense to issues associated with function and manufacture. This aspect was clearly confirmed in the survey of industrial design academics where the lack of the knowledge and application of design methods and processes is of concern. It confirmed also that the teaching of product design as part of the industrial design degrees is seriously neglected.

4. Knowledge of the extent of use of design methodology in the industrial design studio and in professional practice is a prerequisite to the design of models of the design and product-development process. The types of methods available and their potential application have been identified from the literature and key findings arising from Chapter 2.4 are summarised as follows:

i) Design methodology includes the study of the principles, practices and procedures of design. Its primary focus is to develop a deep and practical understanding of the design process and how this process can be modified, made more effective and transparent and be managed to achieve sustainable design outcomes.

ii) Design methodology is not in itself a method but rather a body of knowledge related to methodical and systematic techniques. The term systematic design is alternately used in lieu of design methodology, particularly in practical applications within industry (Hein, 1994).

iii) *Design methods* may be defined as, any procedures, techniques, aids or tools that contribute to the design process. They represent a number of distinct kinds of activities that the designer might use and combine towards the solution of design tasks.

iv) The design methods introduced in the 1960s and 70s drew attention to the need for design to be more transparent and more substantially based on a structure of analysis. However the methods introduced failed to achieve wide acceptance as part of the normal process of designing and were not incorporated into the teaching of design on a significant scale.

v) Maffin (1998) conducted research of sections of industry and reported that quality function deployment, robust design, functional decomposition, concept generation, and evaluation matrices were not widely known, let alone applied.

vi) One reason advanced for the limited use of methodologies was that formal design tools have not been taught widely at colleges and universities in the past (Gill, 1990).

vii) Research by Spring *et al* (1998) has shown that 'designers do not make use of simple tools such as Pareto analysis, cause and effect, control charts and checksheets and such are perceived by design staff as contributing little to the design and development process and are viewed almost with disdain. There is even reluctance to utilise techniques that have direct application to design such as QFD, design of experiments, fault tree analysis and failure mode and effects analysis (FMEA)'.

viii) Eder (1998) writing about engineering designers explains that certain methods are accepted by industry and examples are TQM, QFD and Taguchi. He further laments that such methodologies are used only in a small fraction of industry.

ix) Many student designers struggle with the design or product development process. They tend to approach a major design task in an ad-hoc manner and do not define a process that will help them navigate the various stages.

x) The findings described in i) to ix) point to problems associated with a narrow focus in sections of industry and in universities. A greater emphasis on the design or product development process, as a means of providing a roadmap for passage through ill-defined problems, would be of assistance to the student designer. In addition, the teaching of selected methodologies enables the student to more effectively categorise information and support the stages of design decision-making that occur as design progresses. There has been very little research work done on the application of design methods in industrial design programmes.

5. Knowledge of the design process, particularly as it occurs in the design studio, is essential towards the design of models of the major project process. The research arising from Section 2.5 sought to clarify the process carried out in the studio and the findings are listed as follows:

i) The design process may be represented by rational models that serve to explain the steps in the process. Descriptions of such models are provided by Darke, Lawson and Markus-Maver.

ii) In the earlier years of the degree program the studio focus is aimed towards the student gaining experience in design decision-making. The studio is premised on a particular kind of learning by doing. The studio project requires the student to start the design process even though the student does not understand the process and does not know what designing means (Schon, 1987).

iii) The rational models of the design process do not represent the typical student approach within the studio. The elements of analysis, synthesis, evaluation and decision still occur, however the progression through and between is generally chaotic. The rational models assume a logical progress through the process but the heavy emphasis on the right-brained, solution-focused approach does not encourage a reliance on process. In the final-year the student is required to embark upon a significant, year-long project that requires planning and careful management. However such a project requires a dual-brained approach to balance the requirements of management with creative processes.

iv) The design process emphasised within the studio, of an undergraduate degree, is limited in its scope. The student designer is coached towards a solution-driven approach which seeks to *create* a solution proposal → *evaluate* the proposal → *decide* its appropriateness → and then *communicate* the solution.

v) The findings i) to iv) introduce an understanding of the unique process that occurs in the studio, that is the proffering of solutions and the use of such to learn more about the problem. However this process is both a strength and a weakness and becomes a key finding of the literature research; of how to introduce a higher level of systematic thinking and procedures in the design studio without compromising the creative, solution-focused approach and more effectively integrating teachings from other disciplines. This issue was addressed in Chapter 3 of the thesis, where new theoretical constructs have been proposed.

6.3 FURTHER CHARACTERISTICS OF THE STUDIO DESIGN PROCESS, models of the industrial/product design process, and the proposal of a new model and system to facilitate major studio projects.

6.3a Summary

Chapter 3 considered: the right, left and whole-brained approach to design; models of the design and product development process; a proposed model of the major-project design and tasks within that process; together with a model defining the complexity of final-year major projects. All have been examined and interpreted in relation to published reports as well as from the industrial design literature. The findings listed below clarify a process associated with the major project and means by which it can be assessed.

6.3b Findings:

1. The thinking associated with the studio-based major project can be described by the right, left and whole brained approach to design. The following are found to adequately describe the main characteristics of design studio thinking in relation to project execution.

   i) The brain-based learning theory complements the left and right brain theory in its recognition of the physiological foundations of learning. Unlike the left and right brain theory, however, the brain-based learning theory highlights the significance of holistic learning.

   ii) Hart (1983) asserts that the brain is a parallel processor, for example, the brain performs several activities at once, like tasting, smelling and seeing, and that it processes wholes and parts simultaneously.

   iii) The left and right brain theory has attracted interest from Industrial Design researches. The right brain's contribution to the design process is in the area of visualisation and drawing, creative thinking and in appearance design. The left-brain approaches problems logically, analytically and includes the activity of acquiring and comprehending information upon which to base solution proposals (Lawson, 1997).

   iv) Tovey (1986) argues the balanced contribution of the left and right brains during the studio design process. Tovey's model explains duality of the mind process. More importantly, the model accommodates the situation of students in their final-year projects.

v) The concept and model i) to iv) espoused by Tovey form a basic theory upon which this research proceeded. The findings discussed in the next section use the principle of Tovey's model and seek to define a process that can support the student in the studio when engaged in major projects. These models needed adaptation to suit the educational process involved with major projects at the final-year level of industrial design projects and where suitable methods are integrated.

2. Models of the design and product development processes were studied in Chapters 3.2 and 3.3 to confirm the availability of a model that might serve to guide the final-year, major project process. The following findings summarise available models and their applicability.

   i) Design models are different ways of interpreting the design process applicable to a product or system. They are representations of philosophies or strategies proposed to show how design is or may be carried out (Sivaloganathan et al, 1995).

   ii) The solution-focused model typifies the process employed by most students during studio projects. It is also the most common model conveyed by teachers. This model may suffice for studio projects however it is not appropriate for final-year projects because it does not include nor accommodate the many stages and considerations of a substantial project.

   iii) Archer (1966) proposed a model of six stages including a simple macrostructure and intended that a micro-structure could be developed to meet the needs of a particular project.

   iv) Cross (2000) proposed a model for the engineering design process which can also apply to industrial design. The model encourages solution conjectures and an interaction between the overall problem and sub problems.

   v) Bonollo and Lewis (1996, p.4-19) proposed a generic model of the industrial design process and validated the model in an educational project situation. Particular emphasis was placed on design knowledge and goals relevant to the industrial design educational process.

   vi) The product development process was reviewed to assess its potential to guide major projects. Rosenau (1990) proposed an 8-stage process and Jones (1997) published a model including three principal stages namely *inception*, *creation* and *realisation*. A more promising model from the viewpoint of major projects was published by Bonollo and Tan (2001). This included and built upon the earlier proven industrial-design model referred to above in (v).

vii) In summary, the models referred to in i) to vi) above are found to be limited for student major projects either because of the absence of a stage that enabled review of markets and competitors or the absence of stages that enabled preparation for production and financial assessment at a level appropriate for student projects. The author then researched methods that might accompany an overall model and the findings are summarised below.

3. Research of stages of the design and product development process together with methods appropriate to those stages are documented in Chapters 3.2 to 3.6 in order to arrive at a design process model and a suite of methods to support the final-year major project. The following findings summarise those stages and methods.

i) The models and associated design methods proposed by various authors were reviewed and these included: Cross (2000); Baxter (1995); Maffin (1998); and Eder (1998). Their teachings led to the proposal, by the author, of a summative model of the design process including methods.

ii) The author refined the summative model to propose: a) a model of the Major Project Development Process; and b) a selection of methods appropriate to the Major Project Development Process. These were combined to form a model, entitled the Major Project Development Model (**MPD Model**) (refer Table 3-11). Finally, the author defined the application of the MPD Model as a novel instrument to link the left and right brain activities within the context of a major project design process, shown in Figure 3.15 and reproduced below for convenience as Figure 6.1.

iii) The author has reviewed a range of tasks normally associated with major projects and proposed these within the scope of the MPD Model. These tasks, the associated outcomes and the design methods proposed as tools in the execution of the tasks have been developed and discussed.

iv) A major finding associated with this study is the development of the **MPD System,** included on a CD in Appendix 47. The forty-one methods on the CD facilitate a structured approach to major projects and link systemic and creative aspects of the major project. The MPD System, in this thesis, has been proposed, applied and validated for application in final-year industrial design projects. This has been not only a important finding but a major achievement of this thesis.

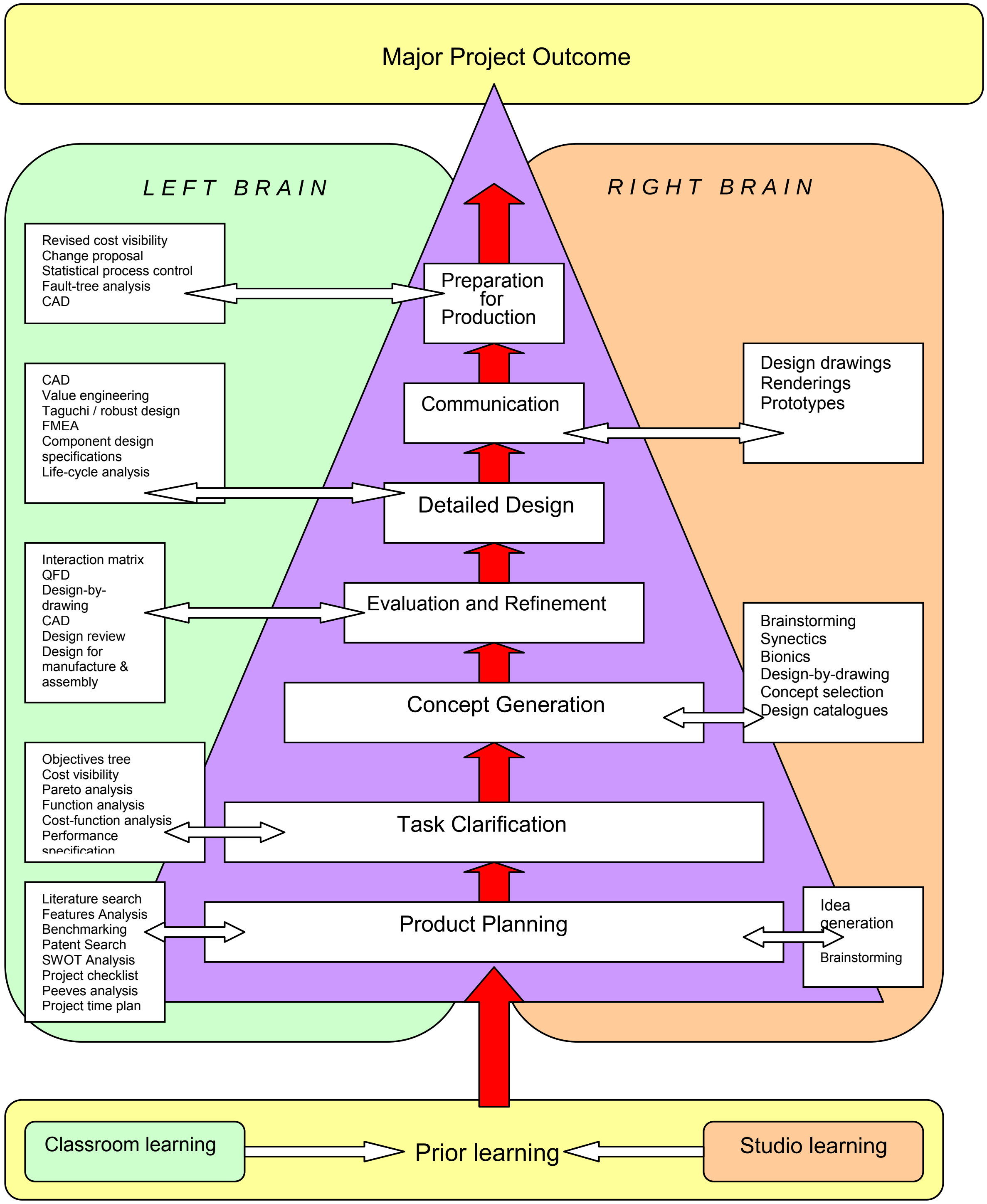


Figure 6.1 Author's application of the MPD Model superimposed over left and right brain activities within the context of a major project

4. Models of *Design Difficulty* and *Complexity* were studied in Chapter 3.9 to develop a new model suitable for student major projects. The following findings summarise the findings and their applicability to student projects.

   i) Moody *et al* (1997) defined a system that considers design difficulty and the resources needed to complete a project.

ii) Burns *et al* (1996) defined complexity in terms of internal product structure and user interface.

iii) Samuel and Weir (1997) described a process of enformulation which is based on what they refer to as problem intensity. The metrics produce a means by which problem intensity can be compared among a number of projects.

v) Samuel and Weir (1997), Griffin (1993), and Lewis and Bonollo (2002) all refer to the need for metrics associated with the measurement of *design difficulty*, *complexity and problem intensity*.

vi) It was found that the above models and descriptions were not applicable to industrial design projects and that a need existed for a model that would measure the relative complexity of student projects. The model should be influenced by certain learning objectives that are essential in a final year, for example, research of constraints arising out of patents, standards and other regulatory systems and health and safety awareness. In addition, the research of scientific issues is important to develop an awareness of the technology and the role of the designer that of capitalising and packaging scientific developments.

vii) A model defining the *complexity* of student major projects has been proposed by the author and a novel instrument to enable the assessment of *complexity* in projects has been developed and tested.

In summary, the models proposed in Chapter 3, namely: the MPD Model (together with its instrument the MPD System); the tasks incorporated (and the instrument of assessing the tasks incorporated in the Projects) within the model; and the Model of complexity (and its instrument of assessment) were investigated and validated in the Research Programme. The development of these models and systems, namely the MPD Model, the MPD System, the models of tasks and their assessment and the complexity model are notable and original developments. The following will clarify the findings arising from the Research Programme.

6.4 RESEARCH PROGRAMME

6.4a Summary

The procedures for conducting the structured survey, the respective surveys of graduates and carrying out the research programme have been described in detail in Chapter 4 along with related nomenclature, terminology and explanation of the temporal and performance variables involved. The information provided includes elaboration of the various design propositions, the methods of obtaining feedback from academics through structured questionnaires, and from students through questionnaires and examination of student's work by an external examiner. Details have also been given of how the MPD Model and MPD System were utilised in the conduct of projects and in the final assessment processes, mindful of the related model operational criteria.

6.4b Findings

1. In Part 1, novel methodology for the conduct of a structured survey of academics has been developed. The questions included in the survey were significant for the following reasons:

i) Understanding of how students employ a structure and methods in projects enabled a clear picture to be developed of the student approaches to final-year projects. Therefore such understanding adds to the field of knowledge.

ii) The methodology used in this situation may guide further studies that are associated with understanding student engagement with significant studio projects.

iii) The survey of lecturers supervising programmes in Australia and other countries enabled a useful picture of the focus in these programs, that is, the nature of industrial design teaching.

2) In Part 2, methodology for the conduct of surveys of graduates and graduands has been developed. This methodology is important because:

i) Through detailed documentation of qualitative and quantitative data (as provided by Appendices 9 to 46) this methodology contributes usefully to the information base on methods of surveying students concerning their involvement in studio projects.

ii) The detailed survey of the respective cohorts enabled demographic criteria to be established which will assist further research into aspects of student performance in industrial design.

3) In Part 3, methodology associated with the examination of major project reports has been developed. Clear guidelines and instruments have been formulated for the assessment of a number of project reports from final-year projects. These formulations are significant for the following reasons:

   i) Application of the instrument for determining the extent to which *tasks* are included in major projects establishes a means by which content and structure is assessed in projects.

   ii) The instrument for determining the complexity of projects presents a novel approach to more comprehensive assessment of projects.

In summary it was found that the survey of academics in the research programme in this thesis, was effective in implementation, the resultant demographics of the academics validated their selection, and a high level of response to the survey was experienced. This survey was able to find valuable information not previously published. It was found also that the demographics of the student cohorts demonstrated the comparative intellectual level of the groups and that the survey of these was consistent and effective. Finally, the examination of the reports of the respective cohorts was carried out thoroughly, validating the models and instruments proposed for this aspect of the research.

6.5 RESULTS and DISCUSSION

6.5a Summary

The results of the research programme have been recorded and discussed in depth in Chapter 5 with reference to: methods and procedures used in industrial design, final-year projects; and validation of the MPD Model and MPD System that links creative and systematic tasks within a major project. In addition, the research programme has examined: tasks associated with major project execution; the complexity of projects; and academic performance.

6.5b Findings: Methods and procedures used in industrial design, final-year projects:

1. The results of the survey of academics in Australian and international industrial design programmes is discussed in Chapter 5.1. The section included four categories of investigation that applied to the attitude and approaches of students in their final-year projects to the categories of:

   1. Management and Research;
   2. Conceptualisation;
   3. Resolution and Presentation;
   4. Design methods and Processes.

   i) It was found from consideration of the demographics of the academics surveyed that they represented a diverse group, as balanced as could be expected in gender; they have extensive experience in the teaching of industrial design and in the supervision of major projects; and they represent programmes in diverse regions and which have particular foci in terms of the nature of their programmes. Because of this, it was reasonable to assume the results associated with the survey would be considered and factual in relation to the approaches and methods employed by students.

   ii) The results revealed that students' approaches to aspects of *management and research*, within their projects, in relation to the mean scores and standard deviations recorded, are disturbing because the scores indicate a consistently low level of application to aspects of project work. It is concluded that application by students' to management and research aspects of projects is unsatisfactory.

   iii) In the category of *Conceptualisation,* the findings reveal an alarming lack of application to conceptual processes. Of note, was that the application of brainstorming, synectics and bionics did not score highly in use by students. Similarly ranking of design concepts and confidence in design decision-making was not a strong area of application. Again, in this area, the application by students is unsatisfactory.

iv) The students approach to *Resolution and Presentation* was also only satisfactory where traditional approaches such as renderings, graphics prototyping and ergonomics were incorporated however approaches reflecting detailed design, estimation of manufacturing costs, financial analysis were not satisfactorily included.

v) In *Design Methods and Process* the findings again were disturbing because scores right across the 43 methods surveyed were consistently low. Design methods such as computer-aided drafting, computer-aided design, renderings and solid modelling scored the highest which would be expected in an industrial design programme. Methods that might normally be associated with product design, such as design-for-assembly, value analysis, quality function deployment, and performance specification method, among others, were seriously lacking in application.

vi) In summarising the above findings, that is, i) to v) the results demonstrate that there is no organised approach within major projects to management, conceptualisation, resolution and design methods and process. This suggests a total lack of awareness and implementation of design methods as well as a serious lack of application of systematic procedures and methods and scholarship in the industrial design programmes surveyed. These important findings reveal a serious situation in industrial design teaching and learning and justify the development of the MPD Model and MPD System proposed as part of this research.

2. The results of the survey of students in their final-year projects; the 2003 and 2004 cohorts is discussed in Section 5.2. The findings of this section are summarised as follows:

   i) Consideration of the demography of the two groups revealed that the UAI, Design Methodology capability and WAM are similar. Therefore it was safe to conclude that the two groups had similar performance capabilities. In addition, the two groups have similar gender representation, their first-language proportions are similar and their age range is comparable. Therefore the principal finding associated with the demographic comparison is that the overall design performance in their major project work was likely to be similar.

ii) It was found that the use of design methods and process by the 2003 cohort in their major projects was modest. Overall 52% of the respondents have used the range of design methods listed in the survey over the seven stages of the MPD Model.

ii) The findings revealed that over the seven phases of the MPD Model the use of design methods by the 2004 cohort was slightly higher (54% of the respondents) than the 2003 cohort. However, when the respective phases of the model were studied it revealed that where a comprehensive method was provided by the MPD System the use of the method was substantially increased. This aspect was confirmed when the first three phases of the MPD System were compared and this showed a higher usage by the 2004 cohort. The difference was tested and found to be significant. This is an important finding because it confirms that, if students are provided with a system to support their project work, they will use it and as a consequence arrive at more comprehensive findings.

iii) Comparison of the use of design methods reveal that the cohorts at UNSW use a wider variety of methods than the students in other programmes as estimated by the academics in the structured survey. However there are many areas where all students use certain methods and these are, brainstorming, anthropometric analysis, design-by-drawing, computer-aided design, rendering, prototypes, and market research. These are traditionally used in industrial design education and practice. In contrast, those not commonly used by students at UNSW and overseas included benchmarking, bionics, fault-tree analysis, morphological analysis, life-cycle analysis and value analysis, quality-function deployment, synectics, among many others that would be of considerable value in clarifying information and decision-making in project work.

iv) Findings determined in i) to iii) above reveal that the application of design methods by students at UNSW is modest, despite the inclusion of a specific course in design methods and the provision of a computer-based system of design methods. However usage at UNSW was still higher than indicated in the survey of academics. The provision of the MPD System to the 2004 cohort did produce a considerable increase in the use of methods. Even though the 2004 cohort used more design methods it is notable that further application would be highly desirable. Findings in Chapters 6.5d and 6.5f, the examination of tasks in student project reports, raises further issues associated with the assessment of projects and the use of design methods by students.

6.5c Findings: Validation of the MPD Model and MPD System that links creative and systematic tasks within the major project.

1. The MPD Model and MPD System have been developed to assist students in their final-year major projects; the MPD Model providing a structure, specifying the stages and tasks of the major project and the MPD System presenting a suite of computer-based design methods to assist students in their project work. In Chapter 5.2.2 the responses to the survey questions provided strong empirical evidence with respect to the value of the MPD model and system.

   i) Of the forty-one respondents in the 2003 cohort, thirty-one (75%) felt the need for a more comprehensive, computer-integrated system of design methods. Eight respondents did not feel the need, and two were not sure. The 2004 cohort included thirty-six respondents; twenty-nine (80%) felt the need, six did not and one was unsure. Therefore it can be concluded that there is a strong perception that there is a need for a computer-based system of design methods that could be applied to major projects.

   ii) The 2003 cohort were asked: in what areas such a model and system might contribute to their project work. Their responses that spanned areas of possible application were summarised in Table 5-27. These suggest that over and above the perception of a need there are quite specific opinions as to where the model and system might contribute to projects.

   iii) Because the 2004 cohort had experience in the use of the MPD Model and System their cohort was asked: to what extent the MPD System had helped in their project work and their mean overall assessment on a scale of 1 (minimal) to 5 (considerable) was 3.3. Based upon this positive affirmation it can be concluded that the statement: “students who have used the MPD System in their project work claim it is of considerable assistance” is valid.

   iv) Criticism of the “system” over the two cohorts amounted to the areas of: too complicated (6.5%); time consuming (8%); did not understand how to apply (4%); and unnecessary (9%). Clearly, this level of criticism is very minor.

   v) The findings i) to iv) reveal a strong confirmation of the need for an expert system of design methods and when provided with such a system the findings are that the MPD System is of definite assistance in project work. The System has the potential to be applied in areas of professional practice and with adaptation to engineering design.

6.5d Findings: Examination of the tasks associated with major project execution and the extent to which structure and methods are included in project reports.

1. The model used to determine the tasks included in project reports was described in Section 3.6.4, Table 3-12. The principles of this model together with the worksheet shown in Table 4-8 were applied to 60 project reports. Thirty 2003 project reports and thirty 2004 project reports were examined to determine the level of incorporated tasks in the project by an independent assessor.

   i) The respective scores for the tasks and structure included in the 2003 and 2004 cohort project reports clearly show a considerable difference between the scores achieved by the respective cohorts. The 2003 cohort achieved a mean score of 498 and the 2004 cohort 736.

   ii) The 2004 cohort clearly demonstrated a greater awareness of the use of design methods and knowledge of the major project development process. It can be concluded that this has been achieved by the reinforcing effect of the MPD System. The 2003 cohort although educated in design methods and the product development process have not consolidated these into their design process to the same level. 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 was not significant. In contrast, the 2004 cohort did have 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 methods was greater.

   iii) It has been demonstrated from the results associated with the 2003 cohort that "students trained in the design and product-development processes including the associated tasks have failed to incorporate these in their project reports to any significant effect." Conversely, it has been demonstrated that "students trained in the stages of the design and product development processes but who have access to the MPD System are more likely to incorporate the stages and tasks in their projects."

   vi) The model that specifies tasks and design methods, developed in this thesis, presents a means of defining the tasks and structure in a range of projects, which may be incorporated into the assessment process, to enable fairer assessment. In addition, the model compliments the MPD System and as a result execution and examination of the project have a common basis.

6.5e Findings: Complexity of Projects:

a) Investigation of the relative complexity of projects by application of the author's model defining complexity.

b) Complex projects and the extent to which these include a higher use of design methods.

a) A new model for determining the Complexity of projects has been proposed, implemented by an independent observer and tested in this thesis. The model was applied to 60 project reports and the results confirmed its applicability and effectiveness in the determination of the levels of complexity.

i) It was found that the average level of complexity of projects produced by the 2003 cohort was significantly less than the average level of the 2004 cohort. In each instance of measurement the 2004 cohort's projects were determined to be more complex by an average margin of 20%. The difference between the cohorts was confirmed as statistically significant.

ii) An alternative method of communicating and presenting the complexity of a range of projects was proposed and presented in this thesis. A matrix method contrasts the scatter of both cohorts and differentiates the two cohorts clearly demonstrating that the 2003 group of projects is less complex than the 2004 group.

iii) This aspect of the research has presented a new means of defining the order of complexity associated with a range of projects which needs to be incorporated into the assessment process of industrial design major projects to ensure a more balanced assessment. In addition, the model assists understanding of aspects of a project such as environmental, scientific, ergonomic, aesthetic, health and safety, regulatory, manufacturing and engineering.

iv) It was found that the model and the associated instrument were effective in application and that use of same produced logical and clearly relevant outcomes. This development as part of this thesis is important with regard to its originality.

b) The complexity of projects was established as discussed in a) i, above. The results were tested against the use of design methods based on a survey of students' use of methods and also based on the examination of the tasks and structure included in project reports.

i) The use of design methods by the 2003 cohort was tested against the complexity of project and it was found that a positive correlation existed. Similarly there was a significant correlation between the task score (discussed in 6.5d) and the complexity of projects.

ii) The use of design methods by the 2004 cohort was tested against the complexity of projects and it was found that a negative correlation existed. However there was correlation between the task score and project complexity.

In summary, the determinant “task score” which was derived from examination of the reports has proven to be a reliable indicator and it is concluded that complex projects do include a higher use of design methods.

6.5f Findings: Academic performance: Investigation of designer performance:
a) by the established assessment process; contrasted with
b) external examination using criteria based on the MPD Model.

a. The project reports produced by the 2003 and 2004 cohorts were examined, following project completion, by an established assessment procedure described in this thesis. The results, of this assessment process, are recorded; the average of the Projects for the 2003 cohort, 67 out of 100 and correspondingly 65 for the 2004 cohort.

b. The reports were examined by an independent assessor and the results are recorded; the average of the projects for the 2003 cohort, 47 out of 100 and correspondingly 68 for the 2004 cohort.

It was found that conflict exists between these determinations and it has to be noted that the normal assessment procedure described in Section 2.1.6.1 does not include a significant proportion of mark allocated to the rigorous assessment of the project reports. The final awarded outcomes are based more on a continuous presentation to panels consisting of lecturers and practitioners over the year rather than on a rigorous assessment of project reports. In addition, there is an inherent tendency by lecturers and industrial design practitioners, when engaged in assessment, to assess the presentation at the expense of rigorous assessment of the reports. Because of this it is has been shown that the assessment outcomes in b. above has produced a more realistic appraisal of the quality of the reports. Cleary, the 2004 cohort has performed more effectively on average, and the assessment worksheet described in Table 4-8 was confirmed as facilitating rigorous interrogation of the reports. This research has demonstrated a methodology for the assessment of major projects. Further work needs to be done to integrate the findings associated with this thesis, such as the task and complexity determining instruments, to realise a comprehensive process of assessment.

6.6 A SUMMARY OF IMPORTANT FINDINGS IN THIS RESEARCH

1. The results arising from the survey of academics revealed a serious situation in most industrial design programmes where the application and engagement of students to major project work does not include a broad consideration of issues and techniques which are considered by the author to be fundamental to the product development process. Students are limiting their application skills and methods to those traditionally taught and applied in industrial design and there is no significant awareness of the importance of alternative approaches that can lead to a wider consideration of issues. The findings revealed also that students were not prepared for the professional practice of product design.

2. The MPD Model provides a structure, tasks and design methods for students engaged in final-year projects. The model has arisen from and is based upon a theoretical framework developed as part of this thesis.

3. The creation of the MPD System, a computer-integrated suite of design methods based on the MPD Model, has taken a number of years to develop and represents a pedagogical breakthrough in relation to the teaching and learning associated with final-year major projects. There is also potential for application by design professionals and in engineering design.

4. The manner in which the MPD Model and MPD System can be applied to the industrial design studio, to facilitate a more dual-brained approach that enables a more systematic approach without compromising the creative thrust of the studio, is important as a framework in the studio.

5. The development and specification of tasks has led to the development of an instrument that has been applied to the assessment of major projects. This development has presented a more systematic basis to the evaluation of student work compared to the chaotic approach in many design schools.

6. The development of the model for complexity evaluation is a new approach to the evaluation in the relative complexity of industrial design project work. The model together with the assessment instrument provides a system by which assessment projects may be considered in relation to complexity.

6.7 REVIEW OF FINDINGS IN RELATION TO THE ORIGINAL RESEARCH PROPOSITIONS

The research propositions promulgated in this research are stated in Section 4.2.1, Table 4.5. These eleven propositions have guided the research and the results associated with each have been discussed in Chapter 5. The findings in relation to these propositions are discussed below.

1. *Industrial design students engaged in final-year major projects do not include design methods and methodology to any significant extent in their project work and in their Project Research and Project reports.*

   i) The survey of industrial design academics in Australia and overseas revealed that the level of use, by students', of design methods and methodologies, was very unsatisfactory. These findings are important because it suggests a serious lack of awareness of the potential value of the use of design methods.

   ii) The extent of use of design methods was determined by the survey of students in cohorts from final years 2003 and 2004. The results presented in this section together with the findings and conclusions in 6.5b) also confirm that the use of design methods is not significant, and a higher level of application would be desirable.

   iii) Therefore the research proposition is supported by the findings.

2. *Students, educated in design methods, but who additionally have access to a computer-integrated suite of design methods, arranged around a Major Project Development Process (MPD System), incorporate design methods to a greater level in their Project Research and Project reports.*

   i) The results from the survey of the 2003 and 2004 cohorts that the 2004 cohort (who had access to the MPD System) achieved in many instances a greater use of methods. This was noticeable when a specific method was provided by the MPD System.

   ii) In addition, the examination of the project reports summarised in Section 5.3.3 proved a significantly greater incidence of the use of tasks and methods by the 2004 cohort who had access to the MPD System.

   iii) Therefore the research proposition is supported by the findings.

3. *Students trained in the stages of the design and product-development processes, including the associated tasks, do not incorporate the stages and tasks, in their projects, to any significant extent.*

i) It has been shown that the 2003 cohort, although previously trained in the stages of the design and product-development processes, including the associated tasks, did not incorporate these to any significant extent in their project reports.

ii) Therefore the research proposition is supported by the findings.

4. *Students trained in the stages of the design and product-development processes, including the associated tasks, but who have access to the MPD System, are more likely to incorporate the stages and tasks in their projects.*

i) The results clearly show a considerable difference between the scores achieved by the respective cohorts. The 2003 cohort achieved an average score of 498 and the 2004 cohort 736. In each stage of the MPD Model the incorporation of tasks by the 2003 cohort was considerably less.

ii) Therefore the research proposition is supported by the findings.

5. *There is a perceived need, by final year students, of a more comprehensive computer integrated selection of design methods, than that which is currently available.*

i) Thirty-one respondents out of forty-one (75.6%) of the 2003 cohort believed there was a need for a computer-integrated system of design methods. Eight respondents (19.5%) felt that such a system was unnecessary and two (4.8%) were unsure.

ii) Twenty-nine respondents out of thirty-six (80.5%) of the 2003 cohort believed there was a need for a computer-integrated system of design methods. Six respondents (16.6%) felt that such a system was unnecessary and one (2.7%) was unsure.

iii) In the light of i) and ii) above, the research proposition, that there is a perceived need for a computer-integrated system of design methods, is confirmed. The positive affirmation of the need for a computer-integrated system justifies the development of the suite of design methods software and CD.

6. *Students who have used the MPD System claim that is of considerable assistance to them in their major project work.*

i) A clear majority of students confirmed that the MPD System was of considerable assistance in their project work.

ii) Therefore the research proposition is supported by the findings.

7. *The higher the motivation towards the major project the higher the use of various design methods.*

i) The determination of the motivation of the 2003 and 2004 cohorts of students was tested against the assessed results of Project Research and Project and the average of these. There is no correlation between motivation and the use of design methods. The use of design methods are more probably related to more pragmatic issues such as planning ability.

iii) Therefore the research proposition is not supported by the findings.

8. *The higher the UAI of the student the higher the use of design methods.*

i) The Universities Admission Index (UAI) for both the 2003 and 2004 cohorts were tested against the assessed results obtained in Project Research, Project and the average of these; the results demonstrate there is no correlation between the UAI and the above assessed results.

ii) Therefore the research proposition is not supported by the findings.

9. *The higher the WAM of the student over the 4-year degree the higher the use of design methods.*

i) The Weighted Average Mark (WAM) for both the 2003 and 2004 cohorts were tested against the extent of use of design methods.

ii) These correlations demonstrate no significant correlation between the WAM and the use of design methods however the WAM demonstrates a positive correlation to project quality.

ii) Therefore the research proposition is not supported by the findings.

10. *A greater incidence of the use of design methods will lead to a higher quality project outcome.*

i) It was shown that the greater incidence of use of design methods and incorporation of tasks did correlate with a higher quality project outcome.

ii) In this category the research proposition is supported.

11. *Complex projects tend to incorporate a higher use of design methods.*

i) The findings indicate that there is correlation between the use of design methods and the complexity of the project. In addition, there is significant correlation between the examined task score and the complexity of the project.

iii) Therefore the research proposition is supported.

6.8 REVIEW OF FINDINGS IN RELATION TO ORIGINAL AIMS

1) In this thesis a critical review of the literature associated with industrial and product design, studio-based teaching and teaching and learning has been carried out. This has enabled an understanding of the problems associated with student engagement in final-year projects conducted in the industrial design studio. This outcome accords with the initial Aim of the thesis described in (1.3.1).

2) The determinations in 1) above were confirmed by a survey of academics in industrial design programmes in Australia and overseas which revealed the approach of students with respect to project management, conceptual development, design resolution and the extent to which design methods and structure was incorporated in final-year, studio major projects. This research was in accord with the original aim (1.3.1) and to the second aim described in (1.3.2).

3) A theoretical framework that modelled the process associated with the final-year major project together with a suite of design methods was developed to provide a reference base for student work in major projects. This theoretical frame work was in accord with the Aim (1.3.3).

4) From the theoretical framework and the suite of proposed methods a computer-based, expert system was developed and referred to as the MPD System. This development accorded with the Aim (1.3.4).

5) In the light of the theory developed in Aim (1.3.1) and within the scope set by Aim (1.3.2), an in-depth investigation has been carried out that analysed the nature and conduct of final-year major projects including an assessment of the tasks and complexity of projects reports. In addition, the research compared the outcomes of student project where a) students had no access to the MPD System and in contrast, b) where students were provided with the MPD System. This research work conforms to the original Aim (1.3.4)

6) Finally, as shown in this chapter, appropriate new findings and conclusions have been drawn, and their significance discussed in a wide context, for the future development of design studio education and the incorporation of structure and methods that; overall a unique compilation of theoretical and empirical information has been realised. These findings accord with Aim (1.3.6) of the thesis. Recommendations for future research will now follow.

6.9 RECOMMENDATIONS FOR FUTURE RESEARCH

1) Student responses to the survey question Appendix 2, Q13 and Appendix 3, Q14 (concerned with suggestions as to how project execution could be improved) repeatedly referred to the need to introduce the study of design process and methods much earlier in the degree programme. This would encourage the development of specific skills in the application of methods and enable a more sensible incorporation of methodologies into the design process. The implications of the earlier introduction of design process and methods into the studio design process require investigation and contrast with current approaches.

2) The development of a specific design process and suites of design methods require development to complement various classifications of industrially-designed products in industry, for example white-goods, automobiles, and furniture, among others. The structure of the design process involved may be derived from research of industrial companies and the methods and tools derived from research and from industrial case studies. The MPD System developed in this thesis may be further refined to include sub-sections that accommodate the various product classifications. The value of such a system applied to both the undergraduate and the industrial context requires investigation with respect to improvements in design outcomes and the process involved.

3) The findings associated with this thesis can be replicated in future years to facilitate a longitudinal study that may seek to confirm or otherwise the results obtained. This is particularly relevant if the suggestion in 6.8(1) and 6.8(2) are included.

4) This study has exposed shortcomings in the assessment process of final-year projects by industrial design staff. The inherent preference of many industrial design staff to focus on the final presentation needs to be studied in conjunction with the introduction of a new process of assessment that includes use of the method of evaluating tasks and the complexity of projects.

5) Research is needed to assess the deployment of the MPD System in engineering design and further research to test the applicability of the MPD System to professional design offices.

6) Further development of the software in conjunction with industry partners to manage copyright and proprietary software issues.

7.0 BIBLIOGRAPHY

Anand, K.N. and Pratap, R. Thinking Beyond Design Specifications: A March Towards Excellence in Customer Satisfaction. *Journal of Engineering Design*, Vol. 9, No. 3, 1998

Andreasen, M. Myrup (1991) Design Methodology *Journal of Engineering Design*, Vol 2, No 4

Andreasen, M.M. (1980) Machine Design methods based on a systematic approach, *Dissertation* (Lunds tekniska Hogskola) (in Danish).

Archer, B.L. (1966) *Systematic Method for Designers,* Design Council, London

Aranjo, C.S., Benedetto, H., Campello, A.C., Segre, F.M. & Wright, I.C. (1996) The utilisation of product development methods: a survey of UK industry, *Journal of Engineering Design*, 7, pp 265-277

Armstrong, J. and Conrad, L., (1995) 'Subject Evaluation', Griffith University, Queensland, Australia.

Australian Manufacturing Council, and Manufacturing Advisory Group (NZ). (1994). Leading the Way: A Study of Best Manufacturing Practices in Australia and New Zealand (report, 2nd edn.). Melbourne, Vic, Australia: Australia Manufacturing Council.

Baback, Y. and Holmes, C. Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. *Journal of Engineering Design*, Vol. 10, No. 1, 1999

Baxter, M. (1995) *Product Design: a practical guide to systematic methods of new product development*, Chapman and Hall

Beitz, W. (1994) Design Science - *The Need for a Scientific Basis for Engineering Design Methodology*. Journal of Engineering Design, vol 5, No. 2.

Bernhardt, E., (1983) *CAE-Computer-aided Engineering for Injection Moulding*. Carl Hanser Verlag, Munich, Germany

Best-Mangard, A. *A Method for Creative Design*

Bingham, A. in Bingham, N., ed. (1993) *The Education of the Architect:* Proceedings of the 22nd annual symposium of the society of architectural historians of Great Britain.

Bogle, M. (1998) Design in Australia 1880 – 1970, Craftsman House. North Ryde.

Boud, D. (1985) Problem-based learning in perspective. In Boud, D.J. (Ed) *Problem-based learning in education for the professions.* pp. 13-18 Sydney: Higher Education Research and Development Society Australasia.

Boud, D. (1991) Introduction, in Boud, D. and Feletti, G. (Eds) *The Challenge of Problem-based Learning*, Kogan Page, London

Bonollo E and Lewis B, *The Industrial Design profession and Models of the Design Process*. Design & Education Volume 6, Number 2, December, 1996.

Bonollo,E., (1993) PhD Thesis “Designing Courses in Industrial Design with particular reference to The Role of Undergraduate Projects”. The University of Melbourne

Boothroyd G., Dewhurst P., and Knight W. *Product Design for Manufacture and Assembly*. Marcel Dekker, Inc., 1995

Boothroyd G., Dewhurst P. Design for Assembly: Manual Assembly, *Machine Design*, December 8, 1983

Boothroyd G., Dewhurst P. Design for Assembly: Automatic Assembly, *Machine Design*, January 26, 1984

Bossert, J.L. *Quality Function Deployment: A Practitioner's Approach*. Marcel Dekker, New York

Burch, D. (1993) Introduction to Technology, Lecture series at the Queensland University of Technology, Brisbane.

Burns, J., Barclay, I and Poolton, J. (1996) A Structured methodology for implementing concurrent engineering in C J Backhouse and N J Brooks *Concurrent Engineering: What's working where*. Gower Publishing.

Clark, K.B. and Fujimoto, T. (1991) Product Development Performance: Strategy, Organisation and Management in the World Auto Industry, Boston, Mass. Harvard Business School press.

Cross, N. (Ed.) (1984) *Developments in Design Methodology,* John Wiley & Sons.

Cross, N. (1989) *Engineering Design Methods*, John Wiley and Sons

Cross, N. (2000) *Engineering Design Methods,* Third Ed., John Wiley & Sons,

Cross, N. and Roozenburg, N. (1992) *Modelling the Design Process in Engineering and in Architecture*, Journal of Engineering Design, Vol 3, No. 4.

Cummings, S. and Bonollo, E. (1999) Experience with dual-flush technology in Australian WC design. Proceedings CIB W62 Water Supply and Drainage, Heriot-Watt University, Edinburgh, Scotland, ppD6-1 to D6-8.

Cushman, W.H. and Rosenberg, D.J. *Human Factors in Product Design*. Elsevier, New York. 1991

Dale, B.G. & Shaw, P. (1990). Failure mode and effect analysis in the motor industry: A state-of-the-art study, *Quality and Reliability Engineering International*, 6, pp 179-188.

Darke, J. (1978). The primary generator and the design process. *New Directions in Environmental Design Research*: proceedings of EDRA 9, pp 325-337, Washington, EDRA.

Denscombe, M., (2003) The Good Research Guide, for small-scale social research projects. Open University Press Maidenhead, Philadelphia.

Dick, M. J., (1992) *High Tech Creativity.* The Institute of Electrical and Electronics Engineers, Inc. New York

Dillman, D. A. (1978). Mailand TelephoneSurvey; Totaldesign Method. New York, US: John Wiley & Sons.

Edelma, G., (1992) *Bright Air; brilliant fire: On the matter of mind*. Basic Books.

Eder, W. E. (1998) Design Modeling-a design science approach (and why does industry not use it?) *Journal of Engineering Design*, Vol 9, No. 4

Esherick, J. (1983) *The Beaux-Arts Experience*, Architectural Education 1, Royal Institute of British Architects, London, pp.23-52.

Fox, J., (1993) *Quality Through Design, The Key to Successful Product Delivery*, McGraw-Hill Book Company, England

Friedman, K. (1996) Subject: Informative and concise essay on the challenges of industrial design. Available: http://interaction.brunel.ac.uk/idforum/96_12/0135.html [1997, 25 September].

Frost, R.B. (1992) The Future of Machine Element Design Courses, Sydney: Conference on Teaching Engineering Designers

Frost, R. B. (1998) Why Does Industry Ignore Design Science? *Journal of Engineering Design*, Vol 10, No 4

Gallup, R.B., et al. (1991) Unlocking Brainstorms, *Journal of Applied Psychology*, 76, pp. 137-142.

Garb, A. and Chawdhry, P.K. Concurrent Specification in the Co-design of Reactive Engineering Systems, *Journal of Engineering Design*, Vol 9, No 1, 1998

Geradin, L. *Bionics*, Weidenfeld and Nicholson 1968

Garb, A. and Chawdhry, P.K. Concurrent Specification in the Co-design of Reactive Engineering Systems, *Journal of Engineering Design*, Vol 9, No 1, 1998

Geschka, H. & Kirchoff, G. (1993) Fluvius – An idea management software system, in: Geschka, H., Moger, S. & Rickards, T (Eds), *Proceedings of the 4th European Conference on Creativity and Innovation*, Darmstadt, 25-28 August, pp 141-149.

Geschka, H., (1993) The Development and assessment of creative thinking techniques: A German perspective, in : Isaksen, S.G. et al. (Eds) *Nuturing and Developing Creativity: The Emergence of a Discipline.* (Norwood, NJ, Ablex, pp 215-236

Giard[1], J., *The Lexicon of industrial design: out with the old, in with the new.* IDSA Design Education Conference Proceedings, Chicago, 1999

Giard[2], J., *Industrial Design Education: Incompatibility with education in art and architecture*. IDSA Design Education Conference Proceedings, Chicago, 1999

Gill, H. (1990) Adoption of design science-why so slow?, *Journal of Engineering Design*, 1, pp. 289-295.

Gordon, W.J. *Synectic. The Development of Creative Capacity*, Harper Row, 1961

Green L. N. (1998) *Value Analysis in Industrial Design, An Industry-University Interface.* The Australian Engineering Education Conference, Waves of Change, Gladstone, Queensland, September 21-28

Green, L. N. (1999) *A review of an Industrial Design Program which considers: the current context of education; competing programs across Australia; the views of graduates and final year students; the views of industry and employers of graduates; and results from the 1996 Course Experience Questionnaire,* 2nd Asia-Pacific Forum on Engineering and Technology Education, Sydney, Australia July 4th –7th.

Green, L. N. (1999) *Adding Value to the Studio: Value Analysis and Industry Involvement in the Studio*. DECA Conference, Sydney September 30 – October 2, 1999

Green, L. N. (1999) *Introducing Structure to Student Projects and Design Decision Making*; Proceedings of International Conference on Cities and Housing estates, Seoul, Korea, November 24, 1999

Green, L. N. (2000) *Educating Graduate Engineers in Industrial Design, 3rd UICEE Annual Conference on Engineering Education, Hobart Australia, 9th – 12th February*

Green[1], L. N. and Bonollo, E. (2001) *Understanding Design Methodology as a basis for its teaching*. 4th UICEE Annual Conference on Engineering Education, Bangkok, Thailand.

Green[2], L. N. and Bonollo, (2001) *The Application of Methodologies to Product Design Teaching Within the Industrial Design Studio*. 3rd Asia-Pacific Forum on Engineering and Technology Education, Changhua, Taiwan.

Green, L. N. and Bonollo, E. (2002) *The Development of a suite of design methods appropriate for teaching product design*. The Global Journal of Engineering Education.

Green, L. N. and Bonollo, E. (2003) *Studio-based Teaching, History and Advantages in the Teaching of Industrial Design*. World Transactions on Engineering and Technology Education. Vol. 2., No. 2. Melbourne 2003

Green[1], L. N. (2003) *The Nature of Industrial Design.* 1st North-East International Conference on Engineering and Technology Education, Changhau, Taiwan, 10-13 November, 2003

Green[2], L. N. (2003) *Design Methods in the Industrial Design Studio.* The Learning Community. First explorations of the Research-Teaching Nexus at UNSW.

Griffin, A., (1993) "Metrics for measuring product-development cycle time" Journal of Product Innovation Management Vol 10 pp112-125

Gropius, W. (1983) *The Bauhaus, in Architectural Education 1*, RIBA Magazines, London

Jones, J. C., (1992) Design Methods, Van Nostrand Reinhold, New York

Hammer M. and Champy J. *Re-Engineering the Corporation*

Hart, L., (1983) *Human Brain, Human Learning*. Longman New York.

Hein, Lars. (1994) *Design Methodology in Practice*. Journal of Engineering Design, Vol 5, No. 2.

Heskett, J. (1997) *Industrial Design.* Thames and Hudson, London.

Hillier, W., Musgrove, J., & O'Sullivan, P. (1984) Knowledge and design, in Cross, N. Developments in Design Methodology (Chichester, Wiley)

Hollins, B. and Pugh, S. (1987) *Successful Product Design*, Butterworth & Co.

Holt, K., (1989) Does the engineer forget the user?, Design Studies Vol. 10 No. 3

Holt, K., (1996) Brainstorming – From Classics to Electronics, *Journal of Engineering Design*, Vol. 7, No. 1, pp 77-82.

Holt, K., (1993) Computer-aided Creativity in Engineering Design, *Journal of Engineering Design*, Vol. 4, No. 4, pp 371-376

Hongo, K., & Amirfazli, A. (1994) Design Philosophy, Journal of Engineering Design, Vol. 5, No. 2.

Huang, G. Q., (Ed) (1996) Design For X, Concurrent Engineering Imperatives. Chapman & Hall.

Huang, G.Q. & Mak, K.L. (1999) Web-based Collaborative Conceptual Design, *Journal of Engineering Design*, Vol. 10, No. 2.

Hubka, V. & Eder, W.E. (1988) *Theory of Technical Systems*: *A Total Concept Theory for Engineering Design*, (Berlin, Springer)

Hubka V. (1984) Attempts and possibilities for rationalization of engineering design, *Proceedings of International Symposium on Design and Synthesis, Tokyo. (Tokyo, Japan Society of Precision Engineering*)

Hubka, V. (1976) *Theorie der Konstruktionsprozesse* (Berlin, Springer)

Hubka, V. (1988) *Theorie of Technical Systems* (Berlin, Springer)

Hsu Hung-Yao and Grier, C.I. A Design-for-assembly-based product Redesign Approach *Journal of Engineering Design*, Vol. 9, No. 2, 1998

Industrial Design Society of America (1996) IDSA, Great Falls, USA.

Johnston, L. *Structure and Methodology in Architectural Education*. Aspects of quality in Australian architectural education. Royal Australian Institute of Architects, New South Wales Chapter. Pp. 45-56

Jones, T., (1997) New Product Development: an introduction to a multifunctional process. Butterworth Heinemann, Oxford.

Kaufman, J. *TNT ~ Industrial design curriculums.* IDSA Design Education Conference Proceedings, Chicago, 1999

Koestler, A. *The Art of Creation*, Hutchinson UK and Pelican 1969

Lawson, B. ((1997) *How Designers Think: the design process demystified (3rd Ed),* Butterworth and Company

Laxton, M. (1969). Design education in practice. *Attitudes in Design Education*. London, Lund Humphries.

Ledewitz, Stefani (1985) *Models of design in studio teaching*, Journal of Architectural Education 38 (2), pp. 2

Lewis B and Bonollo E, (2002) An analysis of professional skills in design: implications for education and research. Design Studies (23) pp385-406.

Maffin, D. (1998) Engineering Design Models: context, theory and practice, *Journal of Engineering Design*, Vol. 9, No. 4

Maitland, B. M. (1991) *Problem-based Learning for an Architecture Degree*, in Boud, D. and Feletti, G. (Eds), The Challenge of problem-based Learning, Kogan Page, London

Markus, T. (1969) The role of building performance measurement and appraisal in design method. *Design Methods in Architecture*. London: Lund Humphries.

Maver, T. (1970) Appraisal in the building design process. In Moore, G.T. (ED.), *Emerging methods in Environmental Design and Planning* (Cambridge, MA, MIT Press.

McCarthy, B., (1996) *The 4-MAT System: Teaching to Learning Styles with Right/Left Mode Techniques*. Oak Brook, Illinois

McQuater, R.E., Dale, B.G., Boaden, R.J. & Wilcox, M. (1996) The effectiveness of quality management tools and techniques: an examination of the key influences in five plants, *IMechE Proceedings, Part B Engineering Manufacture*, 210, pp 329-339.

Meerkamm H. *Design for X – A Core Area of Design Methodology*, Journal of Engineering Design Volume 5, Number 2, 1994.

Miles L.D. *Techniques of Value Analysis and Engineering*, McGraw Hill Book Company 1961

Miyakawa, S., Ohashi, T., Iwata, M. (1990) The Hitachi New Assemblability Evaluation Method, *Transactions of the North American Manufacturing Research*, Institution (NAMRI) of the SME, the NAMR Conference XVIII, May 23-25, 1990, Pennsylvania State University, Dearborn, USA.

MonÖ, R., (1997) Design for Product Understanding, Liber AB, Stockholm

Moody, J., Chapman, W., Van Voorhees, F., and Bahill, A. (1997) Metrics and Case Studies for Evaluating Engineering Designs. Prentice Hall, New Jersey.

Morgan, A. (1983) Theoretical aspects of project-based learning in higher education. British Journal of Educational Technology. 14 (1), pp.66-78.

Moss, M. (1996) *Applying TQM to Product Design and Development*. Marcel Dekker Inc., New York.

Newble, D. and Clarke, R.M. (1985) *The approaches to learning of students in a traditional and in an innovative problem-based medical school.*, Medical Education 20: 267-73.

Norell, M. (1993) The use of DFA, FMEA, and QFD as tools for concurrent engineering in product development processes, *Proceedings of ICED 93* The Hague

Osborn, A.F. (1953) *Applied Imagination*, Charles Scribner New York

Pandey, A. & Clausing, D.P (1991) QFD implementation survey report, *Internal Working Paper*, Department of Mechanical Engineering, Massachusetts Institute of Technology.

Papanek, V. *Design for the Real World*, Paladin, 1977

Pevsner, N. (1940) *Academies of Art – past and present,* Cambridge, at The University Press.

Powers, A., in Bingham, N., ed. (1993) *The Education of the Architect:* Proceedings of the 22nd annual symposium of the society of architectural historians of Great Britian.

Proudfoot, P. (1989) *Phenomenology, A model for architectural education?* Architectural Science Review, Vol. 32, pp95-100

Pugh, S. (1991) *Total Design: integrated methods for successful product engineering*, Addison Wesley

Ramsden, P. (1992) *Learning to Teach in Higher Education*, London: Routledge.

Readers Digest (1984) Great Illustrated Dictionary. The Readers Digest Association Ltd. London.

Richardson, S. and Poulson, D. (1996) Usability-Disability and Elderly. 3rd Annual Concertation Meeting of the Telematics Applications Programme, Applications for the European Information Society. Brussels: Palaisdes Congress, December 2-3.

Romiszowski, A. (1981) Designing Instructional Systems London Kogan Page.

Rowe, P. G. (1987) *Design Thinking*, MIT Press

Rowntree,D. (1981) *Developing courses for students*. London, New York:McGraw-Hill

Ryan, N (Ed) *Taguchi Methods and QFD: Hows and Whys for Management*. ASI Press, Michigan

Samuel A E and Weir J G “ A parametric approach to problem enformulation in engineering design” Proceedings of 11th International Conference on Engineering Design, Tampere University of Technology, Finland, (1997) pp.3/93-3/90

Schmuller, J., (2005) Statistical Analysis with Excel for Dummies. Wiley Publishing, Inc. Hoboken, New Jersey

Schon, D. A., (1987) *Educating the Reflective Practitioner* Jossey-Bass Publishers San Franscisco

Sivaloganathan, S., Evbuomwan, N.F.O., Jebb, A., and Wynn, H.Q. (1995). Design Function Deployment- A Design System for the Future. Design Studies 16.4: p. 447-470.

Talbot, J. (1999) *Evaluation of a user-centred approach to industrial design*. MSc Thesis, School of Safety Science, The University of New South Wales

Tan A.K. and Bonollo E., (2001) *Integrated Genome-Like Product database and Management System*. ASME International 21st Computer and Information in Engineering (CIE) Conference September 9-12, 2001 Pittsburgh, Pennsylvania.

Thorne, P., in Bingham, N., ed. (1993) *The Education of the Architect:* Proceedings of the 22nd annual symposium of the society of architectural historians of Great Britain.

Tovey, M., (1984) *Designing with both halves of the brain*, Design Studies, Vol 5, No 4, pp219-228.

Tovey, M., (1986) *Thinking styles and modelling systems*, Design Studies, Vol 7, No 1, pp20-30.

Trost, Robert L.A., (1989) The Structure of CAC Software, *Creativity in Action (CIA), Newsletter of the Creative Education of the University of Buffalo*, September, October and November p4.

Trost, Robert, L. A., (1993) Computer-assisted brainstorming and the global think-tank, Paper presented at ISPIM 1993, Eindhoven University of Technology, September 5-8.

Tibbetts, K. (1995) An Introduction to TeamSET™ , CSC Manufacturing, Computer Sciences Ltd, Dog Kennel Lane, Shirley, Birmingham, England.

Wallace, K. M. & Hales, C. (1987) Some applications of a systematic design approach in Britain, Konstruktion, 39.

Wang, J. and Ruxton, T. A Design-for-safety Methodology for Large Engineering Systems. *Journal of Engineering Design*, Vol. 9, No. 2, 1998

Warell, A. (1999) Industrial Design Elements: A theoretical foundation for industrial design based on a design science perspective. Linkopings University, Sweden

Weil, S.W. and McGill, I. (Ed.) (1989) Making Sense of Experiential Learning. Open University Press

White, R., (1998) *Value Analysis*

Yeh, Wen-Dih., The Effects of Industrial Design Education and Its Future Directions. IDSA Design Education Conference proceedings.

Young, H. Ed., (1995) *The Genius of Wedgwood*, The Victoria and Albert Museum, London.

Zwicky, F. *Morphological Analysis*, McMillan New York 1969

8.0 GLOSSARY

Anthropometric Analysis	The measurement of people. When designing products for people to use it makes inescapable sense to use measurements of people as a basis for product dimensions.
Benchmarking	A benchmark is a point of reference against which other items are measured. Benchmarking enables a company or designer to establish the best practice that will enable it to design or develop a product, which exceeds those compared. Benchmarking, while it can be applied selectively, is most effective when applied to all aspects of a company or product to give total quality and best practice across the board. Despite other methods of Quality Management constantly being developed, benchmarking is one of the most powerful as it allows comparison with best practices in the world and therefore allows for constant improvement on all levels. By comparison a company can find its weakness and strengths and improve on both.
Bionics	This technique, organised as a creative-thinking approach can be used as a source of ideas using the structure of brain-storming or morphological analysis as a means to organise or contain the ideas. Aspects of this technique could include applications, uses, features or functions taken from the world of: - animals, insects, microbes, viruses, vegetables, plants, fungi. - trees, foliage, swamps, lakes, oceans, volcanoes, air, water - systems for circulation, digestion, reproduction, excretion. - seeds, plants, pollination, seed distribution. (White, 1998)
Brainstorming	A method that stresses using imagination and encourages all members of a group (4–8 persons) to spontaneously contribute their ideas. These are then reduced to a significant few. (Osborne, 1953)
Brain-writing	Similar to brainstorming however participants write their ideas on special forms or cards that circulate within the group. This gives more time to think than in brainstorming where ideas are expressed spontaneously. Developed by Bernd Rohrbach in the late 1960s under the name method 635. The group consists of six members and each generates and writes down three ideas in a 5-minute period. The form is then passed to the adjacent person who writes down three new ideas and so on (Holt,1996).
Computer-Aided Design (CAD)	For communicating information as well as for conceptualisation, modelling using a 3D CAD is a cost-effective alternative to physical modelling when working on complex projects CAD's manipulative capabilities (rotation, magnification or reduction, animation) encourages seeking alternatives. (Dick, 1992)
CAD/CAM	The integration of computers into the entire design-to-fabrication cycle of a product or plant. (Bernhardt, 1983)
Competitor Analysis	Examines the performance of competing companies and the product ranges they offer (Baxter, 1995).
Computer-integrated manufacture (CIM)	A method that links the information flow and technical integration of all operational areas involved in the product development process. It represents a highly sophisticated

	philosophy and system requiring computerised planning, control and optimisation of processes (Warnecke, 1988).
Concept Selection (Pugh)	Pugh's evaluation method gives a graphical technique that centers around a matrix with columns (showing concepts) and rows (giving design criteria). It is simple and fast however no measure is given of the importance of each criteria. The simplicity of this method achieves a good screening process against highly unfeasible concepts and can allow the designer to focus on the best concepts then using an alternative selection method (King and Sivaloganathan, 1999).
Concurrent Engineering (CE)	The concept of CE concerns itself with product development work carried out in parallel processes and with a high degree of cooperation between different domains. It involves the establishment of a product development team whose members come from departments having a direct interest in the product development (Haung, 1996).
Delphi technique	Elicits ideas from participants by means of a series of highly structured and progressively more focused questionnaires.
Design Process	Totality of the activities with which all the information necessary for producing and operating a technical system or product is processed in accordance with the task. The result is a set of product documents.
Design for Assembly (DFA)	The real achievement of DFA methods is their ability to provide measurements of assembly efficiency which allows an effective criteria to apply in a team-based situation. The other real benefit of DFA is that it centers attention on the complete product (or sub-assembly) as a whole and then promotes the ideas of parts reduction, standardised parts and product modularisation.
Design-by drawing	Graphic methods have application as aids for thinking, communicating or both. Their uses in developing product-Oriented ideas involve symbol language, diagrammatic solutions, sketches and detailed illustrations. (Dick, 1992)
Design of Experiments (Taguchi)	Taguchi methods involve systematically considering quality and its optimisation at the product and process design stages. It involves investing early in the product/process development cycle to find appropriate materials and parameter values in order to achieve quality control, and to satisfy customers through have a 'process-capable' system. These methods can be used to investigate the robustness of alternative designs (Samson, 1991).
Design for Manufacture	DFMA provides a systematic procedure for analysing proposed and Assembly (DMFA) designs from the point of view of manufacture and assembly. It encourages teamwork and a dialogue between designers and the manufacturing engineers, and any other individuals who play a part in determining final product costs during the early stages of design.
Design for Service	Design for Service (DFS) helps design teams address serviceability of their designs at the same time as the important decisions are being made for ease of initial assembly.

Design for Disassembly (DFD)	Involves developing products that are easy to take apart and thus facilitate recycling and removal of hazardous materials. The methodology consists of a spreadsheet-like chart and rating scheme for quantifying disassembly difficulty. Difficulty scores derived from work measurement analysis of standard disassembly tasks provide a means of identifying weaknesses in the design and comparing alternatives (Hanft and Kroll, 1996).
Design for Sustainability	
Design for Environment (DFE)	Addresses environmental concerns in all stages of product development – production, transport, consumption, transport, maintenance and repair, recovery and disposal. The aim of DFE is to minimise the environmental impact of products from production through use to disposal (Van Hemel, Keldmann, 1996).
Design for Reliability (DFR)	A method for analysing mechanisms at the early stages of the design process. This method gives designers a greater insight into how and why a proposed design may fail and identifies aspects of the design that may need to be improved. Although the method is based on evidence from mechanism design, the overall approach should be capable of being extended to all other types of mechanical design (Stephenson and Wallace, 1996).
Design for Modularity	This is a method that assists in achieving and evaluating Modularity of product and component designs. Through the use of the method it becomes easier to plan products and predict their performance, as well as to plan and control the development. It uses Quality Function Deployment (QFD) to establish customer requirements and technical solutions which is followed by a systematic generation and selection of modular concepts (Erixon, 1996).
Detailed Design	Takes the outputs from Embodiment Design, that is, a fully developed and tested working prototype, and determines in detail how the product will be made.
Embodiment Design	Begins with a preferred concept and ends with a fully developed and tested working prototype.
Ergonomic Analysis	Is a research topic in its own right and covers aspects of anatomy, physiology and psychology, as well as being applied to design (Baxter, 1995).
Engineering Design	Design with particular emphasis on the technical aspects of a product. Includes activities of analysis as well as synthesis.
Failure Mode, Effects and Criticality Analysis (FMECA)	Failure mode and effects analysis (FMEA) is a procedure that identifies potential component failures and assesses their affect on the system. If the criticality of the effect is also considered in the analysis, the analysis is then referred to as the failure modes, and effects and criticality analysis (FMECA). A FMEA or a FMECA analysis is used to detect potential weak spots in the system design and improve them through design changes focused on increasing the reliability of the system (Sundarajan, 1991; Moss, 1985; Priest, 1988).

Fault-tree Analysis	Begins by listing each conceivable way in which the system as an entity can fail, and tracing the possible causes of each such system failure mode downward, tier by tier, until the ultimate sources have been identified. The findings of an FTA can be depicted in the form of a tree, branching from a single node at its top (Moss, 1996).
Features Analysis	A method whereby the features of a product are identified, weighted in order of importance, compared and ranked against competitive products. The respective summation of the scores for each product enables an understanding of the relative value of the products.
Form Design	Totality of all detailed activities through which the elements of a product are determined, that is the geometrical shape of parts, their dimensions, surface finishes, materials, and their overall combination into a product. The result is a set of detail drawings or detailed specifications.
Function	It is the aspect of design that cause failure or poor performance of the product and is perceived by customers as not meeting their requirements (Fox, 1993).
Function Analysis	The process by which the effective function can be measured against a laid down specification, setting limits of acceptable operation as thresholds for unacceptable performance (Fox, 1993).
Interaction Matrix	To permit a systematic search for connections between elements within a problem
Idea Trees	The idea tree is a graphical method of developing and organising a hierarchy of problem statements and solutions. The idea tree gives an organised, concise picture of several possible solutions. Additionally, alternative hierarchies in organising the idea tree emphasise different perspectives can stimulate even more ideas. (Dick, 1992)
Industrial Design	The ideation, specification, and development of functions, properties and concepts of industrially manufactured products and systems, mainly regarding aspects of user-product interaction, aesthetics and identity considering a totality of ergonomic, usability, technical, economic and social factors.
Integrated Product Development	A human-centered procedure for developing competitive products or services of high quality, within a reasonable amount of time and with excellent price-performance ratio. It describes the integrated application of holistic and multi-disciplinary methods, organisation forms, and both manual and computer-supported tools with minimised and sustainable use of production facilities and resources (Vajna and Burchardt, 1998).
Investigating User Behaviour	To explore the behaviour patterns, and to predict the performa limits, of potential users of a new design iteration.

Literature Searching	To find published information that can favourably Influence the designers' output and that can be obtained without unacceptable cost and delay.
Life-cycle Analysis	Also known as "cradle-to-the-grave" analysis it looks at the environmental cost of each stage of the product life cycle and gives a relative weighting to the manufacture, transport, use and disposal of products.
Market Needs Research	A set of methods for finding out what customers are looking for in a particular type of product.
Morphological Analysis	To widen the area of search for solutions to a design problem
Objectives Tree	The objectives tree method presents a clear and useful format for revealing the objectives of the design project. It shows in diagrammatic form the ways in which different objectives are related to each other and the hierarchical pattern of objectives and sub-objectives.
Opportunity Specification	A concise written document describing the market need for a proposed new product and the business opportunity presented by that product.
Parametric Analysis	A parameter is literally something that can be measured and usually refers to dimensional measurements (eg. Metres, kilograms, Newtons). The parametric analysis of a problem or product , however, usually covers quantitative, qualitative and categorical features (Baxter, 1995).
Pareto Analysis	*A* simple tool for problem solving that involves ranking all potential problem areas or sources of variation according to their contribution to cost or to total variation. Efforts are best concentrated on the 'vital few' causes, temporarily ignoring the 'trivial many.'
Performance Specification Method	This method sets up boundaries to the solution space within which the designer must search. Later in the design process the performance specification can be used in evaluation of the solution.
Product Design	The activities involving the design of products including the activities of engineering design and industrial design.
Product Development	The total sequence of activities required to create a new product, including design, development, manufacture, assembly, installation and operation.
Product Development Risk Audit	Method of exploring different product development options and assessing them in relation to the company's skills and historical track record (Baxter, 1995).
Product Function Analysis	A method of systematically analyzing the functions performed by a product (as perceived by the user).

Product Maturity Analysis	Reveals where each product in the company's product range is their product life cycle and projects forward to estimate when t product is likely to start to decline in sales (Baxter, 1995).
Questionnaires	To collect usable information from the members of a large population.
Rapid prototyping	Rapid prototyping and tooling are increasingly being recognised as significant techniques in the battle to shorten time for product development. The ability to translate a three-dimensional computer representation into a physical model in a very short time enables companies to respond to design change requirements, evaluate components in context and in-situ, and introduce products into the market with speed and precision.
Removing Mental Blocks	To find new directions of search when the apparent search has yielded no wholly acceptable solution.
Statistical Process Control (SPC)	Involves the observation of processes, the collection and analysis of data, and the taking of appropriate process control actions and decisions. Process capability can be determined using control charts and when linked to cause-and-effect diagrams, a problem identification process can be established to eliminate systematic variation. When introduced during the product design phase SPC methods can lead to the potential for appropriate levels of process capability which can have significant economic implications (Samson, 1991).
Task analysis	The simple, almost common sense, approach to studying both the ergonomic and anthropometric aspects of products.
Total Quality Management (TQM)	The extension across all activities of an organisation of the management function that determines and implements the quality policy, that is, the overall intention and direction of the organisation regarding quality as formally expressed by top Management (Samson, 1991).
Tracking Study	An on-going programme of market research which monitors changes in customer perception of a company, brand or product identity (Baxter, 1995).
Trend Studies	Method of exploring trends ???? more?
User interviews	To elicit information that is known only to users of the product system in question.
Value Analysis / Value Engineering	
SCAMPER Analysis	Is an acronym and stands for 'substitute, combine, adapt, magnify or minify, put to other uses, eliminate or elaborate, and rearrange or reverse'.
Synectics	A complex method that forces participants to alter perspectives via analogy and imagination thus stimulating a variety of ideas. (Gordon, 1961)

SWOT Analysis	SWOT stands for Strengths, Weaknesses, Opportunities a Threats. Provides a simple but systematic framework for apprais the company's current business position under the aforementior headings (Baxter, 1995).

NOTES:

Appendix 1 - Survey of Industrial Design Academics

Industrial Design Program,
Faculty of the Built Environment,
The University of New South Wales
Sydney, 2052. Australia
Tel 61 2 9385 6840
Fax 61 2 9385 4507
e.mail l.green@unsw.edu.au

Dear fellow designers and academics,

I am a research student employed at The University of New South Wales (UNSW), Sydney, Australia and studying towards a PhD at The University of Canberra, Australia. Attached to this letter is a questionnaire that seeks to gather information on the approach, attitudes and methods employed by industrial design students as they progress through their final-year, major project. The questionnaire is part of a study of the industrial design studio and its relation to the teaching of product design students.

The questionnaire is divided into four sections:

1. Management and research associated with the project;
2. Conceptualisation demonstrated in the project;
3. Embodiment and resolution; and
4. Design methods and tools employed in the project.

This questionnaire has been sent to the prominent industrial design departments in Australia, New Zealand and Asia. If you cannot answer a particular question for any reason please indicate in the space provided.

This survey seeks to determine the effectiveness of various aspects of students' approaches and the methods they use as they progress through their major projects. In addition to this survey I intend to analyse 60 major student research and project reports which will further identify the effectiveness of student research and project work. I will then introduce an objective taxonomy of the product-development process that will include a range of design methods linked to the various phases of the process. The thesis associated with my PhD study argues that, in many instances, final-year students flounder through their major projects because of the absence of a formal system to provide a structure and tools.

If you have any questions please feel free to contact me at the addresses/numbers below. I would be pleased if you could respond to this questionnaire mail to the address below. Your prompt response will be most appreciated. All responses will be treated confidentially. Thank you very much for your time. I look forward to hearing from you at your earliest convenience.

Sincerely yours,

THE UNIVERSITY OF
NEW SOUTH WALES

INDUSTRIAL DESIGN PROGRAMME

SYDNEY 2052

Survey of Industrial Design Academics

Thank you for taking the time to complete the questionnaire.

A study of the design studio In relation to the teaching of industrial design

On completion, please return in the self-addressed, stamped envelope included with this questionnaire by:
30th March, 2004

If you have any questions regarding this questionnaire or project, please contact Lance Green

phone (02) 9385 6840
fax (02) 9385 4507
E-mail l.green@unsw.edu.au

Management & Research

1. This section includes the tasks associated with the overall management (project coordination, time management, engagement, identification and liaison with industry sponsors) and the research work (identification of product opportunity, market, competitor, and user studies) associated with the project.

	unsatisfactory ← → excellent 1 2 3 4 5	N/A
Time management………………………………………………	☐☐☐☐☐	☐
Generation of project ideas/create new product concept…….	☐☐☐☐☐	☐
Screening of project ideas………………………………………	☐☐☐☐☐	☐
Engagement with project ………………………………………	☐☐☐☐☐	☐
Evaluate market opportunity……………………………..……..	☐☐☐☐☐	☐
Investigate legal / trade restrictions ……………………………	☐☐☐☐☐	☐
Search of patents and design registrations……………………	☐☐☐☐☐	☐
Materials research………………………………………………..	☐☐☐☐☐	☐
Manufacturing research………………………………………..	☐☐☐☐☐	☐
Ergonomics research …………………………………………..	☐☐☐☐☐	☐
Evaluation of competitive products……………………………	☐☐☐☐☐	☐
Screen information and assess relevance……………………..	☐☐☐☐☐	☐
Design questionnaires….………………………………………..	☐☐☐☐☐	☐
Conduct user surveys……………………………………………	☐☐☐☐☐	☐
Market research…………………………………………………..	☐☐☐☐☐	☐
Identify and liaise with industry sponsor………………………	☐☐☐☐☐...	☐
Develop design brief……………………………………………	☐☐☐☐☐	☐
Provision of a realistic time plan……………………….……..	☐☐☐☐☐	☐
………………….………………………………………………..	☐☐☐☐☐	☐

Conceptualisation

2. This section includes the conceptualisation phase that follows the research and the development of a design brief. In this area of the project, students must generate ideas for a product concept, assess and screen these ideas to arrive at a final proposal.

	unsatisfactory ← 1	2	3	4	excellent → 5	N/A
Creative thinking………………………………………………	☐	☐	☐	☐	☐	☐
Conceptualisation…………………………………………….	☐	☐	☐	☐	☐	☐
Idea generation………… …………………………………….	☐	☐	☐	☐	☐	☐
Screening of ideas …………………………………………….	☐	☐	☐	☐	☐	☐
Application of brainstorming techniques………………………	☐	☐	☐	☐	☐	☐
Application of bionics………… ………………………………..	☐	☐	☐	☐	☐	☐
Application of synectics………………………………………	☐	☐	☐	☐	☐	☐
Ranking of design concepts……………………………………	☐	☐	☐	☐	☐	☐
Creative materials selection……………………………………	☐	☐	☐	☐	☐	☐
Confidence in design decision-making…………………………	☐	☐	☐	☐	☐	☐
Flexibility in considering/rejecting ideas………………………..	☐	☐	☐	☐	☐	☐
Consideration of patents and design registrations……………	☐	☐	☐	☐	☐	☐
Search for a visual language……………………………………	☐	☐	☐	☐	☐	☐
Use of semantic space…………………………………………	☐	☐	☐	☐	☐	☐
………………………………………. ………………………	☐	☐	☐	☐	☐	☐

Resolution & Presentation

3. This section includes the tasks associated with evaluating and refining the design, selecting materials, developing specifications, detailed design, determination of product and component costs, investment and bill of materials.

	unsatisfactory ← 1	2	3	4	excellent → 5	N/A
Evaluation and refinement of the design ………………………	☐	☐	☐	☐	☐	☐
Detailed design …………………………………………………..	☐	☐	☐	☐	☐	☐
Appreciation of link between design and manufacturing …….	☐	☐	☐	☐	☐	☐
Appreciation of the link between design and market ……….	☐	☐	☐	☐	☐	☐
Documentation (engineering drawings/specifications)… …….	☐	☐	☐	☐	☐	☐
Materials selection …………………………..…………………..	☐	☐	☐	☐	☐	☐
Prototyping and models ………………………………………	☐	☐	☐	☐	☐	☐
Resolution of ergonomic issues ……………………………….	☐	☐	☐	☐	☐	☐
Resolution of assembly issues …………………………………	☐	☐	☐	☐	☐	☐
Resolution of issues associated with finish ………………….	☐	☐	☐	☐	☐	☐
Renderings ………………………………………………………..	☐	☐	☐	☐	☐	☐
Graphics ………………………………………………………….	☐	☐	☐	☐	☐	☐
Development of business plan ……………………………….	☐	☐	☐	☐	☐	☐
Evaluate investment involved in project ………………………	☐	☐	☐	☐	☐	☐
Financial/investment analysis …………………………………	☐	☐	☐	☐	☐	☐
Estimation/determination of manufacturing costs …………..	☐	☐	☐	☐	☐	☐
Consideration/resolution of strength and structural issues ….	☐	☐	☐	☐	☐	☐
…………………………..………………………………………….	☐	☐	☐	☐	☐	☐

Design Methods & Process

1. What design methods and/or tools are employed by students, in their final-year, major projects? Please rate 1 (least utilised) to 5 (highly utilised), the extent to which these methods are employed in their project work and documentation. Alternatively mark *not applicable* (N/A) when students generally would not employ a particular method.

	least utilised ← 1	2	3	4	highly utilised → 5	N/A
Anthropometric analysis	☐	☐	☐	☐	☐	☐
Benchmarking	☐	☐	☐	☐	☐	☐
Bionics	☐	☐	☐	☐	☐	☐
Brainstorming	☐	☐	☐	☐	☐	☐
Brain-writing	☐	☐	☐	☐	☐	☐
Computer-aided drafting	☐	☐	☐	☐	☐	☐
Computer-aided design	☐	☐	☐	☐	☐	☐
Computer-integrated manufacturing	☐	☐	☐	☐	☐	☐
Concept selection (Pugh)	☐	☐	☐	☐	☐	☐
Concurrent engineering	☐	☐	☐	☐	☐	☐
Cost analysis	☐	☐	☐	☐	☐	☐
Design catalogues	☐	☐	☐	☐	☐	☐
Design-by-drawing	☐	☐	☐	☐	☐	☐
Design drawings (engineering)	☐	☐	☐	☐	☐	☐
Design for assembly (DFA)	☐	☐	☐	☐	☐	☐
Design for disassembly (DFAD)	☐	☐	☐	☐	☐	☐
Design for environment	☐	☐	☐	☐	☐	☐
Design of experiments (Taguchi)	☐	☐	☐	☐	☐	☐

	least utilised ← 1 2 3 4 5 → highly utilised	N/A
Design for long life	☐☐☐☐☐	☐
Design for manufacture and assembly	☐☐☐☐☐	☐
Design review	☐☐☐☐☐	☐
Design for service	☐☐☐☐☐	☐
Design for serviceability	☐☐☐☐☐	☐
Failure mode and effects analysis (FMEA)	☐☐☐☐☐	☐
Fault tree analysis	☐☐☐☐☐	☐
Features analysis	☐☐☐☐☐	☐
Finite element analysis	☐☐☐☐☐	☐
Function analysis	☐☐☐☐☐	☐
Function-cost analysis	☐☐☐☐☐	☐
Ergonomic analysis	☐☐☐☐☐	☐
Integrated product development	☐☐☐☐☐	☐
Literature searches	☐☐☐☐☐	☐
Market research	☐☐☐☐☐	☐
Morphological analysis	☐☐☐☐☐	☐
Objectives trees	☐☐☐☐☐	☐
Patent search	☐☐☐☐☐	☐
Peeves analysis	☐☐☐☐☐	☐
Performance Specification method	☐☐☐☐☐	☐
Project time plan	☐☐☐☐☐	☐
Prototypes	☐☐☐☐☐	☐
Quality-function deployment	☐☐☐☐☐	☐
Questionnaire	☐☐☐☐☐	☐

	least utilised ← 1	2	3	4	highly utilised → 5	N/A
Rapid prototyping	☐	☐	☐	☐	☐	☐
Removing mental blocks	☐	☐	☐	☐	☐	☐
Renderings	☐	☐	☐	☐	☐	☐
Reverse engineering	☐	☐	☐	☐	☐	☐
Solid modelling	☐	☐	☐	☐	☐	☐
Specification checklists	☐	☐	☐	☐	☐	☐
Statistical process control (SPC)	☐	☐	☐	☐	☐	☐
SWOT analysis	☐	☐	☐	☐	☐	☐
Synectics	☐	☐	☐	☐	☐	☐
Total quality management (TQM)	☐	☐	☐	☐	☐	☐
Trend studies	☐	☐	☐	☐	☐	☐
User research	☐	☐	☐	☐	☐	☐
User interview	☐	☐	☐	☐	☐	☐
Value analysis (VA)	☐	☐	☐	☐	☐	☐
Value engineering (VE)	☐	☐	☐	☐	☐	☐

Institution profile

CONFIDENTIAL

5. **Name and address of your institution**...

....

....

Postcode ☐☐☐☐

Department/programme within your institution?

……..………………………………………………………………………………………

Name of respondent/(s) ....

Position of respondent/(s) ....

Background of respondent/(s) (e.g. industrial design, engineering, architecture)

………………………………………………………………………………………..

THANK YOU VERY MUCH FOR YOUR TIME IN COMPLETING THIS QUESTIONNAIRE.
ANY COMMENTS REGARDING THIS QUESTIONNAIRE AND/OR PROJECT ARE MOST WELCOME.

Appendix 2 - Survey Questionnaire of 2003 Projects

THE UNIVERSITY OF
NEW SOUTH WALES

INDUSTRIAL DESIGN PROGRAMME

SYDNEY 2052

Survey Questionnaire of 2003 Projects

A study of the Design Studio in Relation to the Teaching of Industrial Design.

If you have any questions regarding this questionnaire or project, please contact Lance Green

phone (02) 9385 6840
fax (02) 9385 4507
E-mail l.green@unsw.edu.au

General Questions

Part 1 General Description of Respondents

1. Concerning your motivation, with respect to execution of your final year project, please number the following descriptions that most accurately describes your particular motivation in order of importance. (Please number from 1 (= highest importance) to 5 (= lowest importance):

   - □ to just pass?…………………………………….. [ ]
   - □ to gain the highest possible mark?………………… [ ]
   - □ to produce a high-quality project outcome?............... [ ]
   - □ to produce an outcome that was truly creative?......... [ ]
   - □ to showcase a broad range of skills?......................... [ ]

2. What was your TER or UAI result in the Higher School Certificate? …………………………..…… [ ]

3. What was your result in Design Methodology IDES 2091 in 2002?…………………………………………….. [ ]

4. What was your Weighted Average Mark (WAM) over the 4 years of the program? …………………………… [ ]

5. Gender of respondent?…………………………………. [ ] M [ ] F

6. First language of respondent?…………………………………………………..

7. What was the assessment given to your *Project Research* Report by the assessment panel in June 2003?…………… [ ]

8. What was the assessment given to your *Project* Report by the assessment panel in November 2003?……………… [ ]

PART 2. 2003 Students Perception of their Performance and Needs in Final-year Major Projects.

9. Did you use the following design methods?
If Yes, please tick the box against each item.

	Use	*If Yes, was this method included in your reports?*
Anthropometric analysis?	☐ Yes	☐
Benchmarking?	☐ Yes	☐
Bionics?	☐ Yes	☐
Brainstorming?	☐ Yes	☐
Brain-writing?	☐ Yes	☐
Computer-aided drafting?	☐ Yes	☐
Computer-aided design?	☐ Yes	☐
Concept selection?	☐ Yes	☐
Cost determination?	☐ Yes	☐
Design catalogues?	☐ Yes	☐
Design-by-drawing?	☐ Yes	☐
Design drawings (engineering)?	☐ Yes	☐
Design for assembly (DFA)?	☐ Yes	☐
Design for disassembly (DFDA)?	☐ Yes	☐
Design for manufacture and assembly?	☐ Yes	☐
Design review?	☐ Yes	☐
Ergonomic analysis?	☐ Yes	☐

	Use	*If Yes, was this method included in your reports?*
Fault tree analysis?..	☐ Yes	☐
Features analysis?..	☐ Yes	☐
Function analysis?	☐ Yes	☐
Function-cost analysis?	☐ Yes	☐
Life-cycle analysis?...	☐ Yes	☐
Market research?...	☐ Yes	☐
Morphological analysis?..	☐ Yes	☐
Objectives trees?	☐ Yes	☐
Patent search?...	☐ Yes	☐
Peeves analysis?...	☐ Yes	☐
Performance specification method?...............................	☐ Yes	☐
Project time plan?	☐ Yes	☐
Prototypes?..	☐ Yes	☐
Quality-function deployment?	☐ Yes	☐
Questionnaire?...	☐ Yes	☐
Rapid prototyping?...	☐ Yes	☐
Renderings?...	☐ Yes	☐
Solid modelling?..	☐ Yes	☐
Specification checklists?	☐ Yes	☐
SWOT analysis?	☐ Yes	☐
Synectics?..	☐ Yes	☐
Trend studies?	☐ Yes	☐
User research?	☐ Yes	☐
Value analysis (VA)?..	☐ Yes	☐

10. Do you feel the need for a more comprehensive computer-integrated selection of design methods than what is currently available?………………………… ☐ Yes ☐ No ☐ Not sure

- if Yes, go to Question 11
- if No, go to Question 12

11. Do you feel such a system would help you, in:

planning?	☐ Yes	☐ No	☐ Not sure
identification of the steps in the process?..................	☐ Yes	☐	☐
facilitation of idea generation?	☐ Yes	☐	☐
organization of creative proposals?	☐ Yes	☐	☐
systematic classification of data and findings?..........	☐ Yes	☐	☐
communication of project findings?............................	☐ Yes	☐	☐
determination of product cost?..................................	☐ Yes	☐	☐
consideration of manufacturing issues?	☐ Yes	☐	☐

Go to Question 13

12. Why wouldn't such a system help you? (tick as many boxes as you feel necessary)

- too complicated? .... ☐ Yes
- too time consuming? .... ☐ Yes
- did not understand how to use?................................ ☐ Yes
- unnecessary? .... ☐ Yes
- ……….. ☐ Yes
- ……….. ☐ Yes
- ……….. ☐ Yes

13. Please give suggestions as to how you could have executed the final-year, major project more effectively?

- ☐ …. .... …………………
- ☐ .... …………………
- ☐ .... …………………
- ☐ … .... …………………
- ☐ .... …………………
- ☐ …. .... …………………
- ☐ …. .... …………………
- ☐ …. .... …………………

CONFIDENTIAL

Title of project ....

Author of project ....

Address of Author ……………………………………………………

……………………………………………………

… ....

Signature ……………………………………………………

Date: ……………………………………………………

Appendix 3 - Survey Questionnaire of 2004 Projects

THE UNIVERSITY OF
NEW SOUTH WALES

INDUSTRIAL DESIGN PROGRAMME

SYDNEY 2052

Survey Questionnaire of 2004 Projects

A study of the Design Studio in Relation to the Teaching of Industrial Design.

If you have any questions regarding this questionnaire or project, please contact Lance Green

phone (02) 9385 6840
fax (02) 9385 4507
E-mail l.green@unsw.edu.au

General Questions

Part 1 General Description of Respondents

1. Concerning your motivation, with respect to execution of your final year project, please number the following descriptions that most accurately describes your particular motivation in order of importance. (Please number from 1 (= highest importance) to 5 (= lowest importance):

- □ to just pass?……………………………………….. [ ]
- □ to gain the highest possible mark?………………… [ ]
- □ to produce a high-quality project outcome?............... [ ]
- □ to produce an outcome that was truly creative?......... [ ]
- □ to showcase a broad range of skills?......................... [ ]

2. What was your TER or UAI result in the Higher School Certificate? …………………………… [ ]

3. What was your result in Design Methodology IDES 2091 in 2003?…………………………………………….. [ ]

4. What was your Weighted Average Mark (WAM) over the 4 years of the program? …………………………… [ ]

5. Gender of respondent?………………………………… [ ] M [ ] F

6. First language of respondent?…………………………………………………..

7. What was the assessment given to your *Project Research* Report by the assessment panel in June 2004?…………… [ ]

8. What was the assessment given to your *Project* Report by the assessment panel in November 2004?……………… [ ]

PART 2. 2004 Students Perception of their Performance and Needs in Final-year Major projects.

9. Did you use the following design methods?
If Yes, please tick the box against each item.

	Use	*If Yes, was this method included in your reports?*	*Did you use the Taxonomy for this method?*
Anthropometric analysis?………………………..	☐ Yes	☐	☐
Benchmarking?……………………………………	☐ Yes	☐	☐
Bionics?…………………..……………………..	☐ Yes	☐	☐
Brainstorming?…………………..………………..	☐ Yes	☐	☐
Brainwriting?…………………..…………………..	☐ Yes	☐	☐
Computer-aided drafting?………………………..	☐ Yes	☐	☐
Computer-aided design?….……………………..	☐ Yes	☐	☐
Concept selection?………………………………..	☐ Yes	☐	☐
Cost determination?……………..……………..	☐ Yes	☐	☐
Design catalogues?………….…………………..	☐ Yes	☐	☐
Design-by-drawing?……………..………………..	☐ Yes	☐	☐
Design drawings (engineering)?………………..	☐ Yes	☐	☐
Design for assembly?……….…………………..	☐ Yes	☐	☐
Design for disassembly?………. ………………..	☐ Yes	☐	☐
Design for manufacture and assembly? ………..	☐ Yes	☐	☐
Design review?………………..…………………..	☐ Yes	☐	☐
Ergonomic analysis?……………..……………..	☐ Yes	☐	☐

		If Yes, was this method included in your reports?	*Did you use the Taxonomy for this method?*
Fault tree analysis?…………………………………	☐ Yes	☐	☐
Features analysis?……..…….…………………….	☐ Yes	☐	☐
Function analysis?…..……….……………………..	☐ Yes	☐	☐
Function-cost analysis?……..…………………….	☐ Yes	☐	☐
Life-cycle analysis?……………..………………..	☐ Yes	☐	☐
Market research?…………………..………………….	☐ Yes	☐	☐
Morphological analysis?…………..………………..	☐ Yes	☐	☐
Objectives trees?…………………..………………….	☐ Yes	☐	☐
Patent search?…………………..………………….	☐ Yes	☐	☐
Peeves analysis?……………..………………….	☐ Yes	☐	☐
Performance specification method?……………..	☐ Yes	☐	☐
Project time plan?…………………..…………………	☐ Yes	☐	☐
Prototypes?………..……………..………………….	☐ Yes	☐	☐
Quality-function deployment?………..……………..	☐ Yes	☐	☐
Questionnaire?…………….………..………………….	☐ Yes	☐	☐
Rapid prototyping?..……………..………………..	☐ Yes	☐	☐
Renderings?…………………..………………….	☐ Yes	☐	☐
Solid modelling?…..………………..…………………..	☐ Yes	☐	☐
Specification checklists?……..…………………….	☐ Yes	☐	☐
SWOT analysis?…………………..………………..	☐ Yes	☐	☐
Synectics?…………………….………..………………….	☐ Yes	☐	☐
Trend studies?…………………..………………..	☐ Yes	☐	☐
User research?………………..………………..	☐ Yes	☐	☐
Value analysis (VA)?..……………..………………….	☐ Yes	☐	☐

10. The Taxonomy is based around seven stages of the Major Project Development Process. To what extent did the Taxonomy assist you in those seven stages?

minimal ← → considerable

1 2 3 4 5

- □ Product Planning…………………………………… ☐☐☐☐☐

  Strategic review of the market
  Competitor analysis
  Patent searching
  Identify opportunities for product development
  Project planning

- □ Task Clarification ………………………………… ☐☐☐☐☐

  Setting design objectives;
  Materials research;
  Technology research;
  Human factors research;
  Development of a brief.

- □ Conceptualisation ………………………………… ☐☐☐☐☐

  Solution conjecture;
  Generation of ideas;
  Folio of concept sketches;
  Simple models (mock-ups)

- □ Embodiment……..…………………………………. ☐☐☐☐☐

  Evaluation of concepts;
  Refinement candidate solutions;
  Relevant technical information;
  Determination of preferred concept

- □ Detailed Design………………………………..…… ☐☐☐☐☐

  Development of preferred concept
  Specification of materials
  Layout drawings
  Dimensional specifications

- □ Communication……………………………….…… ☐☐☐☐☐

  Folio of presentation drawings
  Technical drawings
  Refined three-dimensional model
  Manufacturing information
  Financial information (ROI)

- □ Preparation for production………………………… ☐☐☐☐☐

  Analysis of costs
  Consideration of tooling
  Estimate production investment
  Consider DFA

11. Do you feel the need for a more comprehensive computer-integrated selection of design methods than what is currently available?………………………… ☐ Yes ☐ No ☐ Not sure

- ☐ if Yes, go to Question 12
- ☐ if No, go to Question 13

12. Do you feel such a system would help you, in:

	Yes	No	Not sure
☐ planning?	☐ Yes	☐ No	☐ Not sure
☐ identification of the steps in the process?.................	☐ Yes	☐	☐
☐ facilitation of idea generation?	☐ Yes	☐	☐
☐ organization of creative proposals?	☐ Yes	☐	☐
☐ systematic classification of data and findings?..........	☐ Yes	☐	☐
☐ communication of project findings?...........................	☐ Yes	☐	☐
☐ determination of product cost?.................................	☐ Yes	☐	☐
☐ consideration of manufacturing issues?	☐ Yes	☐	☐

Go to Question 14

13. Why did the Taxonomy fail to help you?

- ☐ too complicated? .... ☐ Yes
- ☐ too time consuming? .... ☐ Yes
- ☐ did not understand how to use?................................ ☐ Yes
- ☐ unnecessary? .... ☐ Yes
- ☐ … .... ☐ Yes
- ☐ ….. .... ☐ Yes
- ☐ ….. .... ☐ Yes

14. Please give suggestions as to how the Taxonomy could be improved?

- □ …. .... …………
- □ .... …………
- □ .... …………
- □ … .... …………
- □ …. .... …………
- □ …. .... …………
- □ …. .... …………

CONFIDENTIAL

Title of project ……………………………………………………………

Author of project ……………………………………………………………

Address of Author ……………………………………………………………

……………………………………………………………

……………………………………………………………

Signature ……………………………………………………………

Date: ……………………………………………………………

Appendix 4 – Examination to determine project tasks included in Project Research and Project reports

Student Name: ………………………………………………………….

Student number: ……………………………………………….…..

Project name: ……………………………………………………….

Q1. To what extent did the *Project Research* and *Project* reports include tasks normally associated with:

	minimal (=0) considerable (=10)
Product planning…….. ………………………………………..	
Task clarification ……..………………………………………..	
Concept generation ….……………………………………….	
Evaluation and refinement …………………………………….	
Detailed design of preferred concept ………………………..	
Communication of results …………………………………….	
Prepare for production ………………………………………..	

Q2. To what extent did the *Project Research* report follow the established tasks associated with the product-development process?……………………………

minimal (=0) considerable (=10)

Q3 Overall score expressed out of total points available of 1270 points……………………………………..

(=0) (=1270)

Q3 Overall assessment of *Project Research* and *Project* reports ……………………………………..

(=0) (=100)

Appendix 5 – Examination to determine the relative complexity of reports

Student Name: ....

Student number: ....

Project name: ....

	simple (=0)	complex (=10)
Q1. What is the degree of complexity of the project………………..	[ ]	

	simple (=0)	complex (=350)
Q1. What is the degree of complexity expressed as total points….	[ ]	

	simple (=0)	complex (=160)
Q1. What is the degree of complexity of Design Research………	[ ]	

	simple (=0)	complex (=200)
Q1. What is the degree of complexity of Project Research………	[ ]	

Appendix 6

UNIVERSITY OF CANBERRA

PARTICIPANTS INFORMATION FORM

Project title: **A Study of the Design Studio in Relation to the Teaching of Product Design**

Researcher: **Lance Green**
PhD Environmental Design

Supervisor: **Emeritus Professor Elivio Bonollo BE; MEngSc; PhD (Univ Melb)**

Project aim: The research will determine the problems associated with student engagement in final-year, industrial design projects conducted in the industrial design studio.

By research of the final-year student major project reports produced in the years 2003 and 2004 this research will identify and develop an appropriate design process together with a suite of design methods.

In addition this research will survey the perceptions of students in relation to their engagement in final-year major projects.

Benefits: The research will provide an understanding of student issues and problems as they proceed with their final-year projects. Based upon this understanding a "System" of design methods aligned with stages in the Major project Development Process will provide resource that future cohorts of students can use to guide and improve their project outcomes.

In addition the "System" can be used in earlier years of the industrial design degree in studio work to enhance thinking and learning and to improve studio work.

General outline of the project:

The purpose of this study is to test whether students, if provided with knowledge and tools associated with design methods, will apply these in final-year major projects to provide a structure to their design research and use the methods to facilitate decision making and a broad coverage of issues.

Participant Involvement:

The study (in two stages) will involve graduates from the Industrial Design degree programme at the UNSW. It will include two cohorts, namely:

- a cohort who completed their final-year major project in 2003;
- a cohort who completed their final-year major project in 2004.

The study will be based upon:

- a questionnaire designed for the 2003 cohort referred to above;
- a questionnaire designed for the 2004 cohort referred to above.

The study will involve a total of 100 participants. Each participant will be sent a copy of the Questionnaire and invited to complete it.

The response to the questionnaire is a voluntary activity and if at any time the participant prefers not to be involved or not to answer a particular question then that will be perfectly acceptable.

Confidentiality:

The identity of participants will not be disclosed in either the final thesis or following papers or public presentations arising from this research. Participants will be allocated code numbers or pseudonyms so that their personal circumstances cannot be recognised in the work and other readers will not be able to draw conclusions with respect to a particular participant.

Anonymity:

The researcher will securely store the raw material collected and records of the research. Access to this material and records will only be made available to supervisors and examiners of the research, or other researchers of similar fields, subject to confidentiality undertakings that will protect the identity of the research participants.

As required, all draft material, preliminary transcripts, duplicate records of interview and surveys will be disposed of in a manner that protects the identity of the research participants.

Data storage:

The results, findings and conclusions would be published in the form of a PhD Thesis, which would ultimately be located in the library of the University of Canberra. The thesis would not include the name of the respective participant. The participant will be invited to consult the PhD Thesis should they wish to become aware of the conclusions of the study.

Should the participant wish to receive a copy of the research findings then this will be provided by the interviewer.

Ethics Committee Clearance:

This project has been approved by the Committee for Ethics in Human Research of the University of Canberra. The Dean of the Faculty of the Built Environment of the University of New South Wales has advised his approval of the over-arching supervision of issues associated with Ethics by the University of Canberra.

Queries and concerns:

Should the participant wish to express concern or the need to have queries answered then the participant may contact the principal researcher, namely:

Lance Green
Industrial design Program
The University of New South Wales
Sydney, NSW 2052

Email: l.green@unsw.edu.au
Tel: 02) 9385 6840

Appendix 7

UNIVERSITY OF CANBERRA

INFORMED CONSENT

Project title:

" A Study of the Design Studio in Relation to the
Teaching of product Design."

Consent statement:

I have read and understood the information about the research. I am not aware of any condition that would prevent my participation, and I agree to participate in this project. I have had the opportunity to ask questions about my participation in the research. All questions I have asked have been answered to my satisfaction.

Name……………………………………………….

Signature…………………………………

Date………………………………………………..

A summary of the research report can be forwarded to you when published. If you would like to receive a copy, please include your mailing address below.

Name……………………………………………….

Address………………………………………………..

The following section of this thesis has been omitted for privacy reasons

It is available through the University of Canberra Library

Phone (02)6201 2953

email loans@cts.canberra.edu.au

Address The Library
University of Canberra
ACT 2601, Australia

Appendix 9

STRUCTURED SURVEY- Management

In this survey academics were asked to indicate the approach of students to certain questions over a range of 1 to 5 where 1=unsatisfactory and 5= excellent.

No.	Code No.	Time Mgt	Project ideas	Screening proj ideas	Engage-ment	Evaluate market	legal restrict'ns	Patents	Materials research	Manufac'g research	Ergonom research	Compet've products	Screen inform'n	Design question'rs	User surveys	Market research	Identify sponsor	Develop brief	Produce timeplan	Avge.
1	31309	2	4	3	4	1	1	1	1	3	4	2	2	1	1	1	4	4	4	2.4
2	31291	1	3	4	2	2	2	3	2	2	4	4	3	4	5	5	3	4	3	3.1
3	31117	2	3	3	4	2	2	2	3	2	5	5	3	3	5	4	3	4	3	3.2
4	31317	2	4	2	4	1	1	1	2	2	3	4	3	4	4	2	1	3	3	2.6
5	31320	2	2	2	2	1	1	1	2	2	2	3	3	2	2	2	1	2	2	1.9
6	31319	3	4	4	3	2	2	2	3	3	4	2	3	2	2	2	5	4	3	2.9
7	31266	3	2	1	3	4	1	1	3	2	3	2	3	3	2	3	2	4	3	2.5
8	31292	3	4	4	3	4	2	2	3	3	4	4	3	2	4	4	4	4	3	3.3
9	31270	2	2	1	2	3	1	1	2	3	3	2	1	3	2	4	2	3	4	2.3
10	30979	2	3	2	4	3	1	2	3	3	4	4	2	2	3	3	1	3	1	2.6
11	30988	1	3	2	4	3	2	1	2	2	2	3	2	1	1	2	2	3	2	2.1
12	31092	4	3	2	3	4	2	3	2	2	3	4	3	3	3	3	2	2	3	2.8
13	31296	1	2	2	2	3	2	3	2	2	3	4	2	3	3	3	2	2	2	2.4
14	31294	2	2	2	2	4	3	2	2	2	3	3	2	3	2	3	3	2	2	2.4
15	30971	2	2	2	3	2	2	3	4	2	4	2	1	1	1	2	3	3	3	2.3
16	30669	2	3	3	2	1	1	1	2	1	2	3	1	1	1	3	3	1	1	1.8
17	31286	2	3	3	3	3	2	3	2	2	3	3	3	1	2	3	3	3	2	2.6
18	31325	1	2	1	2	2	1	1	2	2	1	3	2	2	1	2	1	1	3	1.7
19	31296	2	3	3	3	2	1	1	1	1	3	2	2	3	2	3	2	3	3	2.2
20	31029	2	3	3	3	2	1	1	1	1	3	2	2	2	2	3	2	3	3	2.2
21	31289	2	3	2	4	2	1	1	3	2	3	3	2	2	3	2	3	2	2	2.3
22	31305	2	3	2	3	3	2	3	3	4	3	4	2	1	2	3	4	3	2	2.7
23	31288	4	3	3	4	2	2	2	3	3	4	3	4	3	3	3	4	4	2	3.1
24	31326	2	4	3	4	2	1	1	2	2	3	1	3	2	2	2	3	3	2	2.3
25	31312	2	3	2	4	2	1	1	2	2	4	2	2	2	3	2	2	2	2	2.2
26	31344	3	4	3	4	4	2	1	5	5	4	3	3	5	5	4	2	4	4	3.6
27	22523	3	4	3	4	4	2	1	5	5	4	3	3	5	5	4	2	4	4	3.6
28	31331	2	3	4	4	4	1	3	4	3	3	4	3	3	3	4	4	3	2	3.2
29	31269	2	3	2	3	3	2	2	3	3	4	4	4	3	3	4	2	2	2	2.8
30	31266	1	2	2	2	3	1	2	2	2	5	2	1	4	4	3	2	1	1	2.2
31	31274	2	4	2	3	2	1	1	3	2	2	4	3	2	2	3	1	2	2	2.3
32	30878	2	3	2	2	3	1	2	2	2	4	2	3	4	4	4	2	2	2	2.6
33	30250	5	4	4	5	4	3	5	4	4	5	4	5	4	5	3	5	5	3	4.3
	Average..	2.2	3.0	2.5	3.2	2.6	1.5	1.8	2.6	2.5	3.4	3.0	2.5	2.6	2.8	3.0	2.6	2.9	2.5	2.6
	Std.Dev..	0.89	0.73	0.87	0.87	0.99	0.62	0.98	1.00	0.97	0.93	0.95	0.90	1.14	1.29	0.88	1.12	1.02	0.83	
	N/A...						2													

Appendix 10

STRUCTURED SURVEY - Conceptualisation

In this survey academics were asked to indicate the approach of students to certain questions over a range of 1 to 5 where 1=unsatisfactory and 5= excellent.

No.	Code No.	Creative thinking	Concep-tualisation	Idea generation	Screening	Brainstor-ming	Bionics	Synectics	Ranking concepts	materials selection	Decision-making	Flexibility	Patents	Visual language	Semantic space	Average
1	31309	4	2	4	3	3	1	2	2	1	5	2	2	2	1	2.4
2	31291	2	3	3	4	4	3	3	5	4	3	4	2	3	3	3.3
3	31117	3	3	4	4	3	2	3	4	4	3	3	2	3	3	3.1
4	31317	4	3	3	2	4	4	4	2	2	3	3	1	2	3	2.9
5	31320	2	2	2	2	2	1	1	2	3	2	2	1	3	2	1.9
6	31319	4	5	3	3	2	1	1	2	3	3	4	2	4	2	2.8
7	31266	4	3	3	2	2	2	2	3	3	2	2	1	3	1	2.4
8	31292	3	4	4	3	2	3	1	3	4	4	4	2	4	3	3.1
9	31270	2	2	3	1	1	1	1	2	2	1	1	1	4	3	1.8
10	30979	2	2	2	2	3	2	2	3	2	2	3	1	3	2	2.2
11	30988	3	3	3	3	2	2	1	2	3	2	2	1	3	3	2.4
12	31092	3	3	2	2	2	2	2	3	3	3	2	2	3	3	2.5
13	31296	2	2	2	2	3	1	1	2	2	1	2	2	3	2	1.9
14	31294	2	2	3	2	3	1	1	3	2	2	2	2	3	3	2.2
15	30971	2	2	3	2	2	1	1	1	1	2	2	2	3	2	1.9
16	30669	3	3	3	1	1	2	1	1	3	1	3	1	4	3	2.1
17	31286	2	2	2	2	2	1	1	1	1	2	2	2	2	1	1.6
18	31325	2	1	2	1	2	1	2	1	2	1	2	1	2	1	1.5
19	31296	3	3	3	2	1	1	1	3	2	2	1	1	3	4	2.1
20	31029	2	2	3	2	2	1	1	2	2	2	1	1	3	4	2.0
21	31289	3	3	4	2	2	1	1	2	2	2	2	1	4	4	2.4
22	31305	4	3	3	2	2	2	2	2	3	2	2	2	1	1	2.2
23	31288	2	2	2	2	2	1	1	2	2	3	2	2	3	3	2.1
24	31326	3	3	2	2	4	3	2	2	3	3	4	1	2	2	2.6
25	31312	3	2	3	2	2	1	1	1	2	2	3	1	2	2	1.9
26	31344	4	4	4	3	4	1	1	2	4	2	4	1	2	3	2.8
27	22523	4	4	4	3	4	1	1	2	4	2	4	1	2	3	2.8
28	31331	3	3	2	3	1	1	1	3	1	4	4	1	3	1	2.2
29	31269	2	2	2	3	3	1	1	4	3	2	3	1	2	2	2.2
30	31266	2	2	2	2	2	1	1	2	2	1	2	1	3	1	1.7
31	31274	3	2	3	2	2	2	1	4	3	3	3	1	3	3	2.5
32	30878	2	2	3	3	3	1	1	2	3	2	2	2	3	3	2.3
33	30250	5	5	5	5	4	1	1	5	4	4	2	4	3	1	3.5
	Average…	2.8	2.7	2.9	2.4	2.5	1.5	1.4	2.4	2.6	2.4	2.5	1.5	2.8	2.4	2.3
	Std. Dev…	0.87	0.92	0.80	0.86	0.94	0.80	0.75	1.06	0.94	0.96	0.94	0.67	0.73	0.96	
	N/A….					1	12	14					3		2	

Appendix 11

STRUCTURED SURVEY - Resolution

In this survey academics were asked to indicate the approach of students to certain questions over a range of 1 to 5 where 1=unsatisfactory and 5= excellent.

No.	Code No.	Evaluation	Detailed Design	Design & manufact'e	Design/ market	Document	Materials selection	prototype	Ergonomic	assembly	Resolve finish	Renderings	Graphics	Business plan	Investment in project	Investment analysis	Determine costs	Structural issues	Avge.
1	31309	3	2	2	1	1	2	4	2	2	2	4	5	2	1	1	1	1	2.1
2	31291	4	4	4	5	3	3	4	4	3	4	5	5	2	2	2	2	1	3.4
3	31117	4	2	3	3	3	3	4	4	3	3	4	5	2	2	2	2	2	3.0
4	31317	2	3	1	1	4	2	3	3	3	2	4	4	1	1	1	1	1	2.2
5	31320	2	3	1	2	2	2	3	2	2	2	3	4	2	1	1	1	1	2.0
6	31319	4	2	4	4	3	2	4	4	3	2	4	1	1	1	1	1	3	2.6
7	31266	3	4	2	3	4	3	3	2	3	1	4	4	1	1	1	1	1	2.4
8	31292	4	3	4	4	3	2	5	4	3	4	4	3	1	2	2	3	3	3.2
9	31270	2	1	1	3	1	3	2	3	1	3	5	2	2	2	1	2	2	2.1
10	30979	3	3	2	3	2	3	3	3	1	1	3	3	2	2	1	1	2	2.2
11	30988	2	2	3	2	3	3	3	3	2	3	3	2	2	1	1	2	2	2.3
12	31092	3	2	2	4	1	2	2	3	2	3	4	3	2	2	2	3	3	2.5
13	31296	2	2	2	2	2	2	3	3	2	2	4	3	2	3	3	2	2	2.4
14	31294	2	2	2	3	1	2	3	3	2	2	4	4	2	2	2	2	1	2.3
15	30971	3	3	3	2	3	3	3	3	2	2	4	4	2	2	2	2	2	2.6
16	30669	2	1	1	3	1	1	3	2	1	3	3	4	1	1	1	2	2	1.9
17	31286	2	2	3	3	3	3	4	3	3	5	5	5	2	1	1	1	2	2.8
18	31325	2	1	3	3	3	2	3	2	1	3	3	3	2	2	1	2	1	2.2
19	31296	3	2	2	3	2	2	4	3	3	2	4	4	1	2	1	2	2	2.5
20	31029	2	1	2	3	1	1	4	3	3	2	3	3	2	1	1	1	1	2.0
21	31289	2	3	2	3	2	3	4	3	2	3	4	4	2	2	1	2	2	2.6
22	31305	3	3	3	3	3	2	4	3	3	3	3	2	2	1	1	2	2	2.5
23	31288	3	3	3	2	3	3	4	3	3	2	4	4	1	1	1	2	3	2.6
24	31326	2	3	1	2	3	3	4	3	1	2	4	1	1	1	1	1	1	2.0
25	31312	2	2	1	2	3	3	5	5	2	1	5	5	1	1	1	1	1	2.4
26	31344	3	3	4	4	2	4	5	3	2	4	5	4	4	2	2	3	3	3.4
27	22523	3	3	4	4	2	4	5	3	2	4	5	4	4	2	2	3	3	3.4
28	31331	3	3	2	4	3	3	2	3	1	2	4	1	1	1	1	1	2	2.2
29	31269	3	2	3	4	3	3	3	4	2	2	4	4	1	1	1	1	1	2.5
30	31266	2	2	2	3	3	2	2	3	2	1	4	4	1	1	1	1	1	2.1
31	31274	2	2	2	3	2	2	3	2	2	3	3	3	3	1	1	1	2	2.2
32	30878	3	2	3	3	2	2	4	4	2	2	4	4	1	1	1	1	1	2.4
33	30250	4	4	5	3	3	4	3	4	3	3	4	4	3	1	1	2	1	3.1

	Evaluation	Detailed Design	Design & manufact'e	Design/ market	Document	Materials selection	prototype	Ergonomic	assembly	Resolve finish	Renderings	Graphics	Business plan	Investment in project	Investment analysis	Determine costs	Structural issues	Avge.
Average…	2.7	2.4	2.5	2.9	2.4	2.5	3.5	3.1	2.2	2.5	3.9	3.5	1.8	1.5	1.3	1.7	1.8	2.5
Std Dev…	0.73	0.83	1.06	0.90	0.87	0.75	0.87	0.72	0.73	0.97	0.66	1.15	0.82	0.56	0.53	0.69	0.75	0.42
N/A…				1	1							1	6	5	6	4	4	

STRUCTURED SURVEY - Methods and Process

In this survey academics were asked to indicate the approach of students to certain questions over a range of 1 to 5 where 1=least utilised and 5= highly utilised.

No.	Code No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain-writing	Comp Aided Dtg	CAD	CIM	Concept Selection	Concurr enginering	Cost analysis	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	Design environ't	Taguchi	Long life	DFMA	Design review	Design service	Design servic'lity
1	31309	1	3	1	4	3	4	2	1	1	1	1	4	2	2	2	2	3	2	3	2	4	2	2
2	31291	4	3	3	4	2	5	5	3	3	3	2	2	2	3	3	3	4	2	4	3	4	4	2
3	31117	4	3	2	4	2	5	5	1	2	1	1	3	4	3	3	3	4	1	3	3	3	3	2
4	31317	2	5	2	5	2	4	4	2	2	1	1	5	4	2	2	2	2	2	2	2	3	2	2
5	31320	2	2	1	3	2	4	4	2	3	1	1	3	3	2	2	1	3	3	2	2	3	2	2
6	31319	3	3	1	2	1	4	4	1	1	3	1	5	5	2	3	3	4	1	1	3	1	4	4
7	31266	3	1	2	4	2	4	4	1	2	1	2	3	4	2	1	3	1	1	2	3	1	1	1
8	31292	4	4	4	3	3	4	4	1	1	2	2	2	4	3	2	3	4	1	3	3	4	2	2
9	31270	3	1	1	3	1	4	5	1	2	1	2	2	3	3	2	1	1	2	1	2	1	1	1
10	30979	3	3	2	3	2	4	4	2	3	2	3	3	3	3	2	2	3	3	3	3	3	2	2
11	30988	4	2	1	2	1	5	5	2	1	2	2	1	3	4	3	2	3	2	3	4	2	2	2
12	31092	3	2	2	2	3	2	2	1	1	1	2	1	3	2	1	1	2	1	1	1	1	1	1
13	31296	3	1	1	3	1	3	4	1	1	1	2	2	4	2	1	1	2	1	1	1	1	1	1
14	31294	3	1	1	3	1	3	4	1	1	1	1	3	4	3	1	1	1	1	1	2	1	1	1
15	30971	3	1	1	2	1	4	3	1	1	1	2	4	3	4	1	1	3	1	1	3	2	1	1
16	30669	4	3	2	3	1	4	5	2	1	1	3	4	3	2	2	2	3	1	2	2	3	1	1
17	31286	3	3	1	5	4	5	3	1	3	1	3	5	2	5	3	1	2	1	2	3	1	1	2
18	31325	2	1	1	2	1	4	1	1	1	1	2	3	4	3	2	1	3	1	1	3	2	1	1
19	31296	5	3	1	2	1	4	3	1	1	1	1	3	3	3	2	2	3	2	2	2	2	2	2
20	31029	2	2	2	2	2	2	4	2	1	1	1	2	3	3	2	2	4	2	3	3	3	2	2
21	31289	4	2	1	2	2	5	4	2	2	1	2	4	4	3	2	2	3	1	2	2	2	2	2
22	31305	3	1	2	3	1	3	4	1	2	2	2	2	2	2	2	1	3	1	1	2	1	2	2
23	31288	4	1	1	3	1	5	5	1	1	1	1	2	3	3	2	2	3	2	2	2	2	3	2
24	31326	3	1	1	3	1	4	3	1	1	1	1	3	4	3	1	1	2	1	1	1	2	1	1
25	31312	4	1	1	2	1	5	3	1	1	1	1	4	4	3	1	1	3	2	2	2	1	1	1
26	31344	4	3	1	5	1	4	4	2	1	3	1	3	5	3	2	1	3	1	3	3	4	2	2
27	22523	4	3	1	5	1	4	4	2	1	3	1	3	5	3	2	1	3	1	3	3	4	2	2
28	31331	3	1	1	1	1	3	5	1	3	1	2	4	3	3	1	1	4	1	1	2	1	1	1
29	31269	3	3	1	3	1	4	4	2	1	1	4	3	4	4	4	1	2	1	1	3	3	1	1
30	31266	4	1	1	3	1	4	5	1	1	1	1	3	4	3	1	1	1	1	1	2	1	1	1
31	31274	3	2	2	2	2	5	4	3	1	1	1	3	5	2	2	4	4	1	4	2	4	1	3
32	30878	4	2	1	3	1	3	4	1	1	1	2	4	4	2	2	2	3	1	2	2	2	2	2
33	30250	5	1	1	5	1	2	5	1	4	1	1	2	4	3	3	3	4	1	4	4	1	1	1

Mean	3.3	2.1	1.4	3.1	1.5	3.9	3.9	1.4	1.6	1.4	1.7	3.0	3.5	2.8	2.0	1.8	2.8	1.4	2.1	2.4	2.2	1.7	1.7
Std Dev	0.88	1.07	0.71	1.09	0.79	0.88	0.98	0.61	0.87	0.70	0.78	1.05	0.87	0.73	0.77	0.87	0.95	0.61	1.00	0.75	1.14	0.85	0.69
No. N/As	0	2	12	1	10	0	1	11	6	10	3	1	0	0	1	3	2	10	3	0	4	5	3

FMEA	Fault tree	Features analysis	Finite element	Function analysis	Func-cost analysis	Ergonomic analysis	Int prod develop't	Literature search	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	mental blocks
1	1	3	1	1	1	1	1	2	2	3	2	1	1	1	3	1	1	1	1	1
2	2	3	2	3	2	4	4	5	5	5	4	4	1	2	3	5	4	5	5	5
1	2	3	1	3	2	4	3	4	5	4	3	3	1	2	2	5	2	4	3	4
2	2	2	2	4	2	3	2	4	3	3	2	2	2	2	2	3	4	4	4	1
3	1	3	1	3	1	2	3	2	2	1	1	1	1	2	2	3	1	2	3	2
1	1	2	1	5	1	3	1	1	1	1	1	1	1	1	5	5	1	1	1	1
1	1	1	1	4	2	3	1	4	4	2	2	2	1	1	4	4	1	3	1	1
1	1	1	3	3	2	4	2	4	4	2	3	1	1	2	4	4	2	4	1	3
1	1	2	1	2	2	3	1	2	4	1	1	3	2	1	5	4	1	5	1	1
1	1	1	1	3	3	4	3	3	4	2	2	3	2	2	4	4	3	2	1	1
1	1	2	1	2	1	3	2	3	3	1	1	2	2	1	4	3	1	3	1	3
1	1	1	1	1	1	2	1	3	2	1	1	3	2	1	3	2	1	3	1	1
1	1	1	1	1	1	2	1	3	2	1	1	3	2	1	2	2	1	3	1	1
1	1	1	1	2	1	3	1	3	2	1	1	2	1	1	2	2	1	3	1	1
1	1	2	1	3	1	3	1	4	3	1	1	4	2	2	3	3	1	5	1	1
1	1	1	1	1	1	3	1	4	4	2	1	1	1	1	4	3	1	3	2	1
1	1	1	1	1	1	2	2	5	5	1	1	3	1	3	5	5	1	1	5	1
1	1	1	1	1	1	1	1	4	3	1	1	1	1	1	2	4	1	1	1	2
1	1	1	1	3	1	4	3	3	3	1	2	1	1	1	3	4	1	4	4	3
1	1	2	1	1	1	1	2	3	3	1	1	1	1	2	1	2	3	3	3	2
2	1	1	1	2	2	3	3	3	3	1	1	1	2	3	4	4	1	4	4	3
1	1	1	1	3	1	3	1	3	2	2	2	3	1	1	1	3	1	2	4	2
1	1	1	1	1	1	4	1	4	3	1	1	2	1	1	3	3	1	3	5	1
1	2	2	1	1	1	4	1	3	3	1	2	2	1	1	2	4	1	3	3	1
1	1	3	1	1	1	5	1	4	3	1	1	2	1	1	2	5	1	3	3	1
1	1	1	1	1	1	3	1	3	3	3	2	1	1	3	3	4	1	4	2	1
1	1	1	1	1	1	3	1	3	3	3	2	1	1	3	3	4	1	4	2	1
1	1	1	1	1	1	3	2	4	4	4	1	1	1	3	3	1	1	3	1	1
1	1	1	1	4	3	4	3	5	4	4	3	2	1	3	4	3	1	4	2	3
1	1	2	1	1	1	3	1	5	3	1	1	2	1	1	2	3	1	4	2	1
1	1	1	1	1	1	3	2	3	3	1	1	1	1	1	4	2	1	2	2	1
1	1	4	1	1	1	4	1	5	4	1	2	2	1	1	3	5	1	4	3	1
1	1	1	1	3	1	5	1	5	1	1	1	5	1	1	3	3	1	4	4	1

1.2	1.1	1.6	1.1	2.1	1.3	3.1	1.7	3.5	3.1	1.8	1.6	2.0	1.2	1.6	3.0	3.4	1.4	3.2	2.4	1.6
0.44	0.33	0.86	0.42	1.20	0.60	1.01	0.89	1.00	1.02	1.17	0.79	1.07	0.44	0.79	1.07	1.14	0.86	1.15	1.39	1.06
13	14	8	15	3	7	0	8	1	1	10	7	6	15	13	0	0	16	0	5	8

Renderings	Reverse engineer	Solid model	Spec'n checklists	SPC	SWOT	Synectics	TQM	Trend studies	User research	User interview	VA	VE	Avge.
4	1	3	3	1	3	1	1	3	2	1	1	1	1.9
5	5	5	4	1	5	3	1	4	4	4	3	1	3.4
4	3	4	3	1	3	2	1	4	4	4	1	1	2.8
4	1	2	3	3	4	3	1	5	4	5	1	1	2.7
3	1	3	3	1	2	1	1	3	3	3	1	1	2.1
3	3	5	1	1	1	1	1	1	2	2	1	1	2.1
4	1	4	1	1	2	2	1	1	3	3	1	1	2.1
4	1	4	2	1	4	1	1	4	4	4	3	3	2.7
5	1	3	1	1	3	1	1	1	3	3	1	1	2.0
4	1	2	2	2	2	1	1	3	4	4	1	1	2.5
5	2	4	2	1	4	1	1	3	3	3	2	2	2.3
4	1	4	1	1	3	1	1	1	2	3	2	1	1.7
4	1	4	1	1	2	1	1	1	2	3	2	1	1.7
5	1	5	1	1	2	1	1	1	3	3	1	1	1.7
5	1	4	3	1	1	1	1	3	2	2	2	1	2.0
4	1	4	1	1	1	1	1	2	3	3	1	1	2.1
5	1	5	2	1	5	1	1	1	5	5	1	1	2.5
3	1	4	1	1	2	1	1	3	3	3	2	1	1.7
4	2	3	4	1	2	2	2	2	2	3	3	3	2.3
3	3	3	4	2	2	2	2	3	3	3	3	2	2.2
5	4	4	2	1	4	1	1	4	4	4	2	2	2.5
3	2	3	2	1	2	2	1	1	2	2	1	1	1.9
5	1	5	3	1	3	1	1	1	3	3	1	1	2.1
4	1	4	1	1	2	1	1	1	3	3	1	1	1.8
5	1	4	1	1	3	1	1	2	3	3	1	1	2.0
5	2	5	5	1	4	1	1	3	3	3	1	1	2.4
5	2	5	5	1	4	1	1	3	3	3	1	1	2.4
4	1	4	3	1	3	1	1	3	4	4	1	1	2.0
4	1	4	4	1	4	1	1	4	4	4	1	1	2.6
4	1	3	1	1	2	3	1	4	4	3	2	1	1.9
5	2	5	3	1	9	1	1	3	5	4	1	1	2.4
5	1	4	1	1	3	1	1	3	4	4	1	1	2.2
4	1	5	1	1	2	2	1	5	5	5	3	1	2.4
4.2	1.6	3.9	2.3	1.1	3.0	1.4	1.1	2.6	3.3	3.3	1.5	1.2	2.2
0.71	1.00	0.86	1.28	0.42	1.53	0.65	0.24	1.27	0.91	0.88	0.76	0.55	0.37
0	11	0	7	19	0	12	19	5	0	0	5	9	

Appendix 13

2003 Cohort Survey - Question9(a), Methods and process used in major project (Yes = 1, No = 2)

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain-writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	DFMA	Design review	Ergonomic analysis	Fault tree	Features analysis	Function analysis
8160.03	2	2	2	1	2	1	2	1	2	2	1	2	1	1	1	2	2	2	1	2
6735.03	1	1	2	1	2	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1
6023.03	1	1	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1
5284.03	1	1	2	1	2	1	1	1	1	1	1	1	1	1	2	2	1	2	1	1
7444.03	2	2	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1	2	1	1
7543.03	1	2	2	1	2	1	1	1	1	2	1	2	1	2	1	2	1	2	2	2
3022.03	1	1	1	2	2	1	1	1	1	2	1	1	2	2	1	1	1	2	1	1
7311.03	1	2	2	1	2	1	1	1	1	2	1	1	1	2	1	2	2	2	2	1
7058.03	1	1	2	1	2	2	2	1	1	1	2	1	1	2	2	2	1	2	1	1
7754.03	2	2	2	1	2	1	1	2	2	2	1	2	2	2	2	2	2	2	2	2
2114.03	2	2	2	1	2	1	1	1	1	1	1	1	1	1	1	2	1	2	1	1
7336.03	2	2	2	1	2	2	1	1	1	2	1	1	1	1	1	2	1	2	2	2
7546.04	1	2	2	1	2	1	1	1	1	1	1	1	1	2	1	1	1	2	2	1
2509.03	1	1	2	1	2	1	2	1	1	1	1	2	1	1	1	2	1	2	1	1
3215.03	2	2	2	1	1	2	1	1	1	2	1	2	1	1	1	2	1	2	1	2
3027.03	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
7409.03	2	1	2	1	2	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1
2485.03	2	2	2	1	2	2	1	1	1	2	1	1	2	2	1	2	1	2	1	2
6742.03	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0944.03	1	2	2	1	2	1	1	1	1	2	1	2	1	2	1	2	1	2	1	1
7685.03	2	2	2	1	2	1	1	2	2	2	1	2	1	2	2	2	1	2	1	2
7373.03	1	2	2	1	2	2	1	1	1	2	1	1	1	2	1	2	1	2	2	2
7959.03	2	2	2	2	2	2	2	2	1	2	1	2	2	2	1	2	1	2	2	2
2871.03	2	2	2	1	2	1	2	1	1	1	1	1	1	2	1	1	1	2	1	1
7249.03	1	2	2	1	2	2	1	1	1	2	2	1	2	2	1	1	2	2	2	2
5153.03	1	1	2	1	2	1	1	1	2	2	1	1	1	2	1	2	1	2	2	2
7462.03	2	2	2	1	2	2	1	1	2	2	2	1	1	2	2	1	1	2	2	2
3022.03	1	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
2184.03	1	2	2	1	2	1	1	1	2	2	2	2	1	1	1	2	1	2	2	1
7557.03	2	2	2	1	2	2	1	1	1	2	1	1	2	2	1	2	2	2	2	2
2476.04	1	1	2	1	2	2	1	1	1	2	1	1	1	1	1	1	1	2	1	1
2956.03	1	2	2	1	2	1	1	1	2	2	1	1	1	1	1	2	1	2	1	1
7504.03	1	1	1	1	2	1	1	1	1	2	1	2	1	1	1	2	1	2	2	2
7347.03	1	2	2	1	2	1	1	1	1	2	2	1	1	2	2	2	1	2	1	2
7741.03	1	2	2	1	2	1	1	1	1	2	1	1	1	1	1	2	1	2	1	1
7423.03	2	2	2	2	2	1	1	2	2	2	1	1	1	2	2	2	2	2	2	2
7324.03	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
6738.03	1	2	2	1	2	2	1	1	1	2	1	1	1	1	1	2	1	2	1	1
3031.03	2	2	2	1	2	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1
7515.03	2	2	2	1	2	2	1	1	1	2	1	2	2	2	1	2	1	2	2	1
5364.03	1	2	2	1	2	2	1	1	1	1	2	2	1	1	1	2	1	2	1	1
…….....	23	11	2	38	4	28	36	37	33	11	35	29	34	18	33	12	35	1	25	25
ses…..	56%	27%	5%	93%	10%	68%	88%	90%	80%	27%	85%	71%	83%	44%	80%	29%	85%	2%	61%	61%

Func-cost analysis	Life-cycle analysis	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	Renderings	Solid model	Spec'n checklists	SWOT	Synectics	Trend studies	User research	VA
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	1	2	2
1	2	1	2	2	1	1	2	1	1	2	1	2	1	2	1	1	2	2	2	2
1	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	2	1	1	1
2	2	1	2	2	1	2	2	1	1	2	1	1	1	1	2	2	2	2	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	1	2	2
2	2	1	2	2	2	2	2	1	2	2	1	1	1	1	2	2	2	1	1	2
2	2	1	2	1	1	1	2	1	2	2	1	2	1	1	2	1	2	2	2	1
1	2	1	2	2	2	2	2	1	1	2	1	2	1	1	1	1	2	1	1	2
1	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	1	2	2	1	2
2	2	2	2	2	1	1	2	1	2	2	1	2	1	1	2	1	2	2	2	2
2	2	1	2	2	2	2	1	1	1	2	1	1	1	1	2	1	2	1	1	2
2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	2	2	2	1	2	2
1	2	1	2	2	1	2	2	1	1	1	1	2	1	1	2	2	2	2	2	1
2	2	1	2	2	1	2	2	1	1	2	1	2	1	2	1	2	2	1	1	2
2	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
1	2	1	2	2	1	2	2	1	1	2	1	2	1	2	1	1	2	1	1	1
2	2	1	2	2	1	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2
1	2	1	2	1	2	1	2	1	1	2	1	2	1	2	1	1	2	2	2	1
1	1	1	2	1	1	2	2	1	1	1	1	2	1	1	1	1	2	1	1	1
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	1	2	1	1	2
2	2	1	2	2	1	2	1	2	2	2	1	2	1	1	2	2	2	1	1	2
2	2	1	2	1	1	2	1	1	2	2	1	2	1	1	2	1	2	2	1	2
2	2	1	2	2	2	2	2	1	2	2	1	2	1	2	2	2	2	2	2	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2
2	2	1	2	2	1	2	2	1	2	2	1	2	1	2	2	1	2	1	1	2
2	2	1	2	2	1	2	1	1	2	2	1	2	2	2	2	2	2	1	2	1
1	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
1	1	1	2	2	2	2	2	2	2	2	1	2	1	1	2	1	2	2	2	2
2	2	1	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2
2	2	1	2	2	1	1	2	1	2	2	1	2	1	1	2	1	2	1	1	2
2	2	1	2	2	1	2	2	2	1	2	2	2	1	1	2	1	2	2	1	2
2	1	1	2	2	1	2	2	1	1	1	1	2	1	1	2	2	2	2	1	2
2	2	1	2	2	2	1	2	1	1	2	1	2	1	1	2	1	2	2	1	1
2	1	1	2	2	1	2	2	1	1	2	1	2	1	1	2	2	2	1	1	2
2	2	1	2	2	2	2	2	1	1	2	2	2	1	2	2	2	2	2	2	2
2	2	1	2	2	2	1	2	1	1	2	1	2	1	1	2	1	2	1	1	2
1	1	1	1	2	1	1	2	1	1	2	1	2	1	2	2	1	2	2	1	2
1	2	1	2	2	2	1	2	1	1	2	1	2	1	1	2	1	2	1	1	1
2	2	1	2	2	2	2	2	1	1	1	1	2	1	1	2	1	2	2	1	2
2	1	1	2	2	1	1	2	1	1	2	1	2	1	1	1	1	2	2	1	2
12	7	39	2	5	23	10	5	37	31	5	38	3	40	26	8	25	0	21	26	9
29%	17%	95%	5%	12%	56%	24%	12%	90%	76%	12%	93%	7%	98%	63%	20%	61%	0%	51%	63%	22%

Appendix 14:

2003 Cohort Survey - Question 9(b), Methods and process used in major project, but included in project reports 1=Yes, 2=No

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain-writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	DFMA	Design review	Ergonomic analysis	Fault tree	Features analysis	Function analysis
8160.03	2	2	2	2	2	1	2	1	2	2	2	2	1	1	2	2	2	2	2	2
6735.03	1	1	2	1	2	1	1	2	1	2	2	1	1	2	1	2	1	2	1	1
6023.03	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1	2	1
5284.03	1	1	2	2	2	1	1	2	1	1	2	1	1	2	2	2	1	2	2	1
7444.03	2	2	2	1	2	1	1	1	1	2	1	1	1	1	2	2	1	2	2	2
7543.03	2	2	2	2	2	1	1	1	1	2	1	2	1	2	1	2	2	2	2	2
3022.03	1	1	1	2	2	1	1	1	1	2	1	1	2	2	1	1	1	2	1	1
7311.03	1	1	2	1	2	1	1	1	1	2	1	1	1	2	1	2	2	2	2	1
7058.03	1	1	2	2	2	2	2	1	1	2	2	1	1	2	2	2	1	2	1	1
7754.03	2	2	2	1	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2114.03	2	2	2	1	2	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2
7336.03	2	2	2	2	2	2	1	2	1	2	1	1	2	2	2	2	2	2	2	2
7546.03	1	2	2	2	2	1	1	2	1	2	2	1	1	2	1	1	1	2	2	1
2509.03	2	2	2	2	2	1	2	1	2	2	1	2	1	1	2	2	2	2	1	1
3215.03	2	2	2	1	1	2	1	1	1	2	1	2	2	1	2	2	1	2	2	2
3027.03	2	2	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	2	2	1
7409.03	2	1	2	1	2	1	1	1	1	2	1	1	1	2	1	2	1	2	2	2
2485.03	2	2	2	1	2	2	1	1	1	2	1	1	2	2	1	2	1	2	2	2
6742.03	2	2	2	1	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1
0944.03	1	2	2	1	2	1	1	1	1	2	1	2	2	2	1	2	1	2	1	1
7685.03	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2
7373.03	1	2	2	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2
7959.03	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2	1	2	2	2
2871.03	2	2	2	1	2	1	2	1	1	1	1	1	1	2	1	1	1	2	1	1
7249.03	1	2	2	1	2	2	1	1	1	2	2	1	2	2	1	1	2	2	2	2
5253.03	1	1	2	2	2	1	1	1	2	2	1	2	1	2	1	2	1	2	2	2
7462.03	2	2	2	1	2	2	1	1	2	2	2	1	1	2	2	1	1	2	2	2
3022.03	1	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
2184.03	1	2	2	1	2	1	1	1	2	2	2	2	1	1	1	2	1	2	2	2
7557.03	2	2	2	1	2	2	1	1	1	2	1	1	2	2	1	2	2	2	2	2
2476.04	2	2	2	2	2	2	1	1	1	2	2	1	1	2	2	2	1	2	1	1
2956.03	2	2	2	2	2	1	2	2	2	2	2	2	1	2	1	2	2	2	2	2
7504.03	1	1	1	1	2	2	1	1	1	2	1	2	1	2	1	2	1	2	2	2
7347.03	1	2	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2
7741.03	1	2	2	2	2	1	2	1	1	2	1	1	2	2	2	2	1	2	1	1
7423.03	2	2	2	2	2	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2
7324.03	1	1	2	1	2	1	1	1	1	1	1	2	1	2	1	1	1	2	1	2
6738.03	1	2	2	1	2	2	1	1	1	2	1	1	2	2	1	2	1	2	1	1
3031.03	2	2	2	1	1	1	1	1	1	2	2	1	2	2	1	2	1	2	1	1
7515.03	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	2
5364.03	1	2	2	1	2	2	1	1	1	2	2	2	1	2	1	2	1	2	1	1
Yes…..	18	9	3	23	3	24	31	30	30	6	21	23	23	9	24	8	28	2	13	17
%Yes….	44%	22%	7%	56%	7%	59%	76%	73%	73%	15%	51%	56%	56%	22%	59%	20%	68%	5%	32%	41%

Func-cost analysis	Life-cycle analysis	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	Renderings	Solid model	Spec'n checklists	SWOT	Synectics	Trend studies	User research	VA
2	2	2	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	1	2	2
1	2	1	2	2	2	2	2	1	1	2	2	2	2	2	1	1	2	2	2	2
2	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	2	1	2	2	2
2	2	1	2	2	1	2	2	1	1	2	1	1	1	1	2	2	2	2	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	1	2	2
2	2	1	2	2	2	2	2	1	2	2	1	2	1	1	2	2	2	1	1	2
2	2	1	2	1	1	1	2	1	2	2	1	2	1	1	2	1	2	2	2	1
1	2	1	2	2	2	2	2	1	2	2	1	2	1	1	1	1	2	1	1	2
2	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	2	2	2	1	2
2	2	2	2	2	2	1	2	2	2	2	1	2	2	1	2	1	2	2	2	2
2	2	1	2	2	2	2	2	1	1	2	1	1	1	1	2	1	2	1	1	2
2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	2	2	2	1	2	2
1	2	1	2	2	1	2	2	1	2	1	1	2	2	1	2	2	2	2	2	1
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	1	2	2	1	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
1	2	1	2	2	1	2	2	1	1	2	1	2	2	2	1	1	2	1	1	1
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1	2	1	2	2	2	2	2	1	1	2	2	2	1	1	2	2	2	1	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	1	2	1	1	2
2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	1	1	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	1	2
2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	2	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2
2	2	1	2	2	2	2	2	1	2	2	1	2	2	2	2	2	2	2	1	2
2	2	1	2	2	1	2	1	1	2	2	1	2	2	2	2	2	2	1	2	1
1	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
2	2	2	2	2	2	2	2	2	2	2	1	2	1	1	2	1	2	2	2	2
2	2	1	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2
2	2	1	2	2	1	1	2	1	2	2	1	2	1	1	2	2	2	2	1	2
2	2	1	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2
2	1	1	2	2	1	2	2	1	1	1	1	2	1	1	2	2	2	2	1	2
2	2	1	2	2	2	2	2	1	2	2	1	2	1	1	2	1	2	2	1	2
2	1	1	2	2	1	2	2	1	2	2	1	2	1	2	2	2	2	1	1	2
2	2	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
2	2	1	2	2	2	2	2	1	1	2	2	2	1	1	2	1	2	1	1	2
2	2	1	2	2	1	2	2	1	1	2	1	2	1	2	2	1	2	2	1	2
1	2	1	2	2	2	1	2	1	1	2	1	2	1	1	2	1	2	1	1	1
2	2	1	2	2	2	2	2	1	2	1	1	2	2	2	2	2	2	2	1	2
2	2	1	2	2	2	2	2	1	1	2	1	2	1	1	1	1	2	2	2	1
7	2	32	0	1	12	5	1	32	23	3	32	3	29	21	5	17	1	18	24	6
17%	5%	78%	0%	2%	29%	12%	2%	78%	56%	7%	78%	7%	71%	51%	12%	41%	2%	44%	59%	15%

Appendix 15:

2004 Cohort Survey - Question 9(a), Methods and process used in major project, but included in project reports 1=Yes, 2=No

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain- writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	DFMA	Design review	Ergonomic analysis	Fault tree	Features analysis	Function analysis
2275.04	1	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	1	2	1	1
2288.04	2	1	2	1	1	1	1	1	1	1	1	1	1	2	2	1	2	2	1	2
2446.04	2	1	2	1	2	1	1	1	1	2	2	1	2	2	2	2	1	2	1	1
2363.04	1	2	1	1	2	2	1	1	1	2	1	2	1	2	2	2	1	2	2	2
8744.04	2	2	2	1	2	1	1	1	1	2	1	2	2	2	2	2	1	2	1	2
1573.04	2	1	1	1	2	1	1	1	1	1	1	1	2	2	1	2	1	2	1	1
9130.04	1	2	2	1	2	1	1	1	2	1	1	1	1	2	1	2	1	2	1	1
2300.04	1	2	1	1	2	1	1	1	1	2	1	2	1	2	2	2	1	2	1	1
7345.04	1	2	2	1	2	1	1	1	1	2	1	1	2	2	2	2	1	2	1	1
2285.04	2	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	1	1
7330.04	1	2	2	1	2	1	2	2	2	2	1	1	2	2	2	2	1	2	1	2
1574.04	1	1	2	1	2	1	2	1	1	1	1	1	2	2	2	2	1	2	1	2
7259.04	1	2	2	1	2	2	1	2	1	2	1	1	2	2	1	2	1	2	1	1
2379.04	1	2	2	1	2	1	1	2	1	2	1	1	2	2	2	2	1	2	2	1
1208.04	1	2	1	1	2	1	1	2	2	2	1	2	2	2	2	2	1	2	2	2
2818.04	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1
4128.04	2	1	2	1	2	1	1	1	1	2	1	1	1	2	1	1	1	1	1	1
7403.04	2	2	2	1	2	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1
8282.04	1	2	1	1	2	1	1	2	2	2	1	1	2	2	1	2	1	2	1	1
2308.04	1	1	1	2	2	1	1	1	1	2	1	1	1	1	1	2	1	2	1	2
4016.04	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	2	1	2	1	1
5244.04	1	1	2	1	1	1	1	1	1	2	1	1	1	1	2	2	1	2	1	1
2397.04	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	1	2	2	2	1
4017.04	1	2	2	1	2	1	1	1	1	1	1	1	1	1	1	2	1	2	1	1
7487.04	1	1	1	1	2	2	1	1	1	2	1	1	1	1	1	1	1	2	1	1
2278.04	2	2	2	1	2	1	1	2	1	1	1	1	1	2	1	1	1	2	1	1
5240.04	2	2	1	1	2	1	1	2	1	2	1	1	1	1	1	2	2	2	1	1
7762.04	1	1	2	2	2	1	1	1	2	1	1	1	2	2	2	2	2	2	2	2
7373.04	1	1	2	1	2	1	1	1	2	2	1	1	1	2	1	2	1	2	2	1
2272.04	1	1	1	1	2	1	1	2	1	2	1	2	1	1	1	2	2	2	1	1
2544.04	2	2	1	1	2	1	1	1	2	2	1	1	1	1	1	1	2	2	1	2
0745.04	1	2	2	1	1	1	1	1	2	1	1	1	2	2	2	1	1	1	1	1
2350.04	1	1	2	1	2	2	1	1	1	2	1	1	2	2	2	2	1	2	1	1
2345.04	1	1	1	1	2	1	2	1	1	1	1	2	2	2	1	1	1	2	1	2
2424.04	2	2	2	1	2	1	1	1	1	2	1	1	1	2	1	1	1	2	1	1
4009.04	2	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1
No. Yes	22	17	14	33	5	30	33	28	27	12	34	28	19	10	19	12	30	2	30	26
% Yes	61%	47%	39%	92%	14%	83%	92%	78%	75%	33%	94%	78%	53%	28%	53%	33%	83%	6%	83%	72%

Func-cost analysis	Life-cycle analysis	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	Renderings	Solid model	Spec'n checklists	SWOT	Synectics	Trend studies	User research	VA	Yes Responses
2	2	1	2	2	1	1	2	1	1	2	1	2	1	1	2	1	2	1	1	2	24
2	2	1	2	2	1	1	2	1	1	2	1	2	1	2	2	1	2	1	1	1	24
1	1	1	2	1	2	1	2	1	1	2	1	2	1	2	1	1	2	1	1	1	24
2	2	2	2	2	1	2	2	1	1	2	1	2	1	1	2	2	1	1	1	2	18
2	2	1	1	1	2	1	2	1	2	2	1	2	1	2	1	1	2	2	1	1	19
1	2	1	1	1	1	1	2	1	1	1	2	2	1	1	2	1	1	1	1	2	29
2	2	2	2	2	1	1	2	1	2	2	2	2	1	1	1	1	2	2	1	2	21
2	2	1	2	1	1	1	2	1	1	2	1	2	1	1	2	1	2	2	2	2	22
2	2	2	1	2	1	2	2	1	2	2	2	2	1	1	2	2	1	2	2	2	17
1	2	1	2	1	2	1	1	1	1	2	2	1	1	1	2	1	2	1	1	2	28
2	2	1	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	1	2	11
2	1	1	2	2	1	1	2	1	1	2	2	2	1	1	2	1	2	1	2	2	21
2	2	1	2	1	1	2	2	1	1	2	1	2	1	1	2	1	2	2	1	2	20
2	2	1	2	2	2	2	2	2	2	2	1	2	1	1	2	2	2	2	1	2	14
2	2	2	1	2	2	2	2	1	2	2	2	2	1	1	2	2	1	2	2	2	12
1	2	1	2	1	1	1	2	1	1	2	1	1	1	1	1	1	1	1	1	2	33
1	2	1	2	1	1	1	2	1	1	1	1	2	1	1	1	1	2	1	1	2	30
2	2	1	2	1	2	1	2	1	1	2	1	2	1	1	2	1	1	2	1	2	20
2	1	2	1	2	1	2	2	1	1	2	1	2	1	1	2	2	2	1	1	2	21
2	1	1	2	2	1	1	1	1	1	1	1	2	1	1	2	1	2	1	1	2	28
1	1	1	2	1	1	1	2	1	1	2	1	2	1	1	2	1	1	1	1	1	32
2	2	1	1	2	2	1	2	2	1	2	2	2	1	1	2	1	2	1	2	2	23
2	2	2	2	1	2	2	2	2	1	2	2	1	2	1	2	2	2	1	2	2	10
1	2	1	2	1	1	1	2	1	1	2	1	2	1	1	1	1	2	1	1	1	30
1	1	1	1	2	1	1	2	1	2	2	1	2	1	2	1	1	1	1	1	2	30
2	2	2	2	2	2	2	2	1	2	2	1	2	1	1	2	1	2	1	2	2	19
2	2	1	1	2	2	2	2	1	1	2	2	2	1	1	2	1	2	2	1	2	20
2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	11
2	2	2	2	2	2	1	2	2	2	2	1	2	1	1	2	1	2	2	2	2	17
2	2	2	2	1	1	1	2	1	1	2	2	2	1	1	2	1	1	2	2	2	22
1	2	2	2	1	2	1	2	1	2	2	1	2	1	1	2	1	2	2	2	2	20
2	2	1	2	1	1	2	1	1	1	2	1	2	1	1	2	1	2	1	1	2	26
1	2	1	2	2	1	1	2	1	2	2	2	2	1	1	2	1	2	2	2	2	19
1	1	1	2	1	1	1	2	1	1	2	1	2	1	2	2	1	1	1	2	2	26
1	2	1	2	1	1	1	2	1	1	2	2	2	1	1	1	1	2	2	1	2	25
1	2	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	2	1	1	1	33
13	7	25	9	18	23	24	4	30	25	4	22	3	34	30	8	29	10	20	23	6	
36%	19%	69%	25%	50%	64%	67%	11%	83%	69%	11%	61%	8%	94%	83%	22%	81%	28%	56%	64%	17%	

Appendix 16:

2004 Cohort Survey - Question 9(b), Methods and process used in major project, but included in project reports 1=Yes, 2=No

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain-writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	DFMA	Design review	Ergonomic analysis	Fault tree	Features analysis	Function analysis
2275.04	1	2	2	2	2	2	2	2	1	2	1	1	2	2	2	2	1	2	1	1
2288.04	2	1	2	1	1	1	1	1	1	1	1	1	1	2	2	1	2	2	1	2
2446.04	2	1	2	1	2	1	1	2	1	2	2	2	2	2	2	2	1	2	1	1
2363.04	1	2	1	1	2	2	1	2	1	2	1	2	1	2	2	2	2	2	2	2
8744.04	2	2	2	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	1	2
1573.04	2	1	1	1	2	1	1	1	1	1	1	1	2	2	1	2	1	2	1	1
9130.04	1	2	2	1	2	1	1	1	2	1	1	1	1	2	2	2	1	2	1	1
2300.04	1	2	1	2	2	1	1	1	1	2	1	2	1	2	2	2	1	2	2	1
7345.04	1	2	2	1	2	1	1	1	1	2	1	1	2	2	2	2	1	2	1	1
2285.04	2	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	1	1
7330.04	1	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	1	2	1	2
1574.04	2	1	2	2	2	2	2	1	1	2	2	2	2	2	2	2	1	2	1	2
7259.04	2	2	2	1	2	2	1	2	1	2	1	1	2	2	1	2	1	2	1	1
2379.04	2	2	2	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2	2	2
1208.04	1	2	2	2	2	1	1	2	2	2	1	2	2	2	2	2	1	2	2	2
2818.04	2	2	1	1	1	1	1	1	1	2	1	1	1	2	1	1	2	2	1	1
4128.04	2	1	2	1	2	1	1	1	1	2	1	1	1	2	2	1	2	2	1	1
7403.04	2	2	2	1	2	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1
8282.04	1	2	1	1	2	1	1	2	2	2	1	1	2	2	1	2	1	2	1	1
2308.04	1	1	1	2	2	1	1	1	1	2	1	1	1	2	2	2	2	2	1	2
4016.04	1	1	1	1	2	2	1	1	1	2	1	1	2	2	2	2	1	2	1	1
5244.04	1	2	2	1	1	1	1	1	1	2	1	1	1	2	2	2	1	2	2	2
2397.04	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	1	2	2	2	1
4017.04	2	2	2	1	2	1	1	1	1	2	1	2	2	2	2	2	1	2	1	1
7487.04	1	1	1	1	2	2	1	1	1	2	1	1	1	1	1	1	1	2	2	1
2278.04	2	2	2	1	2	1	1	2	1	2	1	1	2	2	2	1	1	2	2	2
5240.04	2	2	1	2	2	1	1	2	1	2	2	1	1	1	1	2	2	2	1	1
7762.04	1	1	2	2	2	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2
7373.04	1	2	2	2	2	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2
2272.04	1	1	1	2	2	1	1	2	1	2	1	2	1	1	1	2	2	2	1	1
2544.04	2	2	2	2	2	1	1	1	2	2	2	1	1	1	2	2	2	2	1	2
0745.04	2	2	2	2	1	1	1	1	2	2	1	2	2	2	2	2	1	2	1	1
2350.04	1	1	2	1	2	2	1	1	1	2	1	1	2	2	2	2	1	2	1	1
2345.04	1	1	2	1	2	1	2	1	1	2	1	2	2	2	2	2	1	2	1	2
2424.04	2	2	2	1	2	1	1	1	1	2	1	1	1	2	1	1	1	2	2	1
4009.04	2	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1
No. Yes	17	14	11	26	5	30	36	29	27	4	30	23	15	5	10	9	27	0	25	22
% Yes	47%	39%	31%	72%	14%	83%	100%	81%	75%	11%	83%	64%	42%	14%	28%	25%	75%	0%	69%	61%

Func-cost analysis	Life-cycle analysis	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	Renderings	Solid model	Spec'n checklists	SWOT	Synectics	Trend studies	User research	VA
2	2	1	2	2	1	1	2	1	1	2	1	2	1	1	2	1	2	1	1	2
2	2	1	2	2	1	1	2	1	1	2	1	2	1	2	2	1	2	1	1	1
1	1	1	2	1	2	2	2	1	2	2	1	2	2	2	2	1	2	2	1	2
2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	2	2	1	1	1	2
2	2	1	1	1	2	1	2	1	2	2	1	2	2	2	1	1	2	2	1	1
1	2	1	1	1	1	1	2	1	1	1	2	2	1	1	2	1	1	1	1	2
2	2	2	2	2	2	1	2	1	2	2	2	2	1	1	2	1	2	2	1	2
2	2	1	2	2	1	2	2	1	1	2	1	2	1	1	2	1	2	2	2	2
2	2	2	1	2	1	2	2	1	2	2	2	2	1	1	2	2	1	2	2	2
1	2	1	2	1	2	1	1	1	1	2	2	1	1	1	2	1	2	1	1	2
2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2
2	2	1	2	2	1	1	2	2	1	2	2	2	2	1	2	1	2	2	2	2
2	2	1	2	1	1	2	2	1	1	2	1	2	1	1	2	1	2	2	1	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
2	2	2	2	2	2	2	2	1	2	2	2	2	1	1	2	2	1	2	2	2
1	2	1	2	1	2	1	2	1	1	2	1	1	1	1	2	1	2	2	1	2
1	2	1	2	1	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1	2
2	2	1	2	1	2	1	2	1	1	2	2	2	1	1	2	1	1	2	1	2
2	1	2	1	2	1	2	2	1	1	2	1	2	1	1	2	2	2	1	1	2
2	2	1	2	2	1	1	1	1	1	1	1	2	1	2	2	1	2	2	1	2
2	2	1	2	2	1	1	2	1	1	2	1	2	1	1	2	1	1	2	1	2
2	2	1	1	2	2	2	2	2	2	2	2	2	1	1	2	1	2	1	2	2
2	2	2	2	1	2	2	2	2	1	2	2	1	2	1	2	2	2	1	2	2
1	2	1	2	1	1	1	2	1	2	2	2	2	1	2	1	1	2	2	1	2
1	1	1	1	2	1	1	2	1	2	2	1	2	1	2	1	1	1	1	1	2
2	2	2	2	2	2	2	2	1	2	2	1	2	1	1	2	1	2	2	2	2
2	2	1	1	2	2	2	2	1	1	2	2	2	1	1	2	1	2	2	1	2
2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	1	2	2	2	2
2	2	2	2	1	1	1	2	1	1	2	2	2	2	2	2	1	1	2	2	2
1	2	2	2	1	2	1	2	1	2	2	2	2	1	1	2	1	2	2	2	2
2	2	1	2	1	2	2	2	1	1	2	1	2	1	1	2	1	2	1	1	2
2	2	1	2	2	1	2	2	2	2	2	2	2	1	1	2	1	2	2	2	2
1	2	1	2	1	1	2	2	1	1	2	2	2	1	2	2	1	2	1	2	2
2	2	1	2	1	1	1	2	1	1	2	2	2	2	1	1	1	2	2	1	2
1	2	1	1	1	2	1	1	1	1	2	2	2	1	1	2	1	2	1	1	1

10	3	23	8	16	17	18	3	28	21	3	15	3	28	27	5	29	8	13	22	3
28%	8%	64%	22%	44%	47%	50%	8%	78%	58%	8%	42%	8%	78%	75%	14%	81%	22%	36%	61%	8%

Appendix 17:

2004 Cohort Survey - Question 9(c), Methods and process used in major project, but included in project reports 1=Yes, 2=No

Case No.	Anthrop'ic analysis	Bench marking	Bionics	Brain storming	Brain- writing	Comp Aided Dtg	CAD	Concept Selection	Cost determine	Design catalogues	Design-by drawing	Design drawings	DFA	DFAD	DFMA	Design review	Ergonomic analysis	Fault tree	Features analysis	Function analysis
2275.04	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	2	1	1
2288.04	2	1	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	1	2
2446.04	2	1	2	1	2	1	1	2	1	2	2	2	2	2	2	2	2	2	1	1
2363.04	2	2	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2
8744.04	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2
1573.04	2	1	1	1	2	1	1	1	1	2	1	2	2	2	2	2	2	2	1	2
9130.04	2	2	2	1	2	2	2	1	2	1	2	2	2	2	2	2	2	2	1	1
2300.04	2	2	1	1	2	2	2	1	2	2	1	2	2	2	2	2	2	2	1	1
7345.04	2	2	2	1	2	2	2	1	1	2	1	1	2	2	2	2	2	2	1	2
2285.04	2	1	2	1	1	2	2	1	1	1	1	1	2	2	2	2	1	2	1	1
7330.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1574.04	2	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
7259.04	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2	2	2	1	1
2379.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1208.04	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2818.04	2	2	1	1	1	1	1	1	1	2	1	1	1	2	2	1	2	2	1	1
4128.04	2	1	2	2	2	2	2	1	1	2	1	2	2	2	2	2	2	2	1	1
7403.04	2	2	2	1	2	1	1	1	2	2	1	2	1	2	2	2	2	2	1	1
8282.04	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2
2308.04	1	1	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2
4016.04	2	1	1	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	1	1
5244.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2397.04	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2
4017.04	1	2	2	1	2	2	2	2	1	2	2	2	1	1	2	2	2	2	1	1
7487.04	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
2278.04	2	2	2	1	2	2	2	2	1	2	1	1	2	2	2	2	2	2	2	2
5240.04	2	2	1	1	2	2	1	2	1	2	1	1	1	1	1	2	2	2	1	1
7762.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7373.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2272.04	2	1	1	2	2	2	2	2	1	2	1	2	1	1	1	2	2	2	1	1
2544.04	2	2	2	1	2	1	1	2	2	2	2	1	2	2	2	2	2	2	1	2
0745.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2350.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
2345.04	2	2	1	1	2	2	2	1	1	2	1	2	2	2	1	2	1	2	1	2
2424.04	2	2	2	1	2	1	1	1	1	2	1	2	2	2	2	2	2	2	1	2
4009.04	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
No. Yes	3	9	11	19	2	6	8	13	20	2	12	6	5	3	4	1	4	0	26	16
% Yes	8%	25%	31%	53%	6%	17%	22%	36%	56%	6%	33%	17%	14%	8%	11%	3%	11%	0%	72%	44%

Func-cost analysis	Life-cycle analysis	Market research	Morpholog analysis	Objectives tree	Patent search	Peeves analysis	Perf spec method	Proj time plan	Prototype	QFD	Question-nairs	Rapid prototype	Renderings	Solid model	Spec'n checklists	SWOT	Synectics	Trend studies	User research	VA
2	2	2	2	2	1	1	2	1	2	2	2	2	2	2	2	1	2	2	2	2
2	2	1	2	2	1	1	2	1	2	2	1	2	2	2	2	1	2	2	2	1
2	2	2	2	1	2	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2
2	2	2	2	2	2	2	2	1	2	2	1	2	1	1	2	2	2	2	1	2
2	2	2	1	1	2	1	2	1	2	2	2	2	2	2	1	1	2	2	2	1
2	2	1	2	1	1	1	2	1	1	1	2	2	1	1	2	1	1	1	1	2
2	2	2	2	2	1	1	2	1	2	2	2	2	1	1	1	1	2	2	2	2
2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	1	2	2	2	2
2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2
1	2	1	2	1	2	1	1	1	1	2	2	1	1	1	2	1	2	1	1	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	2	2	2	1	1	2	1	1	2	2	2	2	1	2	1	2	2	2	2
2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2
1	2	2	2	1	2	1	2	1	1	2	1	1	1	1	2	1	1	2	1	2
1	2	2	2	1	2	1	2	1	2	1	2	2	2	2	1	1	2	2	2	2
2	2	1	2	1	2	1	2	1	1	2	1	2	1	2	2	1	1	2	2	2
2	1	2	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	2	2	2	1	2	1	2	1	2	2	2	2	2	1	2	2	1	2
2	2	2	2	2	1	1	2	1	2	2	2	2	2	2	2	1	1	2	2	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	1	2	2	2	2	1	2	2	1	2	1	2	2	2	2	2	2
1	2	2	2	1	1	1	2	1	2	2	2	2	2	2	1	1	2	2	2	2
1	1	1	1	2	1	1	2	1	2	2	1	2	1	2	1	1	1	1	1	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	1	1	2	2	2	2	1	1	2	2	2	1	1	2	1	2	2	1	2
2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	1	1	1	2	1	2	2	2	2	2	2	2	1	1	2	2	2
1	2	2	2	1	2	1	2	1	2	2	2	2	2	2	2	1	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
1	1	2	2	1	1	1	2	1	2	2	1	2	2	2	2	1	1	2	2	2
1	2	1	2	1	1	2	2	1	1	2	2	2	1	2	1	1	2	2	2	2
1	2	2	1	1	2	1	2	1	2	2	2	2	2	2	2	1	2	2	2	1

9	5	9	6	15	15	19	1	25	8	3	7	3	6	7	5	24	9	3	7	4
25%	14%	25%	17%	42%	42%	53%	3%	69%	22%	8%	19%	8%	17%	19%	14%	67%	25%	8%	19%	11%

Appendix 18: 2003 Respondents who felt the need for a more comprehensive, computer-integrated system of design methods than is currently available.

Case No.	Yes	No	Not sure
8160.03	1		
6735.03	1		
6023.03	1		
5284.03	1		
7444.03		1	
7543.03	1		
3022.03	1		
7311.03	1		
7058.03	1		
7754.03	1		
2114.03		1	
7336.03	1		
7546.03	1		
2509.03	1		
3215.03	1		
3027.03	1		
7409.03	1		
2485.03	1		
6742.03	1		
0944.03		1	
7685.03	1		
7373.03		1	
7959.03	1		
2871.03	1		
7249.03		1	
5153.03	1		
7462.03	1		
3022.03		1	
2184.03	1		
7557.03		1	
2476.03	1		
2956.03			1
7504.03	1		
7347.03	1		
7741.03	1		
7423.03			1
7324.03	1		
6738.03	1		
3031.03	1		
7515.03		1	
5364.03	1		
Totals…..	**31**	**8**	**2**

Appendix 19 – 2004 Respondents who felt the need for a more comprehensive, computer-integrated system of design methods than is currently available

Case No.	Yes	No	Not sure
2275.04	1		
2288.04	1		
2446.04	1		
2363.04		1	
8744.04	1		
1573.04	1		
9130.04	1		
2300.04		1	
7345.04	1		
2285.04	1		
7330.04			1
1574.04	1		
7259.04	1		
2379.04		1	
1208.04		1	
2818.04	1		
4128.04	1		
7403.04		1	
8282.04	1		
2308.04	1		
4016.04	1		
5244.04		1	
2397.04	1		
4017.04	1		
7487.04	1		
2278.04	1		
5240.04	1		
7762.04	1		
7373.04	1		
2272.04	1		
2544.04	1		
0745.04	1		
2350.04	1		
2345.04	1		
2424.04	1		
4009.04	1		
Sum =	29	6	1

Appendix 20 – 2004 Respondents; the extent to which the MPD System contributed to the stages of the 2004 cohorts major project.

Case No.	Product Planning	Task Clarification	Conceptual-isation	Embodiment	Detailed Design	Communication	Prepare Production
2275.04	3	3	5	5	5	3	2
2288.04	5	5	3	3	3	5	2
2446.04	4	3	3	4	3	3	4
2363.04	2	3	1	2	2	5	5
8744.04	2	3	4	4	4	2	2
1573.04	5	5	5	4	4	3	2
9130.04	5	5	3	2	4	4	5
2300.04	4	4	4	5	4	3	2
7345.04	2	4	5	5	5	4	5
2285.04	3	4	4	4	5	3	5
7330.04	2	3	3	2	2	1	1
1574.04	2	3	4	3	4	3	3
7259.04	3	4	1	2	2	2	5
2379.04	2	1	1	1	2	2	1
1208.04	3	2	3	2	1	1	1
2818.04	3	2	4	3	5	5	4
4128.04	3	4	4	5	4	3	5
7403.04	4	4	5	3	5	5	4
8282.04	3	4	2	2	2	1	4
2308.04	4	3	1	3	4	5	5
4016.04	4	4	2	3	4	1	4
5244.04	2	2	4	2	2	2	2
2397.04	3	5	3	4	2	3	4
4017.04	5	5	3	4	2	2	5
7487.04	3	4	4	4	3	5	5
2278.04	1	3	2	1	2	1	3
5240.04	2	4	3	4	4	2	1
7762.04	5	3	1	3	3	3	4
7373.04	2	3	4	4	4	4	2
2272.04	4	3	1	2	3	3	4
2544.04	3	3	4	3	5	3	1
0745.04	4	5	5	4	3	5	3
2350.04	4	4	2	2	2	3	5
2345.04	5	5	5	4	3	4	4
2424.04	4	3	4	4	4	3	3
4009.04	2	3	3	4	4	2	3
Average=	3.3	3.6	3.2	3.2	3.3	3.0	3.3

Appendix 21 – 2003 Cohort Survey - Question 11, Do you feel a system of computer-integrated design methods would help in the areas listed below:
1= Yes; 2= No; 3= Not sure; 9=not applicable

Case No.	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
8160.03	1	1	2	1	1	1	3	3
6735.03	1	1	2	1	1	2	1	1
6023.03	1	1	1	1	1	1	1	1
5284.03	1	1	2	2	1	2	2	1
7444.03	9	9	9	9	9	9	9	9
7543.03	1	1	1	1	1	1	1	2
3022.03	1	1	3	1	1	1	1	1
7311.03	1	1	2	1	2	1	1	1
7058.03	1	1	1	1	1	1	1	3
7754.03	1	1	1	1	1	1	1	2
2114.03	9	9	9	9	9	9	9	9
7336.03	3	1	3	1	1	3	1	1
7546.03	1	1	3	3	1	1	1	1
2509.03	1	1	2	2	1	1	1	1
3215.03	1	1	1	3	1	2	1	1
3027.03	2	3	1	1	1	1	1	2
7409.03	1	1	3	1	1	1	2	2
2485.03	1	2	1	1	1	1	1	1
6742.03	1	1	1	2	1	1	1	1
0944.03	9	9	9	9	9	9	9	9
7685.03	1	1	1	1	1	1	1	1
7373.03	9	9	9	9	9	9	9	9
7959.03	1	1	2	1	1	1	1	1
2871.03	1	1	2	2	1	1	1	1
7249.03	9	9	9	9	9	9	9	9
5153.03	1	1	2	2	1	1	2	2
7462.03	1	1	3	3	1	1	1	1
3022.03	9	9	9	9	9	9	9	9
2184.03	1	1	2	1	1	1	1	1
7557.03	9	9	9	9	9	9	9	9
2476.03	1	1	3	1	3	2	1	1
2956.03	1	1	1	1	1	1	1	1
7504.03	1	1	1	1	1	1	1	1
7347.03	1	1	3	2	1	1	2	2
7741.03	3	1	3	3	1	1	1	1
7423.03	3	3	3	3	3	3	3	3
7324.03	1	1	3	1	3	3	2	3
6738.03	1	1	1	3	1	1	1	1
3031.03	1	1	1	1	1	1	1	1
7515.03	9	9	9	9	9	9	9	9
5364.03	3	1	1	1	3	1	1	3

	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
Yes…….	28	30	14	21	28	26	26	22
No……..	1	1	9	6	1	4	5	6
Not sure..	4	2	10	6	4	3	2	5
N/A……..	8	8	8	8	8	8	8	8

Appendix 22 – 2004 Cohort Survey - Question 12, Did you feel the computer-integrated design methods helped you in the areas listed below:
1= Yes; 2= No; 3= Not sure; 9=not applicable

Case No.	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
2275.04	1	1	1	1	1	1	1	1
2288.04	1	2	2	1	1	1	1	1
2446.04	1	1	2	1	1	1	1	1
2363.04	9	9	9	9	9	9	9	9
8744.04	1	2	1	1	1	2	1	1
1573.04	1	1	2	1	1	1	1	1
9130.04	3	3	3	3	3	1	3	1
2300.04	9	9	9	9	9	9	9	9
7345.04	1	1	1	1	1	1	1	1
2285.04	1	1	1	3	1	1	1	1
7330.04	9	9	9	9	9	9	9	9
1574.04	1	1	2	1	1	1	1	1
7259.04	1	1	1	1	1	1	1	1
2379.04	9	9	9	9	9	9	9	9
1208.04	9	9	9	9	9	9	9	9
2818.04	1	1	3	1	3	1	1	1
4128.04	1	1	3	1	3	1	1	1
7403.04	9	9	9	9	9	9	9	9
8282.04	1	1	3	3	1	1	1	1
2308.04	1	1	2	1	1	1	1	1
4016.04	1	1	1	1	1	1	1	1
5244.04	9	9	9	9	9	9	9	9
2397.04	1	1	2	1	1	2	2	2
4017.04	1	2	3	1	1	1	1	1
7487.04	1	1	2	1	1	1	1	1
2278.04	1	1	2	2	1	2	1	1
5240.04	2	2	1	2	1	1	2	1
7762.04	1	1	2	1	1	1	1	1
7373.04	1	1	2	2	3	1	2	3
2272.04	1	2	2	2	1	1	1	1
2544.04	1	1	2	1	1	1	1	1
0745.04	1	1	1	1	1	3	3	3
2350.04	1	2	2	2	1	2	1	1
2345.04	1	1	1	3	1	1	1	1
2424.04	1	3	1	1	1	1	3	3
4009.04	1	1	2	2	1	1	1	1

	Planning	Identification	Facilitation	Organisation	Systematic	Communication	Determination	Consideration
Yes…..	27	21	10	19	25	24	23	25
No…….	1	6	14	6	0	4	3	1
Not sure…	1	2	5	4	4	1	3	3
N/A……..	7	7	7	7	7	7	7	7

Appendix 23 – 2003 Cohort Survey - Question 12. In what ways might a computer-integrated design methods not help you in the areas listed below:

- □ planning;
- □ identification of the steps in the process;
- □ facilitation of idea generation;
- □ organisation of creative proposals;
- □ systematic classification of data;
- □ communication of project findings;
- □ determination of product cost;
- □ consideration of manufacturing issues.

1= Yes; 2= No; 9=not answered or not applicable

Case No.	too complicated	Time consuming	did not understand	Unnecessary
8160.03	9	9	9	9
6735.03	9	9	9	9
6023.03	9	9	9	9
5284.03	9	9	9	9
7444.03	1	9	1	9
7543.03	9	9	9	9
3022.03	9	9	9	9
7311.03	9	9	9	9
7058.03	9	9	9	9
7754.03	9	9	9	9
2114.03	9	9	9	1
7336.03	9	9	9	9
7546.03	9	9	9	9
2509.03	9	9	9	9
3215.03	9	9	9	9
3027.03	9	9	9	9
7409.03	9	9	9	9
2485.03	9	9	9	9
6742.03	9	9	9	9
0944.03	1	1	1	2
7685.03	9	9	9	9
7373.03	9	9	9	1
7959.03	9	9	9	9
2871.03	9	9	9	9
7249.03	1	1	1	1
5153.03	9	9	9	9
7462.03	9	9	9	9
3022.03	9	9	9	1
2184.03	9	9	9	9
7557.03	9	9	9	9
2476.04	9	9	9	9
2956.03	1	1	9	9
7504.03	9	9	9	9
7347.03	9	9	9	9
7741.03	9	9	9	9
7423.03	9	9	9	9
7324.03	9	9	9	9
6738.03	9	9	9	9
3031.03	9	9	9	9
7515.03	9	9	9	1
5364.03	9	9	9	9

Yes…….	4	3	3	5
No……	0	0	0	1
N/A…..	37	38	38	35

Appendix 24 – 2004 Cohort Survey - Question 13, In what ways did the MPD System fail to help you in:

- □ planning;
- □ identification of the steps in the process;
- □ facilitation of idea generation;
- □ organisation of creative proposals;
- □ systematic classification of data;
- □ communication of project findings;
- □ determination of product cost;
- □ consideration of manufacturing issues.

1= Yes; 2= No; 9=not answered or not applicable

Case No.	too complicated	too time consuming	did not understand	Unnecessary
2275.04	9	9	9	9
2288.04	9	9	9	9
2446.04	9	9	9	9
2363.04	2	1	2	1
8744.04	9	9	9	9
1573.04	9	9	9	9
9130.04	9	9	9	9
2300.04	2	2	2	2
7345.04	9	9	9	9
2285.04	9	9	9	9
7330.04	9	1	9	9
1574.04	9	9	9	9
7259.04	9	9	9	9
2379.04	9	1	9	9
1208.04	9	9	9	9
2818.04	9	9	9	9
4128.04	9	9	9	9
7403.04	9	9	9	9
8282.04	9	9	9	9
2308.04	9	9	9	9
4016.04	9	9	9	9
5244.04	1	9	9	1
2397.04	9	9	9	9
4017.04	9	9	9	9
7487.04	9	9	9	9
2278.04	9	9	9	9
5240.04	9	9	9	9
7762.04	9	9	9	9
7373.04	9	9	9	9
2272.04	9	9	9	9
2544.04	9	9	9	9
0745.04	9	9	9	9
2350.04	9	9	9	9
2345.04	9	9	9	9
2424.04	9	9	9	9
4009.04	9	9	9	9

Yes….	1	3	0	2
No….	2	1	2	1
N/A……	33	32	34	33

Appendix 25: Survey Responses 2003 Cohort: Question 13

Respondent	Item
2509.03	Have Methods course in semester 2 of 3rd year so that it is fresh in the mind of students
	Incorporate methods in Studio 3 and 4 making it part of design process
	Introduce methods guidelines to follow for Research + Project
3027.03	Planning time important, need to stress, generate time plan each week.
	Better management of feedback from lecturers.
	Go out into the field to experience environment and industry contact
6738.03	Use other methods to generate ideas, for example, morphological analysis.
	Be more aware of developments in new technology, materials etc.
	Generate CAD as early as possible as it helps to pinpoint faults.
5153.03	Better decision-making at critical stages
	Structured phases in design process (knowing the next step)
	Better pairing of students and lecturers
	Scope and goals contained in brief more realistic within the time frame.
7058.03	Employ systematic design methods
	Introduce instruction booklet/software that outlines the different methods available
	Examples of how to achieve a good project and advice about state-of-the-art manufacturing technique introduction.
7557.03	Work hard and be wary of complacency as you can never have too much research or concepts
7959.03	Concept generation submissions could be assessed better so that the student has a good idea about what is needed and where they need to place more effort.
0944.03	Starting conceptual stage during project research
	Starting Project Research in Session 2 of the previous year.
	Having a bigger workshop with more staff.
	Academic staff to enforce timelines
	Something to aid student motivation.
	More weighting on the student provision of a model.
5284.03	Better time planning and response to systematic checkpoints / criteria
2485.03	More consultation time
	More academics available
	More resources, (workshop staff, materials)
7311.03	Decided on project earlier, planned time better
	More help in workshop
	Management of workshop materials supply could be better
7324.03	Better access to secondary resources
	Mentors to encourage use of design methods
	More effective time planning
	Incorporate more consideration of cost in execution of product
3031.03	More feedback on the specific criteria needed to pass. Time wasted on irrelevant areas.
2476.03	Model-making consumes a lot of time
	Provide a more concrete structure for the development process
	Provide some type of checklist system that can be tailored for each project.
	Provide milestones that must be met.
7685.03	Milestones specified for the whole process
	Written list of deliverables at the end of the project.

7462.03	More thorough pre-process plan
	More time on methodology selection
	Better understanding of exactly what design methodology is.
7336.03	The provision of a more structured planning procedure
	The costing part of the project could have been covered at an earlier stage.
	Relating more of the techniques that were learnt during the course.
	Ergonomic aspects could have been dealt with more effectively.
7347.03	More time should be spent on Project Planning
3022.03	Start project earlier
	Project report could be completed after final presentation.
7409.03	Could have incorporated more design methodologies into the project, for example, Objectives Trees, Peeves Analysis, SWOT Analysis. Such methodologies might have substantiated the research.
7754.03	Using computer-integrated system could have helped with initial research and the collation/interpretation of initial results.
	More industry-based projects needed.
7515.03	Could have prepared more before start of project to understand the steps and prepare information.
	Establish an effective time plan.
7504.03	Would recommend Edward de Bono's "lateral Thinking" a text for students to read. Many of us are deeply rooted in what he calls "vertical thinking".
6735.03	Having the major project as a single course.
	More professional review from external sources at allocated times.
7543.03	Better project management planning.
	Improve public speaking.
	Get the student going on the project as soon as possible.
	Commence refinement of concepts earlier and then progress to detail design.
6742.03	More detailed time plan
	Need a better understanding of how it would be done in the real world of product development.
5364.03	More effective and supervision and supervision that had specific experience.
2114.03	Argue for more time with supervisor.
	Seek advice about the quality of design concept.
	Seek more understanding of the design process.
3022.03	More hands-on approach to manufacturing.
	My initial research was too broad and I could have made it more specific earlier.
8160.03	Stricter adherence to schedule
	Meticulous listing of tasks
	Collaboration with other faculties students
	Less focus on appearance model
7741.03	More emphasis on time management
	More understanding of the process
	Improved workshop and facilities.
6023.03	More interaction through focus groups
	Greater access to workshops
	Collaborations with past graduates and professionals from industry.
2817.03	Improve time planning
	Minimise time spent on modelling
	More understanding of the design process
7546.03	If provided with a user-friendly computer program to take you through the project step by step. Including examples of how to write the report in the program would be helpful.

2184.03	Use more systematic techniques at the beginning of project to more quickly focus towards a well-defined set of objectives so that more time could be made available into the process of designing the physical object.
7373.03	Better time scheduling. See more things. Get more ideas. Read more books and note current events.

Appendix 26: Survey Responses 2004 projects, Question 14

Respondent	Item
2272.04	Break up into sections that might equate to specific types of projects, for example furniture or a hand-held electronic device
2300.04	Provide a larger variety of examples/case studies
2308.04	Complete set of examples of each step of a real life product and explain how each step contributes to the product development process
	Direction to where more information on manufacturing, ie. Contacts for suppliers, contacts for metal casting etc.
2818.04	Make the examples in the in the various stages consistent with respect to one type of product.
	Categorise the methodologies to suit different approaches ie., innovative design, improving an existing product, etc.
2275.04	Apply MPD System in the studio but select projects that demand selected methodologies so that students can experience the range of methods.
	Commence application of the taxonomy from year 1. This is the only way to consolidate expertise.
2272.04	It is believed the taxonomy is very helpful in product planning and task verification but not so much in conceptualisation. If the taxonomy could trigger creative thought through images, examples of innovations, these might interest students more.
2288.04	I think the MPD System is great however time allowed for Project does not allow enough time to pursue.
2544.04	Make MPD System in PDF form for printing out.
	More examples of cost determination.
	More help on manufacturing
	Guide to calculate cost
2278.04	The MPD System should be demonstrated in a “walk through” manner prior to embarking on the final-year project.
	Insisting that the MPD System is used throughout the Planning and development stages. Once a student starts a project in his own way then it is difficult for him to adjust to a methodology.
	The MPD System is a way of thinking and therefore one must adopt a certain disposition for it to be of value. Must be used from the first as a form of mental discipline.
2350.04	The MPD System’s importance in certain areas of the project should be stressed to students. Such areas are cost determination, manufacturing and planning.
1208.04	By completing the sections where the software states “awaiting content”. More importantly start integrating it earlier than year 4. Stress the importance to students.
2446.04	Could be made even more comprehensive which would save users a great deal of time.
1574.04	Provide a checklist to be able to see what stage you are up to and be aware of the next step.
1573.04	Provide links to supplement the more complicated areas
	Provide more clear examples.
2285.04	Make methodology examples less complicated and more understandable
4017.04	Conduct the Design Methods earlier in the program so that students are more aware of design methods
	Incorporate methods into the studio
	Set the MPD System as part of studio projects to determine how it can introduce a more holistic approach.

2345.04	More focus on the first two stages of the MPD System (Project Planning and Task Verification).
	To provide the capability for users to post and thus share useful web-links etc.
5244.04	Simplify the MPD System to make it less overwhelming.
7373.04	Emphasise certain steps in the MPD System.
	Provide a hard copy.
9130.04	More information on “communication techniques”, reference books, software.
0745.04	Students should learn the MPD System during their 3rd or 4th semester instead of 4th year. This will provide more time to absorb/learn the MPD System.
7304.04	Some of the design methods do not apply once the final concept has been determined. More emphasis on methods appropriate to embodiment and detail design might be helpful.
4016.04	Implementing the gradual introduction of design methods early in the program to instil their usefulness and importance to students.
8282.04	Provide many more examples within the MPD System.
7259.04	I don’t think there is anything on the market that provides the same functions so comprehensively. The only substitute I can think of is the internet and you would have to do hundreds of searches to find the same information.
5240.04	Provide more examples
8744.04	To enable printout.
	Provide further samples.
	More comprehensive instruction.
7487.04	The costing section was not easily effected. It needed understanding of manufacturing rates, cycles etc.
	Also wanted to understand which methodologies to use.
	The rest of the MPD System was clear and helpful. I would not have concluded my report without it.
4009.04	Simplify the explanation in each step in the MPD System as some of the processes are too complicated and difficult to understand.

Appendix 26: Survey Responses 2004 projects, Question 14

Respondent	Item
2272.04	Break up into sections that might equate to specific types of projects, for example furniture or a hand-held electronic device
2300.04	Provide a larger variety of examples/case studies
2308.04	Complete set of examples of each step of a real life product and explain how each step contributes to the product development process
	Direction to where more information on manufacturing, ie. Contacts for suppliers, contacts for metal casting etc.
2818.04	Make the examples in the in the various stages consistent with respect to one type of product.
	Categorise the methodologies to suit different approaches ie., innovative design, improving an existing product, etc.
2275.04	Apply MPD System in the studio but select projects that demand selected methodologies so that students can experience the range of methods.
	Commence application of the taxonomy from year 1. This is the only way to consolidate expertise.
2272.04	It is believed the taxonomy is very helpful in product planning and task verification but not so much in conceptualisation. If the taxonomy could trigger creative thought through images, examples of innovations, these might interest students more.
2288.04	I think the MPD System is great however time allowed for Project does not allow enough time to pursue.
2544.04	Make MPD System in PDF form for printing out.
	More examples of cost determination.
	More help on manufacturing
	Guide to calculate cost
2278.04	The MPD System should be demonstrated in a “walk through” manner prior to embarking on the final-year project.
	Insisting that the MPD System is used throughout the Planning and development stages. Once a student starts a project in his own way then it is difficult for him to adjust to a methodology.
	The MPD System is a way of thinking and therefore one must adopt a certain disposition for it to be of value. Must be used from the first as a form of mental discipline.
2350.04	The MPD System’s importance in certain areas of the project should be stressed to students. Such areas are cost determination, manufacturing and planning.
1208.04	By completing the sections where the software states “awaiting content”. More importantly start integrating it earlier than year 4. Stress the importance to students.
2446.04	Could be made even more comprehensive which would save users a great deal of time.
1574.04	Provide a checklist to be able to see what stage you are up to and be aware of the next step.
1573.04	Provide links to supplement the more complicated areas
	Provide more clear examples.
2285.04	Make methodology examples less complicated and more understandable
4017.04	Conduct the Design Methods earlier in the program so that students are more aware of design methods
	Incorporate methods into the studio
	Set the MPD System as part of studio projects to determine how it can introduce a more holistic approach.

2345.04	More focus on the first two stages of the MPD System (Project Planning and Task Verification).
	To provide the capability for users to post and thus share useful web-links etc.
5244.04	Simplify the MPD System to make it less overwhelming.
7373.04	Emphasise certain steps in the MPD System.
	Provide a hard copy.
9130.04	More information on "communication techniques", reference books, software.
0745.04	Students should learn the MPD System during their 3rd or 4th semester instead of 4th year. This will provide more time to absorb/learn the MPD System.
7304.04	Some of the design methods do not apply once the final concept has been determined. More emphasis on methods appropriate to embodiment and detail design might be helpful.
4016.04	Implementing the gradual introduction of design methods early in the program to instil their usefulness and importance to students.
8282.04	Provide many more examples within the MPD System.
7259.04	I don't think there is anything on the market that provides the same functions so comprehensively. The only substitute I can think of is the internet and you would have to do hundreds of searches to find the same information.
5240.04	Provide more examples
8744.04	To enable printout.
	Provide further samples.
	More comprehensive instruction.
7487.04	The costing section was not easily effected. It needed understanding of manufacturing rates, cycles etc.
	Also wanted to understand which methodologies to use.
	The rest of the MPD System was clear and helpful. I would not have concluded my report without it.
4009.04	Simplify the explanation in each step in the MPD System as some of the processes are too complicated and difficult to understand.

CORRELATIONS STUDY - 2003 COHORT: MOTIVATION, UAI, WAM, IDES2091, GENDER, 1ST LANGUAGE

		Motivation	UAI	IDES2091	WAM	Gender	First Language	Proj_Resch	Project	Average project Research	Yes Responses
Motivation	Pearson Correlation	1	-0.194	-0.168	0.068	0.062	-0.061	0.178	0.016	0.121	0.261
	Sig. (2-tailed)		0.225	0.295	0.674	0.701	0.707	0.267	0.919	0.452	0.099
	N	41	41	41	41	41	41	41	41	41	41
UAI	Pearson Correlation	-0.194	1	.500(**)	-0.019	0.208	0.018	0.039	-0.066	-0.019	-0.184
	Sig. (2-tailed)	0.225		0.001	0.904	0.191	0.913	0.809	0.68	0.907	0.25
	N	41	41	41	41	41	41	41	41	41	41
IDES2091	Pearson Correlation	-0.168	.500(**)	1	-0.085	0.191	0.242	-0.184	0.139	-0.024	-0.2
	Sig. (2-tailed)	0.295	0.001		0.599	0.231	0.128	0.249	0.386	0.88	0.209
	N	41	41	41	41	41	41	41	41	41	41
WAM	Pearson Correlation	0.068	-0.019	-0.085	1	-.350(*)	-0.223	.322(*)	.440(**)	.484(**)	-.344(*)
	Sig. (2-tailed)	0.674	0.904	0.599		0.025	0.16	0.04	0.004	0.001	0.028
	N	41	41	41	41	41	41	41	41	41	41
Gender	Pearson Correlation	0.062	0.208	0.191	-.350(*)	1	.515(**)	0.106	-0.158	-0.036	0.189
	Sig. (2-tailed)	0.701	0.191	0.231	0.025		0.001	0.508	0.323	0.821	0.236
	N	41	41	41	41	41	41	41	41	41	41
First Language	Pearson Correlation	-0.061	0.018	0.242	-0.223	.515(**)	1	-0.148	-0.18	-0.208	0.05
	Sig. (2-tailed)	0.707	0.913	0.128	0.16	0.001		0.357	0.261	0.192	0.755
	N	41	41	41	41	41	41	41	41	41	41
Proj_Resch	Pearson Correlation	0.178	0.039	-0.184	.322(*)	0.106	-0.148	1	0.247	.779(**)	-0.127
	Sig. (2-tailed)	0.267	0.809	0.249	0.04	0.508	0.357		0.119	0	0.428
	N	41	41	41	41	41	41	41	41	41	41
Project	Pearson Correlation	0.016	-0.066	0.139	.440(**)	-0.158	-0.18	0.247	1	.800(**)	-0.028
	Sig. (2-tailed)	0.919	0.68	0.386	0.004	0.323	0.261	0.119		0	0.861
	N	41	41	41	41	41	41	41	41	41	41
Average project Research	Pearson Correlation	0.121	-0.019	-0.024	.484(**)	-0.036	-0.208	.779(**)	.800(**)	1	-0.097
	Sig. (2-tailed)	0.452	0.907	0.88	0.001	0.821	0.192	0	0		0.546
	N	41	41	41	41	41	41	41	41	41	41
Yes Responses	Pearson Correlation	0.261	-0.184	-0.2	-.344(*)	0.189	0.05	-0.127	-0.028	-0.097	1
	Sig. (2-tailed)	0.099	0.25	0.209	0.028	0.236	0.755	0.428	0.861	0.546	
	N	41	41	41	41	41	41	41	41	41	41

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Appendix 28

CORRELATIONS STUDY - 2004 COHORT: MOTIVATION, UAI, WAM, IDES2091, GENDER, 1ST LANGUAGE

		Motivation	UAI	IDES2091	WAM	Gender	First language	Project Research	Project	Average Project Research	Yes Reponses
Motivation	Pearson Correlation	1	-0.006	-0.021	0.057	-0.084	-0.167	0.138	-0.098	-0.001	0.015
	Sig. (2-tailed)		0.972	0.905	0.742	0.627	0.331	0.422	0.568	0.998	0.931
	N	36	36	36	36	36	36	36	36	36	36
UAI	Pearson Correlation	-0.006	1	.519(**)	-0.027	0.288	-.538(**)	0.076	0.006	0.042	-0.302
	Sig. (2-tailed)	0.972		0.001	0.875	0.088	0.001	0.658	0.972	0.807	0.073
	N	36	36	36	36	36	36	36	36	36	36
IDES2091	Pearson Correlation	-0.021	.519(**)	1	-0.217	0.29	-0.227	-0.199	-0.054	-0.137	-0.138
	Sig. (2-tailed)	0.905	0.001		0.203	0.086	0.184	0.245	0.754	0.427	0.422
	N	36	36	36	36	36	36	36	36	36	36
WAM	Pearson Correlation	0.057	-0.027	-0.217	1	-0.213	-0.061	.459(**)	.613(**)	.658(**)	-0.032
	Sig. (2-tailed)	0.742	0.875	0.203		0.212	0.725	0.005	0	0	0.852
	N	36	36	36	36	36	36	36	36	36	36
Gender	Pearson Correlation	-0.084	0.288	0.29	-0.213	1	-0.013	-0.269	-0.104	-0.206	0.243
	Sig. (2-tailed)	0.627	0.088	0.086	0.212		0.941	0.113	0.547	0.228	0.153
	N	36	36	36	36	36	36	36	36	36	36
First language	Pearson Correlation	-0.167	-.538(**)	-0.227	-0.061	-0.013	1	-0.152	-0.072	-0.126	0.042
	Sig. (2-tailed)	0.331	0.001	0.184	0.725	0.941		0.376	0.675	0.463	0.807
	N	36	36	36	36	36	36	36	36	36	36
Project Research	Pearson Correlation	0.138	0.076	-0.199	.459(**)	-0.269	-0.152	1	.376(*)	.760(**)	-0.234
	Sig. (2-tailed)	0.422	0.658	0.245	0.005	0.113	0.376		0.024	0	0.17
	N	36	36	36	36	36	36	36	36	36	36
Project	Pearson Correlation	-0.098	0.006	-0.054	.613(**)	-0.104	-0.072	.376(*)	1	.888(**)	0.062
	Sig. (2-tailed)	0.568	0.972	0.754	0	0.547	0.675	0.024		0	0.719
	N	36	36	36	36	36	36	36	36	36	36
Average Project Research	Pearson Correlation	-0.001	0.042	-0.137	.658(**)	-0.206	-0.126	.760(**)	.888(**)	1	-0.072
	Sig. (2-tailed)	0.998	0.807	0.427	0	0.228	0.463	0	0		0.675
	N	36	36	36	36	36	36	36	36	36	36
Yes Reponses	Pearson Correlation	0.015	-0.302	-0.138	-0.032	0.243	0.042	-0.234	0.062	-0.072	1
	Sig. (2-tailed)	0.931	0.073	0.422	0.852	0.153	0.807	0.17	0.719	0.675	
	N	36	36	36	36	36	36	36	36	36	36

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Appendix 29

2003 STATISTICAL ANALYSIS (Q1 - Q8):

No.	Respondent Number	Motivation (3)	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language	Proj Resch (9)	Project (10)	Av. Proj Rsrch & Project	Yes Responses
1	8160.03	52	N/A	N/A	69	M	English	77	59	68	14
2	6735.03	48	75	68	65	M	Indonesian	74	86	80	24
3	6023.03	50	N/A	N/A	64	M	English	75	56	66	35
4	5284.03	49	90	60	58	M	English	70	63	67	24
5	7444.03	49	96	67	68	F	Chinese	80	70	75	19
6	7543.03	46	96	72	72	M	Chinese	64	65	65	18
7	3022.03	43	81	73	60	M	Chinese	50	69	60	24
8	7311.03	51	79	66	60	F	English	60	72	66	22
9	7058.03	51	92	72	67	F	Indonesian	75	62	69	21
10	7754.03	47	82	73	64	M	English	50	67	59	11
11	2114.03	48	73	67	50	F	Chinese	78	59	69	25
12	7336.03	50	82	65	65	F	English	80	83	82	16
13	7546.03	51	90	69	62	M	English	66	62	64	24
14	2509.03	36	52	67	71	M	English	60	90	75	23
15	3215.03	48	79	72	72	M	English	67	58	63	21
16	3027.03	54	90	75	60	F	Korean	70	67	69	28
17	7409.03	48	87	70	70	M	English	75	76	76	19
18	2485.03	48	N/A	76	59	F	Korean	58	76	67	20
19	6742.03	48	78	66	58	F	Indonesian	55	55	55	33
20	944.03	51	76	72	58	M	English	75	59	67	20
21	7685.03	48	N/A	65	70	M	Chinese	58	68	63	15
22	7373.03	52	89	70	62	M	Chinese	50	60	55	20
23	7959.03	35	78	67	58	M	Chinese	62	54	58	8
24	2871.03	46	79	69	57	F	Chinese	55	50	53	22
25	7249.03	52	91	63	76	M	English	89	87	88	13
26	5153.03	50	80	85	67	M	English	65	65	65	13
27	7462.03	46	84	73	61	M	English	74	58	66	14
28	3022.03	48	N/A	59	58	M	English	50	75	63	25
29	2184.03	46	87	68	59	M	English	61	50	56	17
30	7557.03	48	88	67	72	M	English	72	85	79	10
31	2476.03	52	N/A	69	69	M	English	87	80	84	25
32	2956.03	44	80	71	54	F	English	67	55	61	20
33	2424.03	45	95	65	64	M	English	75	79	77	23
34	7347.03	38	90	67	67	M	English	60	60	60	20
35	7741.03	49	86	56	57	M	English	54	69	62	24
36	7423.03	39	91	68	69	F	Chinese	83	57	70	9
37	7324.03	52	85	68	68	F	Chinese	68	71	70	26
38	6738.03	48	97	71	62	F	Indonesian	60	60	60	25
39	3031.03	41	74	70	52	F	Chinese	75	71	73	24
40	7515.03	51	82	63	59	F	Chinese	65	52	59	17
41	5364.03	55	N/A	62	61	M	Indonesian	65	55	60	23
41		48	84	68	63	26M : 15F		67	66	67	20

2004 STATISTICAL ANALYSIS (Q1 - Q8):

No.	Respondent Number	Motivation (3)	UAI (4)	IDES2091 (5)	WAM (6)	Gender (7)	First language	Project Research (9)	Project (10)	Av. Proj Rsrch & Project	Yes Responses
1	2275.04	49	92	63	70	M	English	74	85	80	24
2	2288.04	51	81	65	60	F	Chinese	71	58	65	24
3	2446.04	46	85	66	61	M	Chinese	53	57	55	24
4	2363.04	48	96	73	67	F	English	70	68	69	18
5	8744.04	51	78	65	61	F	Chinese	64	53	59	19
6	1573.04	46	N/A	68	65	M	Chinese	58	68	63	29
7	9130.04	49	77	73	52	M	English	70	52	61	21
8	2300.04	51	85	60	68	M	Chinese	80	77	79	22
9	7345.04	42	94	67	71	M	English	77	65	71	17
10	2285.04	37	74	70	64	F	Chinese	50	62	56	28
11	7330.04	52	84	65	64	M	English	78	52	65	11
12	1574.04	52	N/A	59	60	M	Spanish	61	62	62	21
13	7259.04	48	91	75	66	F	English	65	66	66	20
14	2379.04	48	92	77	67	F	English	68	56	62	14
15	1208.04	46	80	67	70	M	Norwegian	67	70	69	12
16	2818.04	46	84	69	65	F	Chinese	75	80	78	33
17	4128.04	48	97	68	61	F	Chinese	51	35	43	30
18	7403.04	48	80	67	58.7	F	Chinese	54	72	63	20
19	8282.04	46	N/A	58	61	M	Norwegian	66	61	64	21
20	2308.04	48	99	69	75	M	English	74	90	82	28
21	4016.04	54	N/A	67	71	M	English	62	76	69	32
22	5244.04	48	86	60	56	M	English	78	57	68	23
23	2397.04	42	82	67	60	M	Chinese	51	63	57	10
24	4017.04	46	N/A	51	62	M	Malay	59	55	57	30
25	7487.04	46	88	67	51	F	English	55	75	65	30
26	2278.04	51	99	72	75	M	English	80	89	85	19
27	5240.04	54	89	68	61	M	English	62	36	49	20
28	7762.04	51	89	61	64	M	English	60	73	67	11
29	7373.04	44	79	65	61	M	English	74	57	66	17
30	2272.04	49	92	67	74	M	English	69	93	81	22
31	2544.04	49	78	69	66	M	Chinese	80	60	70	20
32	0745.04	48	N/A	N/A	76	M	Chinese	81	73	77	26
33	2350.04	54	90	62	63	M	English	57	53	55	19
34	2345.04	46	82	61	63	M	English	50	62	56	26
35	2424.04	49	76	63	56	M	English	56	34	45	25
36	4009.04	55	85	68	64	F	Chinese	51	53	52	33
36		48	86	66	64	25M : 11F		65	64	65	22

Appendix 31

2003 COHORT STATISTICAL ANALYSIS (examined reports):

No.	Respondent Number	Motivation	UAI	IDES2091	WAM	Gender	First language	Proj Resch	Project	Combined Result	O/A Assessment	Yes Responses	Task Score	Complexity Score
1	8160.03	52	N/A	N/A	69	M	English	77	59	68	45	14	41	50
2	6735.03	48	75	68	65	M	Indonesian	74	86	80	55	24	50	58
3	6023.03	50	N/A	N/A	64	M	English	75	56	66	55	35	51	53
5	7444.03	49	96	67	68	F	Chinese	80	70	75	40	19	30	25
7	3022.03	43	81	73	60	M	Chinese	50	69	60	45	24	36	46
9	7058.03	51	92	72	67	F	Indonesian	75	62	69	75	21	69	67
11	2114.03	48	73	67	50	F	Chinese	78	59	69	40	25	37	37
12	7336.03	50	82	65	65	F	English	80	83	82	45	16	33	30
13	7546.03	51	90	69	62	M	English	66	62	64	15	24	15	43
14	2509.03	36	52	67	71	M	English	60	90	75	75	23	64	81
16	3027.03	54	90	75	60	F	Korean	70	67	69	70	28	64	61
17	7409.03	48	87	70	70	M	English	75	76	76	85	19	76	70
18	2485.03	48	N/A	76	59	F	Korean	58	76	67	55	20	49	47
19	6742.03	48	78	66	58	F	Indonesian	55	55	55	30	33	28	40
21	7685.03	48	N/A	65	70	M	Chinese	58	68	63	55	15	41	49
23	7959.03	35	78	67	58	M	Chinese	62	54	58	30	8	24	25
25	7249.03	52	91	63	76	M	English	89	87	88	55	13	46	49
27	7462.03	46	84	73	61	M	English	74	58	66	20	14	19	35
30	7557.03	48	88	67	72	M	English	72	85	79	40	10	26	25
31	2476.03	52	N/A	69	69	M	English	87	80	84	75	25	76	70
32	2956.03	44	80	71	54	F	English	67	55	61	60	20	34	44
34	7347.03	38	90	67	67	M	English	60	60	60	20	20	22	37
36	7423.03	39	91	68	69	F	Chinese	83	57	70	25	9	19	36
37	7324.03	52	85	68	68	F	Chinese	68	71	70	30	26	30	38
40	7515.03	51	82	63	59	F	Chinese	65	52	59	55	17	40	35

25		47	83	69	64	26M : 15F		70	68	69	48	20	41	46
		5.2	9.6	3.5	6.2			10.1	11.9	8.7	19.2	6.9	17.8	15.1

Appendix 32

2004 COHORT STATISTICAL ANALYSIS (examined reports):

No.	Respondent Number	Motivation	UAI	IDES2091	WAM	Gender	First language	Proj Resch	Project	Combined result	O/A Assessment	Yes Responses	Task Score	Complexity Score
1	2275.04	49	92	63	70	M	English	74	85	80	85	24	72	60
2	2288.04	51	81	65	60	F	Chinese	71	58	65	40	24	61	49
3	2446.04	46	85	66	61	M	Chinese	53	57	55	75	24	68	53
4	2363.04	48	96	73	67	F	English	70	68	69	70	18	5	57
5	8744.04	51	78	65	61	F	Chinese	64	53	59	75	19	69	61
6	1573.04	46	N/A	68	65	M	Chinese	58	68	63	83	29	75	52
7	9130.04	49	77	73	52	M	English	70	52	61	55	21	45	46
8	2300.04	51	85	60	68	M	Chinese	80	77	79	60	22	53	41
9	7345.04	42	94	67	71	M	English	77	65	71	75	17	63	58
10	2285.04	37	74	70	64	F	Chinese	50	62	56	60	28	58	56
11	7330.04	52	84	65	64	M	English	78	52	65	55	11	41	49
12	1574.04	52	N/A	59	60	M	Spanish	61	62	62	50	21	40	39
13	7259.04	48	91	75	66	F	English	65	66	66	50	20	51	58
16	2818.04	46	84	69	65	F	Chinese	75	80	78	65	33	52	41
18	7403.04	48	80	67	58.7	F	Chinese	54	72	63	75	20	59	60
20	2308.04	48	99	69	75	M	English	74	90	82	85	28	79	70
21	4016.04	54	N/A	67	71	M	English	62	76	69	75	32	61	45
22	5244.04	48	86	60	56	M	English	78	57	68	78	23	66	65
23	2397.04	42	82	67	60	M	Chinese	51	63	57	75	10	69	69
24	4017.04	46	N/A	51	62	M	Malay	59	55	57	45	30	38	51
25	7487.04	46	88	67	51	F	English	55	75	65	60	30	45	60
26	2278.04	51	99	72	75	M	English	80	89	85	95	19	72	74
28	7762.04	51	89	61	64	M	English	60	73	67	55	11	46	61
29	7373.04	44	79	65	61	M	English	74	57	66	65	17	54	49
30	2272.04	49	92	67	74	M	English	69	93	81	85	22	79	67
31	2544.04	49	78	69	66	M	Chinese	80	60	70	68	20	54	53
32	0745.04	48	N/A	N/A	76	M	Chinese	81	73	77	65	26	42	50
33	2350.04	54	90	62	63	M	English	57	53	55	60	19	46	44
34	2345.04	46	82	61	63	M	English	50	62	56	75	26	58	60
36	4009.04	55	85	68	64	F	Chinese	51	53	52	70	33	64	49
30	Means…	48	86	66	64	25M : 11F		66	67	66	68	23	56	55
	Std dev'n…	3.9	6.9	5.0	6.3			10.6	12.1	9.1	13.2	6.2	15.3	9.0

CORRELATIONS STUDY - 2003 COHORT (Examined Reports): PROJECT RESEARCH, PROJECT

		Motivation	UAI	IDES2091	WAM	Gender	First Language	Project Resch	Project	Combined Result	OA Assessment	Yes Responses	Task Score
Motivation	Pearson Correlation	1	-0.156	-0.204	0.087	0.225	0.015	.398(*)	0.12	0.315	0.249	0.322	0.301
	Sig. (2-tailed)		0.456	0.328	0.68	0.279	0.944	0.049	0.569	0.125	0.229	0.116	0.144
	N	25	25	25	25	25	25	25	25	25	25	25	25
UAI	Pearson Correlation	-0.156	1	.546(**)	-0.087	0.273	0.024	0.051	-0.048	-0.003	-0.291	-0.174	-0.346
	Sig. (2-tailed)	0.456		0.005	0.679	0.186	0.909	0.808	0.819	0.987	0.158	0.406	0.09
	N	25	25	25	25	25	25	25	25	25	25	25	25
IDES2091	Pearson Correlation	-0.204	.546(**)	1	-0.153	0.276	0.318	-0.201	0.243	0.049	-0.004	-0.15	-0.045
	Sig. (2-tailed)	0.328	0.005		0.464	0.182	0.121	0.335	0.242	0.815	0.986	0.473	0.831
	N	25	25	25	25	25	25	25	25	25	25	25	25
WAM	Pearson Correlation	0.087	-0.087	-0.153	1	-.424(*)	-0.375	0.374	.587(**)	.623(**)	0.207	-0.309	0.24
	Sig. (2-tailed)	0.68	0.679	0.464		0.035	0.065	0.066	0.002	0.001	0.321	0.132	0.247
	N	25	25	25	25	25	25	25	25	25	25	25	25
Gender	Pearson Correlation	0.225	0.273	0.276	-.424(*)	1	.533(**)	0.044	-0.273	-0.162	-0.003	0.157	-0.073
	Sig. (2-tailed)	0.279	0.186	0.182	0.035		0.006	0.833	0.186	0.439	0.987	0.455	0.729
	N	25	25	25	25	25	25	25	25	25	25	25	25
First Language	Pearson Correlation	0.015	0.024	0.318	-0.375	.533(**)	1	-0.312	-0.21	-0.327	-0.04	0.034	-0.043
	Sig. (2-tailed)	0.944	0.909	0.121	0.065	0.006		0.129	0.314	0.111	0.849	0.873	0.837
	N	25	25	25	25	25	25	25	25	25	25	25	25
Project Resch	Pearson Correlation	.398(*)	0.051	-0.201	0.374	0.044	-0.312	1	0.228	.742(**)	0.164	-0.214	0.21
	Sig. (2-tailed)	0.049	0.808	0.335	0.066	0.833	0.129		0.274	0	0.433	0.305	0.313
	N	25	25	25	25	25	25	25	25	25	25	25	25
Project	Pearson Correlation	0.12	-0.048	0.243	.587(**)	-0.273	-0.21	0.228	1	.822(**)	.414(*)	-0.068	.411(*)
	Sig. (2-tailed)	0.569	0.819	0.242	0.002	0.186	0.314	0.274		0	0.04	0.748	0.041
	N	25	25	25	25	25	25	25	25	25	25	25	25
Combined Result	Pearson Correlation	0.315	-0.003	0.049	.623(**)	-0.162	-0.327	.742(**)	.822(**)	1	0.381	-0.172	.406(*)
	Sig. (2-tailed)	0.125	0.987	0.815	0.001	0.439	0.111	0	0		0.06	0.412	0.044
	N	25	25	25	25	25	25	25	25	25	25	25	25
OA Assessment	Pearson Correlation	0.249	-0.291	-0.004	0.207	-0.003	-0.04	0.164	.414(*)	0.381	1	0.201	.946(**)
	Sig. (2-tailed)	0.229	0.158	0.986	0.321	0.987	0.849	0.433	0.04	0.06		0.335	0
	N	25	25	25	25	25	25	25	25	25	25	25	25
Yes Responses	Pearson Correlation	0.322	-0.174	-0.15	-0.309	0.157	0.034	-0.214	-0.068	-0.172	0.201	1	0.328
	Sig. (2-tailed)	0.116	0.406	0.473	0.132	0.455	0.873	0.305	0.748	0.412	0.335		0.11
	N	25	25	25	25	25	25	25	25	25	25	25	25
Task Score	Pearson Correlation	0.301	-0.346	-0.045	0.24	-0.073	-0.043	0.21	.411(*)	.406(*)	.946(**)	0.328	1
	Sig. (2-tailed)	0.144	0.09	0.831	0.247	0.729	0.837	0.313	0.041	0.044	0	0.11	
	N	25	25	25	25	25	25	25	25	25	25	25	25

CORRELATIONS STUDY - 2004 COHORT (Examined Reports): PROJECT RESEARCH, PROJECT

		Motivation	UAI	IDES2091	WAM	Gender	First language	Proj_Resch	Project	Combined Result	OA Assessment	Yes Responses	Task Score
Motivation	Pearson Correlation	1	-0.07	-0.039	0.107	-0.078	-0.051	0.176	0.001	0.103	-0.076	-0.004	-0.084
	Sig. (2-tailed)		0.714	0.838	0.575	0.68	0.789	0.351	0.997	0.588	0.691	0.982	0.659
	N	30	30	30	30	30	30	30	30	30	30	30	30
UAI	Pearson Correlation	-0.07	1	.513(**)	-0.059	0.25	-.571(**)	0.131	0.116	0.153	0.21	-.368(*)	0.151
	Sig. (2-tailed)	0.714		0.004	0.758	0.183	0.001	0.489	0.542	0.419	0.265	0.046	0.426
	N	30	30	30	30	30	30	30	30	30	30	30	30
IDES2091	Pearson Correlation	-0.039	.513(**)	1	-0.259	0.26	-0.266	-0.206	-0.008	-0.125	0.138	-0.108	0.187
	Sig. (2-tailed)	0.838	0.004		0.167	0.165	0.155	0.275	0.966	0.51	0.467	0.57	0.323
	N	30	30	30	30	30	30	30	30	30	30	30	30
WAM	Pearson Correlation	0.107	-0.059	-0.259	1	-0.277	-0.17	.431(*)	.627(**)	.667(**)	.455(*)	0.066	0.234
	Sig. (2-tailed)	0.575	0.758	0.167		0.139	0.368	0.017	0	0	0.012	0.731	0.213
	N	30	30	30	30	30	30	30	30	30	30	30	30
Gender	Pearson Correlation	-0.078	0.25	0.26	-0.277	1	0.115	-0.275	-0.091	-0.22	-0.246	0.261	-0.201
	Sig. (2-tailed)	0.68	0.183	0.165	0.139		0.544	0.141	0.634	0.242	0.191	0.164	0.288
	N	30	30	30	30	30	30	30	30	30	30	30	30
First language	Pearson Correlation	-0.051	-.571(**)	-0.266	-0.17	0.115	1	-0.247	-0.264	-0.319	-0.35	0.232	-0.089
	Sig. (2-tailed)	0.789	0.001	0.155	0.368	0.544		0.188	0.159	0.086	0.058	0.218	0.638
	N	30	30	30	30	30	30	30	30	30	30	30	30
Proj_Resch	Pearson Correlation	0.176	0.131	-0.206	.431(*)	-0.275	-0.247	1	0.285	.771(**)	0.1	-0.186	-0.047
	Sig. (2-tailed)	0.351	0.489	0.275	0.017	0.141	0.188		0.126	0	0.6	0.325	0.805
	N	30	30	30	30	30	30	30	30	30	30	30	30
Project	Pearson Correlation	0.001	0.116	-0.008	.627(**)	-0.091	-0.264	0.285	1	.831(**)	.521(**)	0.185	0.317
	Sig. (2-tailed)	0.997	0.542	0.966	0	0.634	0.159	0.126		0	0.003	0.327	0.088
	N	30	30	30	30	30	30	30	30	30	30	30	30
Combined Result	Pearson Correlation	0.103	0.153	-0.125	.667(**)	-0.22	-0.319	.771(**)	.831(**)	1	.404(*)	0.015	0.184
	Sig. (2-tailed)	0.588	0.419	0.51	0	0.242	0.086	0	0		0.027	0.937	0.331
	N	30	30	30	30	30	30	30	30	30	30	30	30
OA Assessment	Pearson Correlation	-0.076	0.21	0.138	.455(*)	-0.246	-0.35	0.1	.521(**)	.404(*)	1	0.06	.604(**)
	Sig. (2-tailed)	0.691	0.265	0.467	0.012	0.191	0.058	0.6	0.003	0.027		0.751	0
	N	30	30	30	30	30	30	30	30	30	30	30	30
Yes Responses	Pearson Correlation	-0.004	-.368(*)	-0.108	0.066	0.261	0.232	-0.186	0.185	0.015	0.06	1	0.162
	Sig. (2-tailed)	0.982	0.046	0.57	0.731	0.164	0.218	0.325	0.327	0.937	0.751		0.393
	N	30	30	30	30	30	30	30	30	30	30	30	30
Task Score	Pearson Correlation	-0.084	0.151	0.187	0.234	-0.201	-0.089	-0.047	0.317	0.184	.604(**)	0.162	1
	Sig. (2-tailed)	0.659	0.426	0.323	0.213	0.288	0.638	0.805	0.088	0.331	0	0.393	
	N	30	30	30	30	30	30	30	30	30	30	30	30

Appendix 35: Statistical analysis of the 2003 examined reports

		Complexity Score
Motivation	Pearson Correlation	0.120
	Sig. (2-tailed)	0.568
	N	25
UAI	Pearson Correlation	-0.339
	Sig. (2-tailed)	0.098
	N	25
IDES2091	Pearson Correlation	-0.057
	Sig. (2-tailed)	0.785
	N	25
WAM	Pearson Correlation	0.276
	Sig. (2-tailed)	0.181
	N	25
Gender	Pearson Correlation	-0.253
	Sig. (2-tailed)	0.222
	N	25
First Language	Pearson Correlation	-0.204
	Sig. (2-tailed)	0.327
	N	25
Project Resch	Pearson Correlation	0.049
	Sig. (2-tailed)	0.815
	N	25
Project	Pearson Correlation	0.363
	Sig. (2-tailed)	0.074
	N	25
Combined Result	Pearson Correlation	0.279
	Sig. (2-tailed)	0.177
	N	25
OA Assessment	Pearson Correlation	0.779
	Sig. (2-tailed)	0.000
	N	25
Yes Responses	Pearson Correlation	0.404
	Sig. (2-tailed)	0.045
	N	25
Task Score	Pearson Correlation	0.864
	Sig. (2-tailed)	0.000
	N	25
Complexity Score	Pearson Correlation	1
	Sig. (2-tailed)	
	N	25

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Appendix 36: Statistical analysis of the 2004 examined reports

		Complexity Score
Motivation	Pearson Correlation	-0.275
	Sig. (2-tailed)	0.141
	N	30
UAI	Pearson Correlation	0.445
	Sig. (2-tailed)	0.014
	N	30
IDES2091	Pearson Correlation	0.179
	Sig. (2-tailed)	0.345
	N	30
WAM	Pearson Correlation	0.207
	Sig. (2-tailed)	0.272
	N	30
Gender	Pearson Correlation	-0.025
	Sig. (2-tailed)	0.894
	N	30
First language	Pearson Correlation	-0.409
	Sig. (2-tailed)	0.025
	N	30
Proj_Resch	Pearson Correlation	-0.026
	Sig. (2-tailed)	0.890
	N	30
Project	Pearson Correlation	0.405
	Sig. (2-tailed)	0.027
	N	30
Combined Result	Pearson Correlation	0.254
	Sig. (2-tailed)	0.176
	N	30
OA Assessment	Pearson Correlation	0.605
	Sig. (2-tailed)	0.000
	N	30
Yes Responses	Pearson Correlation	-0.259
	Sig. (2-tailed)	0.168
	N	30
Task Score	Pearson Correlation	0.444
	Sig. (2-tailed)	0.014
	N	30
Complexity Score	Pearson Correlation	1
	Sig. (2-tailed)	
	N	30

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Appendix 37: Normal distributions, 2003 Cohort

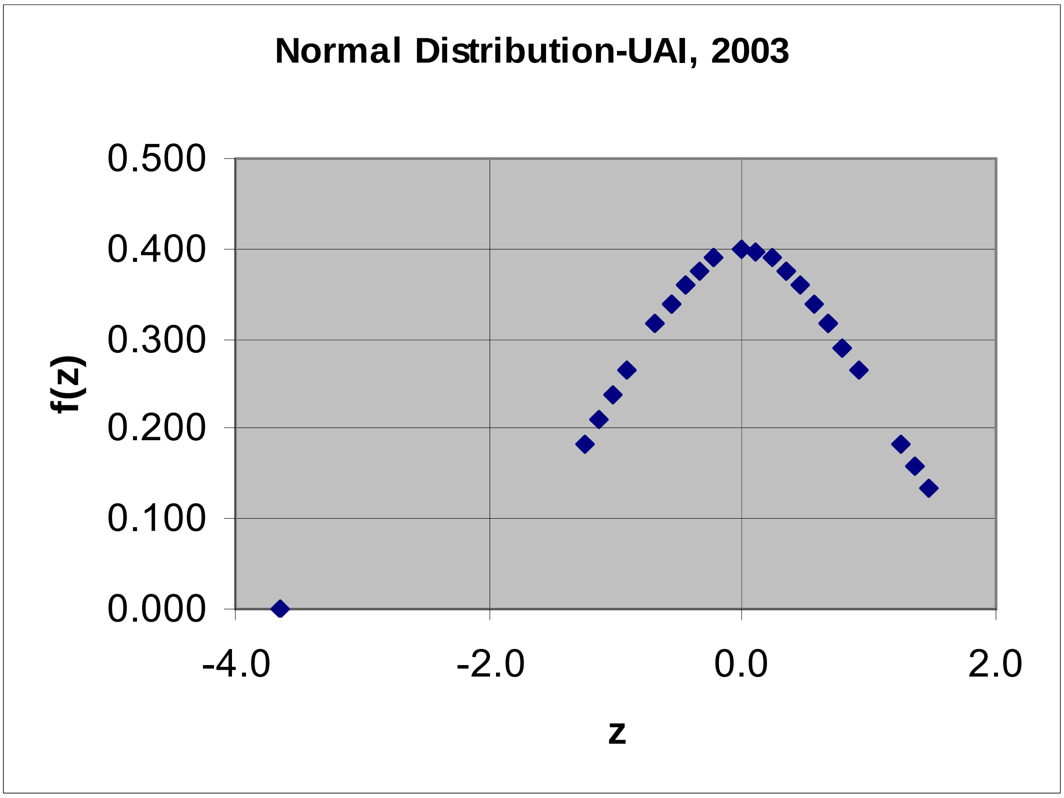


Figure A-1 Normal distribution, 2003 Cohort UAI results

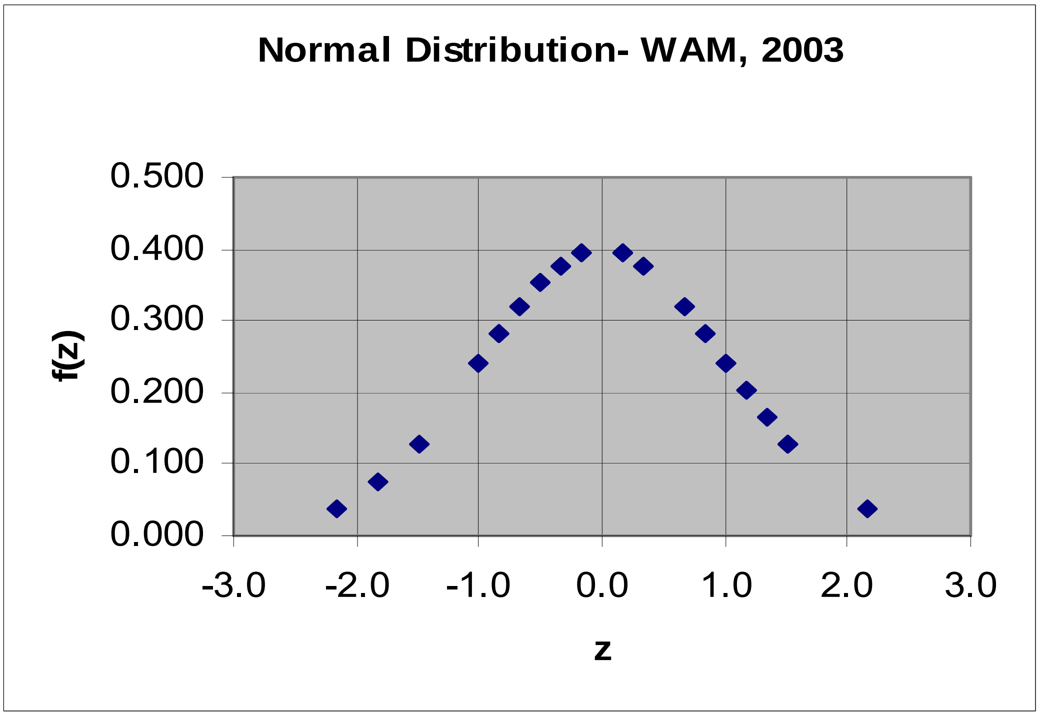


Figure A-2 Normal distribution, 2003 Cohort WAM results

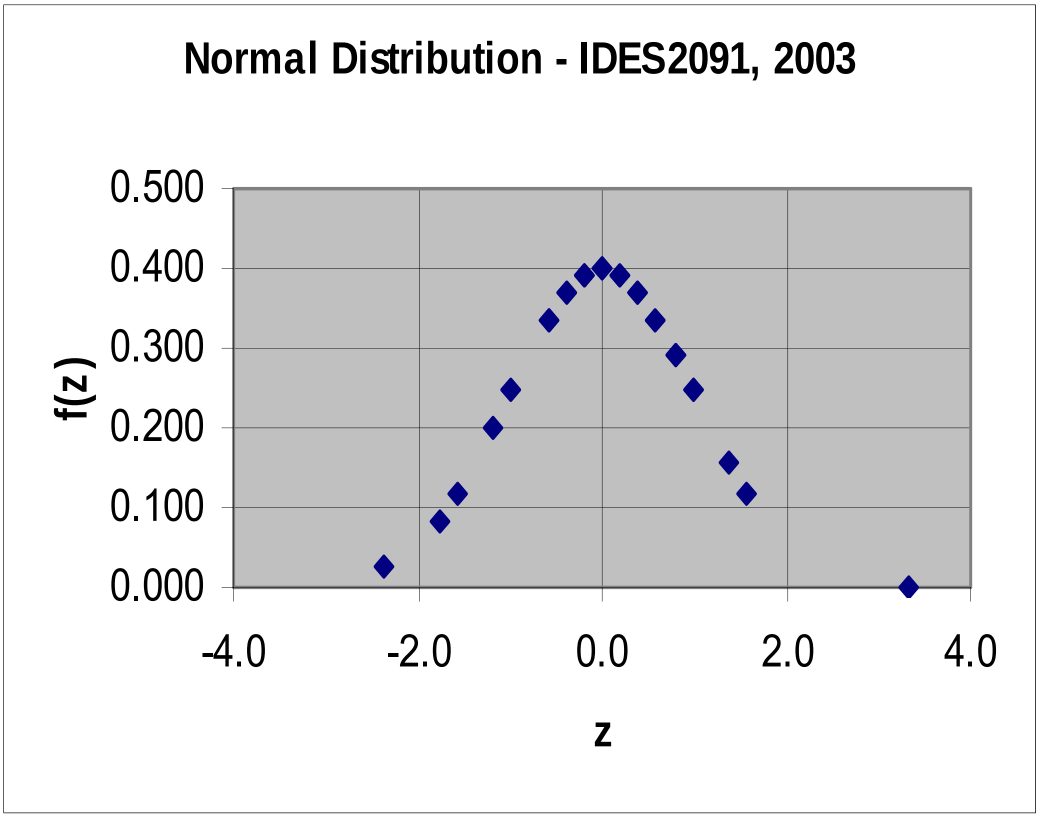


Figure A-3 Normal distribution, 2003 Cohort IDES-2091 results

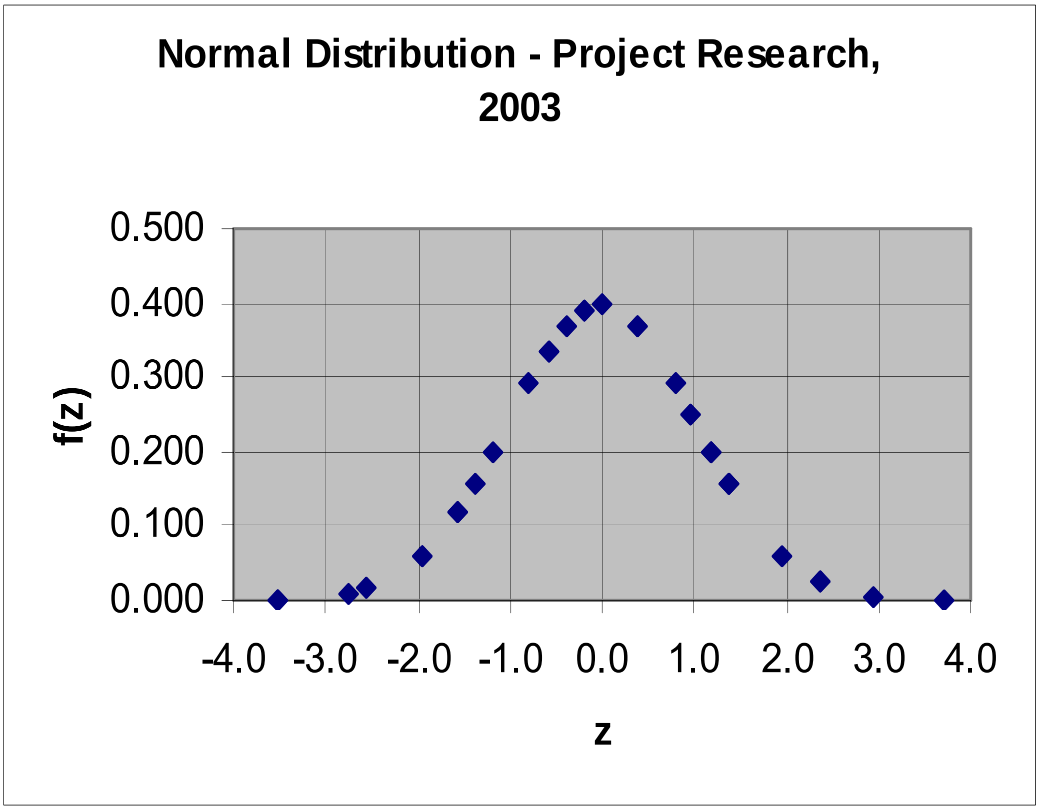


Figure A-4 Normal distribution, 2003 Cohort Project Research results

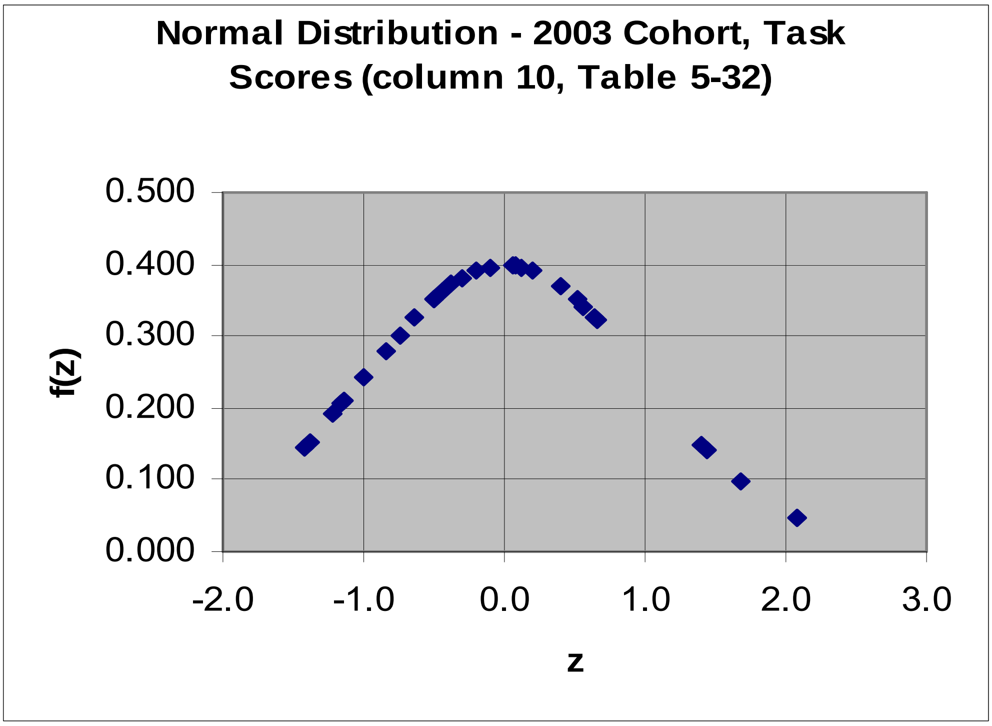


Figure A-5 Normal distribution, 2003 Cohort Overall Task score

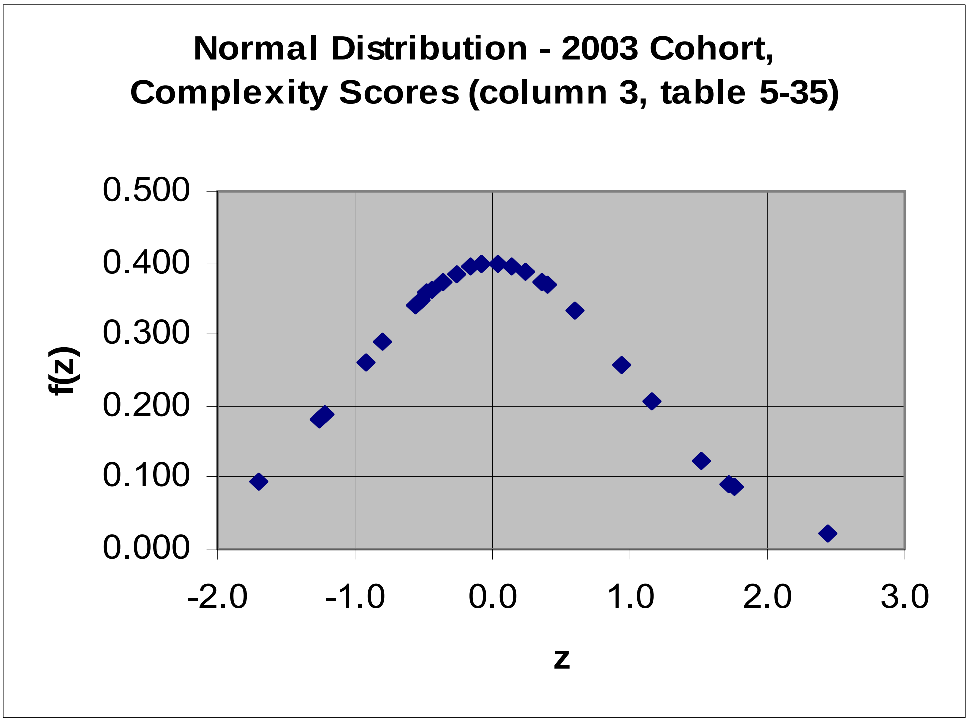


Figure A-6 Normal distribution, 2003 Cohort Overall Complexity scores

Appendix 38: Normal distributions, 2004 Cohort

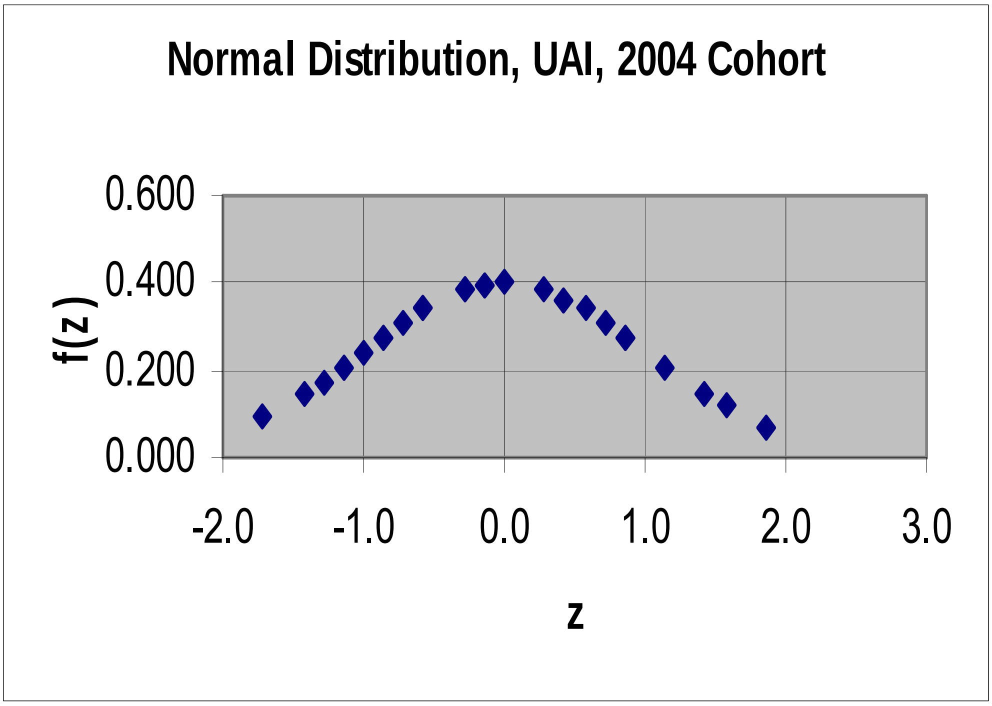


Figure A-1 Normal distribution, 2004 Cohort UAI results

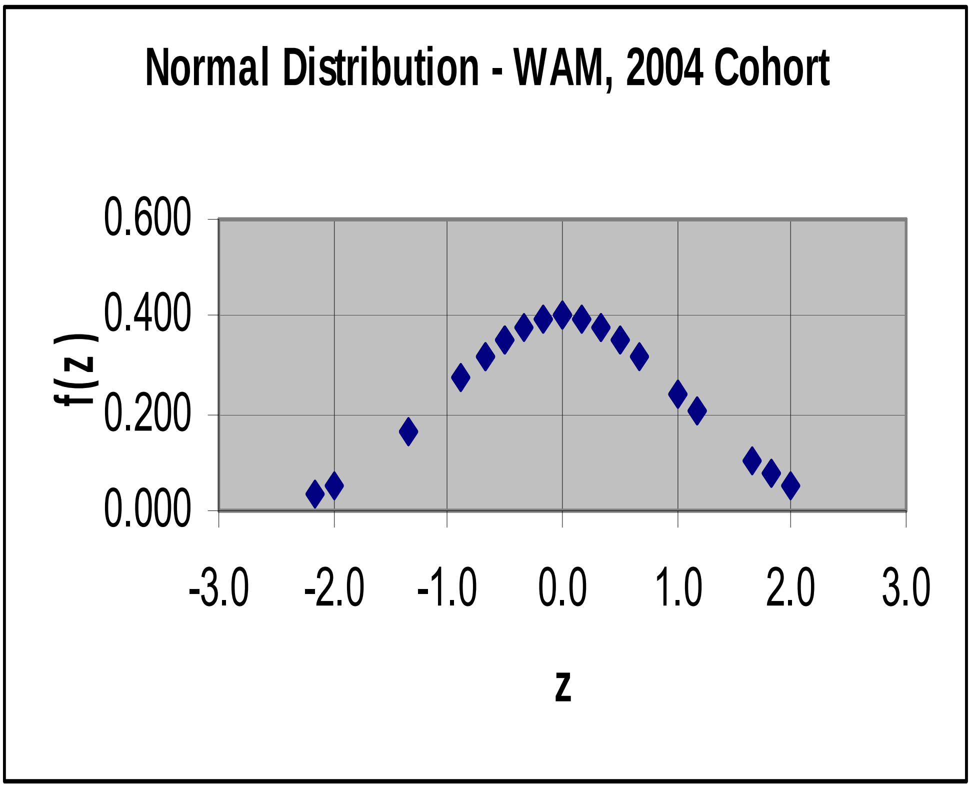


Figure A-2 Normal distribution, 2004 Cohort WAM results

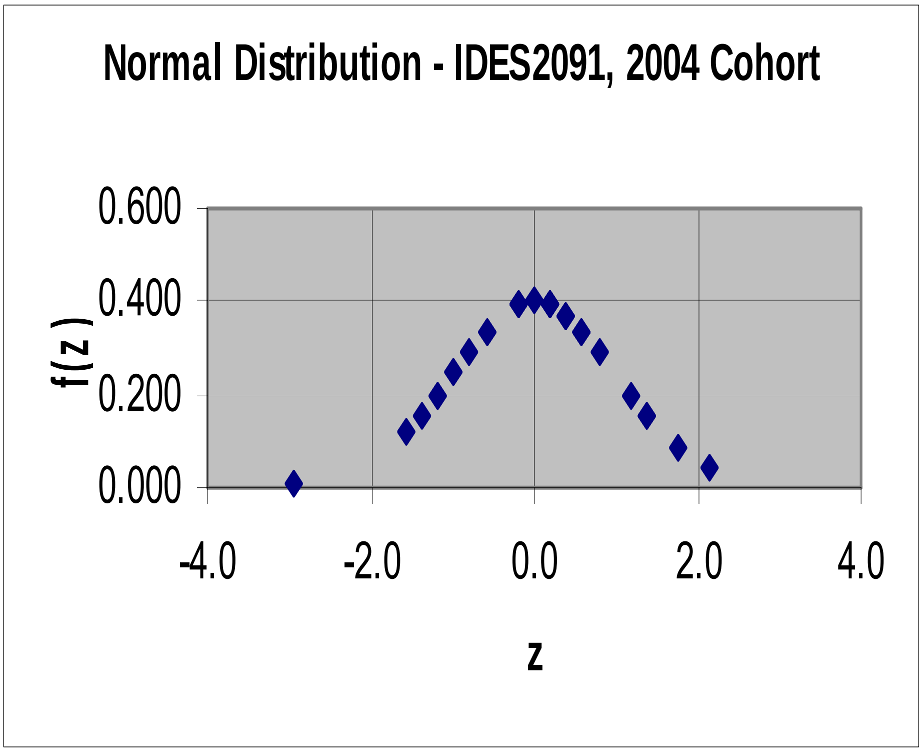


Figure A-3 Normal distribution, 2004 Cohort IDES-2091 results

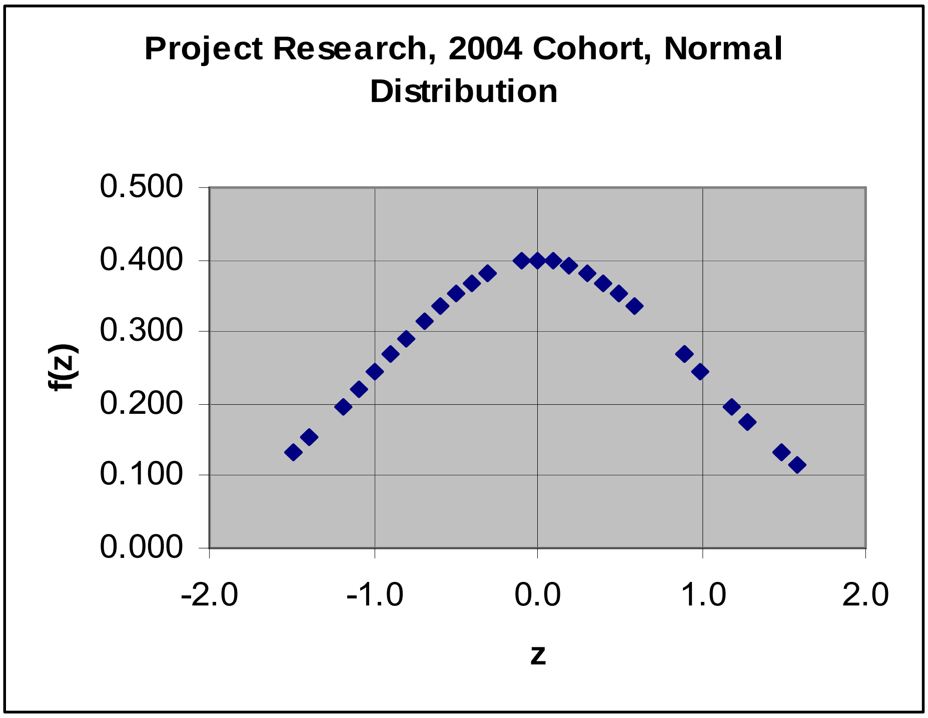


Figure A-4 Normal distribution, 2004 Cohort Project Research results

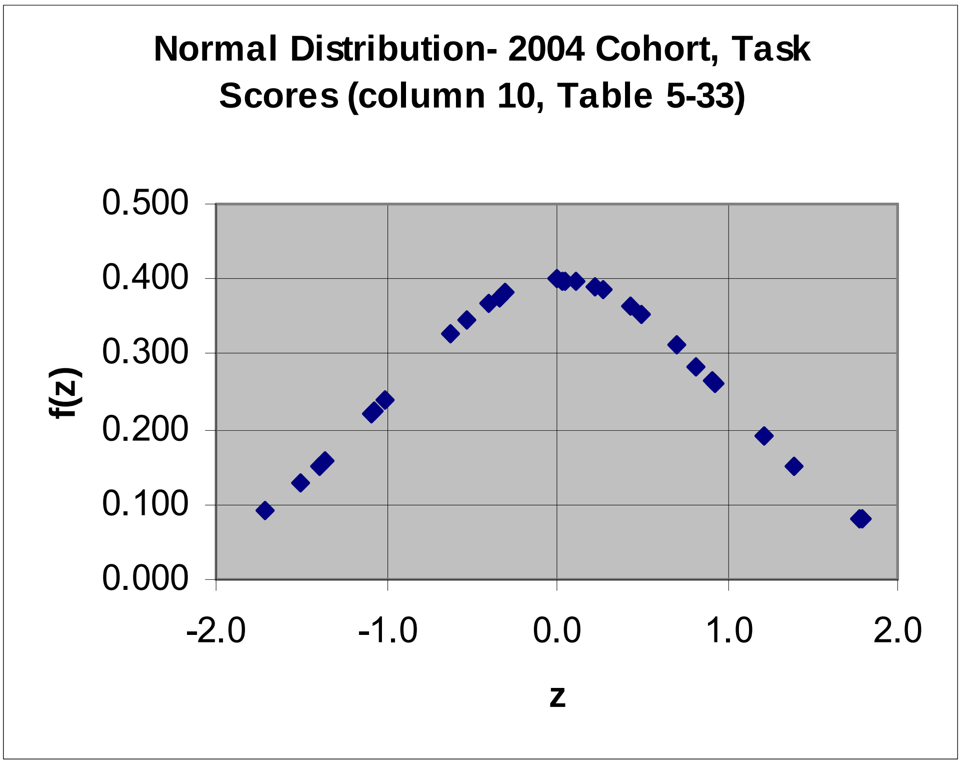


Figure A-5 Normal distribution, 2004 task determination

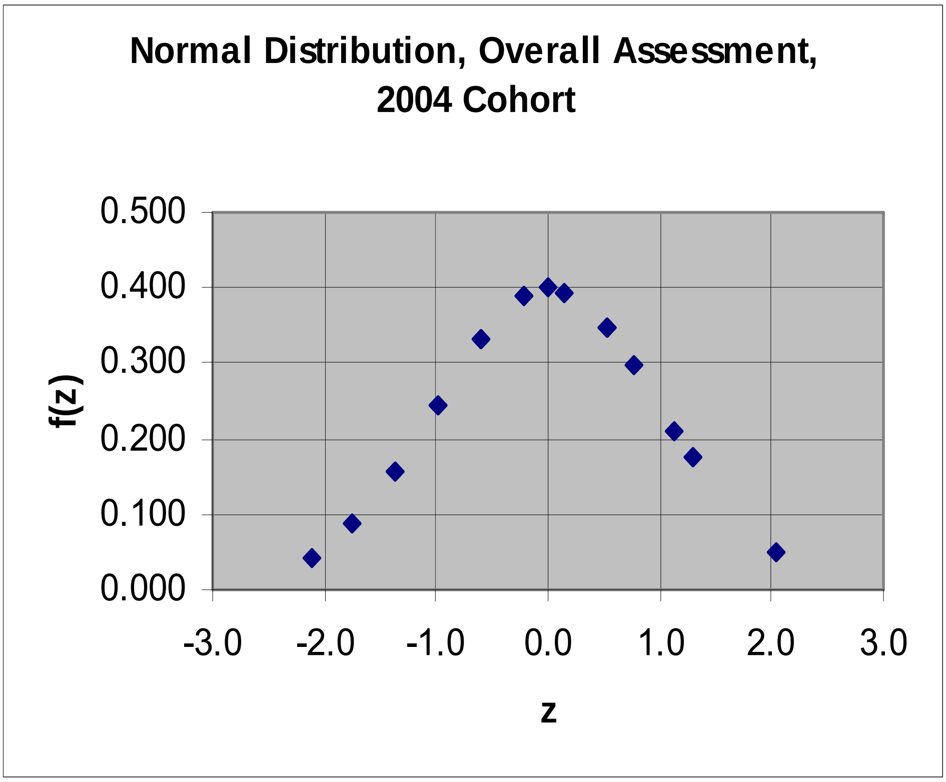


Figure A-6 Normal distribution, 2004 task determination, overall assessment

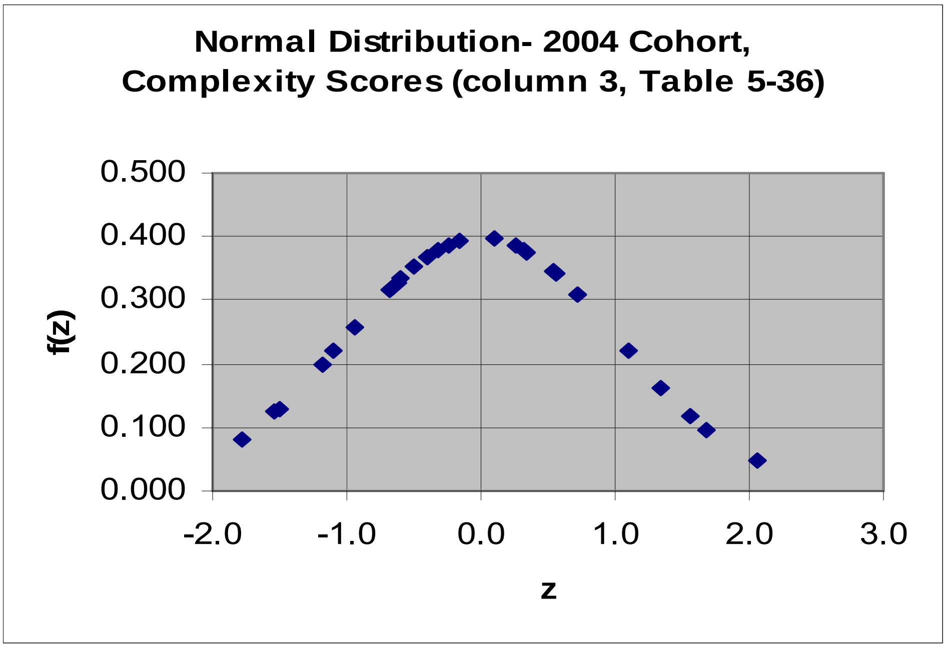


Figure A-7 Normal distribution, 2004 task determination, complexity scores

Appendix 39: Assessment Sheet - *Project*

Assessor:

Designer:	**Name**	Mark
Project:	Title	
	'by-line'/description	
Project scope and complexity	Was the project addressed at a level appropriate for the final year of a four-year industrial design degree program?	
Users (market) and context of use	Has the designer: a. identified the appropriate target group(s) for which to design? b. addressed the needs/aspirations of the target group(s)?	
Management	Has the designer effectively managed the project according to an appropriate timetable? Were appropriate design methods/processes used?	
Concept development	Did the design work successfully explore the requirements identified in the project research? Did the development work reflect a creative approach and yield innovative results?	
Design resolution	Does the final design fulfil an identified need or provide new insight into significant issue? Does the final design appear to be well suited to its intended market? Has the designer handled the resolution of form successfully Is the choice of technologies used appropriate? Have appropriate materials been used? Have ergonomics issues been appropriately considered? Have 'software' interface considerations been adequately addressed? Has an appropriate level of resolution of mechanical detail been achieved? Is the proposed design suitable for production distribution? Overall, to what extent has the final design been successfully resolved?	
Business issues	Does there appear to be a reasonable 'business case' for development of the proposed design?	
Communication	Is the design communicated in a professional manner? Verbal presentation Visuals/models (including physical models, computer models/images, drawings/renderings) Engineering drawings Written material	
Overall Mark or Grade	**Please suggest an overall mark out of 100 :**	
	And/or you may indicate an appropriate grade level:	
Grade levels	Fail (FL) below 50%, Pass (PS) 50-64, Credit (CR) 65-74, Distinction (DN) 75-84, High Distinction (HD) above 85%	

Appendix 40:

PROJECT RESEARCH **- ASSESSMENT CRITERIA**

IDES 4301

Project Research 2003 assessment criteria

Student ID	Name	supervisor	Topic	Project management	Communication:Style/ Structure/Presentation	Statement of Problem/ Aim/Methodology	Market investigation also analysis of existing products	Ergonomic Inquiry/Testing	Functional requirements	Technology inquiry -also standards/patents	Product appeal issues	Production issues -technology/costing	Conclusions/ Design criteria/ proposals	Prelim MARK /100	**FINAL MARK**

APPENDIX 41: PUBLISHED PAPERS FROM THIS RESEARCH

A number of publications have arisen from this study. These are listed below and three of these publications are included in the following pages. In many of my published papers I have collaborated with Professor Elivio Bonollo of the University of Canberra who is the supervisor of my PhD study. Also it should be noted that my papers are published and recognised outside my immediate discipline, predominantly published in World Transactions on Engineering and Technology Education, The Global Journal of Engineering Education, the UICEE Annual Conference Proceedings on Engineering Education and the Asia-Pacific Forum on Engineering and Technology Education.

A. Papers in refereed journals

i) Green, L. N. and Bonollo, (2004) *The Importance of Design Methods to Student Industrial Designers*. Global Journal of Engineering Education. Vol. 8., No. 2. Melbourne 2004. pp 175-182

ii) Green, L. N. and Bonollo, (2003) *Studio-based Teaching, History and Advantages in the Teaching of Industrial Design*. World Transactions on Engineering and Technology Education. Vol. 2., No. 2. Melbourne 2003. pp 260-272

iii) Green, L. N. and Bonollo, E. (2002) *The Development of a suite of design methods appropriate for teaching product design*. The Global Journal of Engineering Education. pp.45-51

B Refereed published conference paper

i) Green, L. N. and Bonollo, E. (2004) *The importance of design methods to student industrial designers*. 4th Global Conference on Engineering Education, Bangkok, Thailand, 5-9 July,2004.

ii) Green, L, (2003) *The Nature of Industrial Design.* 1st North-East International Conference on Engineering and Technology Education, Changhau, Taiwan, 10-13 November, 2003. pp. 24-28

iii) Green, L. N. and Bonollo, (2001) *The Application of Methodologies to Product Design Teaching Within the Industrial Design Studio*. 3rd Asia-Pacific Forum on Engineering and Technology Education, Changhua, Taiwan. 8-11 July, 2001 pp. 210-211

iv) Green, L. N. and Bonollo, E. (2001) *Understanding Design Methodology as a basis for its teaching*. 4th UICEE Annual Conference on Engineering Education, Bangkok, Thailand.

D. Chapters in books

Green, L, (2003) *Design Methods in the Industrial Design Studio.* The Learning Community. First explorations of the Research-Teaching Nexus at UNSW pp.45-48

UNIVERSITY OF CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

Appendix 41, Part A

This chapter has been removed due to copyright restrictions.

This chapter is available as:

Green, L. N. and Bonollo, E. (2002) The Development of a suite of design methods appropriate for teaching product design. *The Global Journal of Engineering Education*. 6(1), pp.45-51.

Links to this chapter:

Print	http://webpac.canberra.edu.au/record=b1248772~S4
Online subscribed content (UC community)	
Online general public	http://www.wiete.com.au/journals/GJEE/Publish/vol6no1/Green.pdf
DOI	

Abstract

The development of new methods for design for manufacture and assembly, the need to incorporate quality during the design phase and the recent focus on transparent design work and communication have all created a need for a more structured approach to design. However the number of design methods and tools available to the designer in the process of design is numerous and for many practicing designers it has become unclear when and how to apply these. In addition, the teaching of these methods is even more problematic because of the extent of the proliferation of design methods and because design teaching is overwhelmed by other subjects in traditional mechanical engineering programmes. In industrial design the situation is similar, with a lack of knowledge about the appropriate methods and tools and a culture that believes methods impede creativity. This paper reviews present knowledge and state of the art associated with design methodology and clarifies the relationship of design methods to stages in the design process.

UNIVERSITY OF CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

Appendix 41, Part B

This chapter has been removed due to copyright restrictions.

This chapter is available as:

Green, L. N. and Bonollo, (2003) Studio-based Teaching, History and Advantages in the Teaching of Industrial Design. *World Transactions on Engineering and Technology Education*. Vol. 2., No. 2. pp 260-272.

Links to this chapter:

Print	http://webpac.canberra.edu.au/record=b1248772~S4
Online subscribed content (UC community)	
Online general public	http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.2,%20No.2%20(2003)/GreenBonollo10.pdf
DOI	

Abstract

The teaching of industrial design and product design is usually conducted in an industrial design studio, a place that has developed traditions of learning-by-doing within the traditions of project-based and problem-based education. However, the design studio has been, and still is, an anachronism within the university context, perceived by some as craft-like and imprecise, lacking rigour, when compared to the intellectual arts and objective credibility and when set against the methods used by the natural sciences. The paper describes the historical background of the architectural studio and how the studio evolved to better facilitate industrial design thinking and learning. It will discuss the educational advantages of the studio together with certain shortcomings and suggest ways that it could be enhanced in order to enable it to be more effective for the teaching of both product designers and design engineers.

UNIVERSITY OF CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

Appendix 41, Part C

This chapter has been removed due to copyright restrictions.

This chapter is available as:

Green, L. N. and Bonollo, (2004) The Importance of Design Methods to Student Industrial Designers. *Global Journal of Engineering Education*. Vol. 8., No. 2. pp 175-182

Links to this chapter:

Print	http://webpac.canberra.edu.au/record=b1248772~S4
Online subscribed content (UC community)	
Online general public	http://www.wiete.com.au/journals/GJEE/Publish/vol8no2/Green.pdf
DOI	

Abstract

In this article, the authors discuss the predicament of student designers, where many struggle to develop expertise in the design process. Because of the repudiation of methodological techniques by many professional designers, the teaching of formal design methodologies has not achieved wide acceptance by educationalists in industrial design. As a consequence, practitioners who were not taught design methods largely fail to incorporate them into their professional design work. The purpose of this article is to review the situation with design methods, to explain the predicament of students as they struggle with the process of designing, and to argue the need for the broader introduction of systematic techniques so as to support the student design process.

APPENDIX 42: ANALYSIS OF THE USE OF DESIGN METHODS OVER THE FIRST THREE PHASES OF THE MPD MODEL BY THE 2003 AND 2004 COHORTS

In this appendix the calculations associated with the use of methods over the 3 phases of the MPD Model namely: the Product Planning, Task Clarification and Conceptualisation phases. The data are listed in the spreadsheet and analysis applied using EXCEL function-analysis software, that is, mean, standard deviation, TTest and Chi-square.

	2003 Cohort	2003 Cohort
	61	83
	27	47
	56	64
	61	81
	24	67
	90	83
	95	67
	51	56
	63	64
	56	61
	12	50
	61	72
	29	36
	93	61
	93	92
	10	14
	90	78
	5	39
	0	28
	27	33
	5	25
mean…	48	57
stddev…	33	22
Ttest…	0.042784566	
Chitest…	3.31006E-29	

These results suggest the difference between the results is significant based on the Chi-squared result.

APPENDIX 43: Statistical Analysis of Task Scores, 2003 and 2004 cohorts, examined reports

In this analysis the tasks scores determined in the examination of the 2003 and 2004 reports are tested for the significance of their difference. The results from the Chi-square test particularly suggest the difference is significant p<.01andthe difference is not by chance. It is due to the influence of the MPD System.

	2003 Cohort	2004 Cohort
	525	919
	640	777
	644	860
	180	743
	386	876
	455	947
	873	571
	474	675
	414	802
	189	736
	819	526
	612	508
	811	642
	963	656
	623	753
	355	1005
	517	769
	311	842
	544	873
	587	477
	241	575
	332	919
	227	583
	399	685
	963	1007
	431	691
	276	530
	244	584
	387	742
	511	810
Mean…	498	736
StdDevn…	223	151

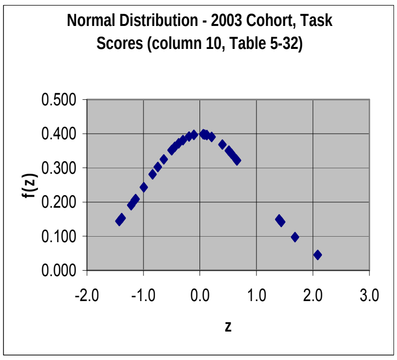
2003 NORMAL DISTRIBUTION

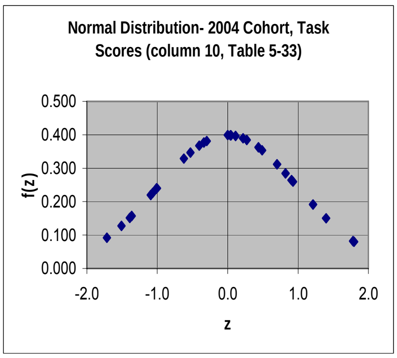
2.1	0.045	963	FALSE
2.1	0.045	963	FALSE
1.7	0.097	873	FALSE
1.4	0.142	819	FALSE
1.4	0.149	811	FALSE
0.7	0.322	644	FALSE
0.6	0.326	640	FALSE
0.6	0.341	623	FALSE
0.5	0.350	612	FALSE
0.4	0.368	587	FALSE
0.2	0.391	544	FALSE
0.1	0.396	525	FALSE
0.1	0.397	517	FALSE
0.1	0.398	511	FALSE
-0.1	0.397	474	FALSE
-0.2	0.392	455	FALSE
-0.3	0.381	431	FALSE
-0.4	0.372	414	FALSE
-0.4	0.362	399	FALSE
-0.5	0.352	387	FALSE
-0.5	0.352	386	FALSE
-0.6	0.325	355	FALSE
-0.7	0.302	332	FALSE
-0.8	0.281	311	FALSE
-1.0	0.243	276	FALSE
-1.1	0.209	244	FALSE
-1.2	0.205	241	FALSE
-1.2	0.191	227	FALSE
-1.4	0.153	189	FALSE
-1.4	0.144	180	FALSE

2004 NORMAL DISTRIBUTION

1.8	0.080	1007	FALSE
1.8	0.082	1005	FALSE
1.4	0.150	947	FALSE
1.2	0.191	919	FALSE
1.2	0.191	919	FALSE
0.9	0.260	876	FALSE
0.9	0.264	873	FALSE
0.8	0.285	860	FALSE
0.7	0.312	842	FALSE
0.5	0.354	810	FALSE
0.4	0.363	802	FALSE
0.3	0.385	777	FALSE
0.2	0.390	769	FALSE
0.1	0.396	753	FALSE
0.0	0.399	743	FALSE
0.0	0.399	742	FALSE
0.0	0.399	736	FALSE
-0.3	0.382	691	FALSE
-0.3	0.377	685	FALSE
-0.4	0.368	675	FALSE
-0.5	0.347	656	FALSE
-0.6	0.329	642	FALSE
-1.0	0.240	584	FALSE
-1.0	0.239	583	FALSE
-1.1	0.226	575	FALSE
-1.1	0.220	571	FALSE
-1.4	0.157	530	FALSE
-1.4	0.152	526	FALSE
-1.5	0.128	508	FALSE
-1.7	0.092	477	FALSE

Pearson= -0.026
Ttest= 0.000006
ChiSqu= 0.0000





APPENDIX 44: Statistical Analysis of Complexity Scores, 2003 and 2004 cohorts, examined reports

In this analysis the complexity scores determined in the examination of the 2003 and 2004 reports are tested for the significance of their difference. The results from the Chi-square test particularly suggest the difference is significant p<.01andthe difference is not by chance. It is due to the influence of the MPD System.

2003 Cohort	2004 Cohort
174	209
203	173
185	187
63	200
86	215
160	182
234	162
130	143
104	202
149	195
282	171
149	135
214	203
244	144
166	210
139	246
172	157
88	227
145	242
172	179
124	209
87	258
88	215
111	170
246	235
155	184
128	176
125	154
134	209
123	172

Mean...	153	192
StdDevn...	53	32

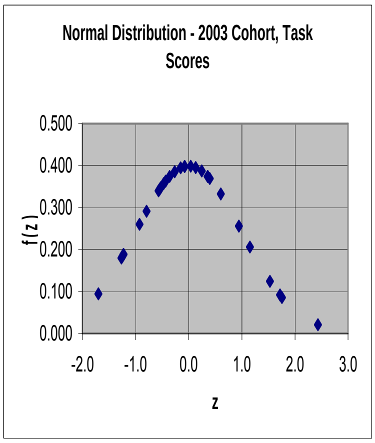
Pearson= -0.303
Ttest= 0.000544
ChiSqu= 0.0000

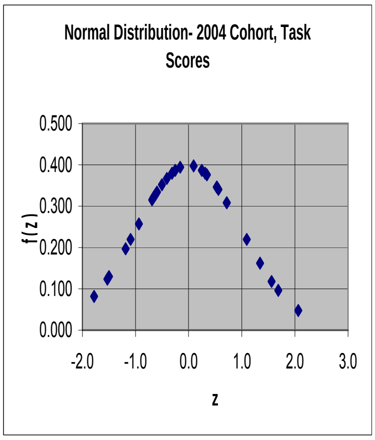
2003 NORMAL DISTRIBUTON

2.4	0.021	282	FALSE
1.8	0.086	246	FALSE
1.7	0.091	244	FALSE
1.5	0.124	234	FALSE
1.2	0.206	214	FALSE
0.9	0.256	203	FALSE
0.6	0.332	185	FALSE
0.4	0.369	174	FALSE
0.4	0.374	172	FALSE
0.4	0.374	172	FALSE
0.2	0.387	166	FALSE
0.1	0.395	160	FALSE
0.0	0.399	155	FALSE
-0.1	0.398	149	FALSE
-0.1	0.398	149	FALSE
-0.2	0.394	145	FALSE
-0.3	0.385	139	FALSE
-0.4	0.374	134	FALSE
-0.4	0.363	130	FALSE
-0.5	0.357	128	FALSE
-0.5	0.347	125	FALSE
-0.5	0.343	124	FALSE
-0.6	0.340	123	FALSE
-0.8	0.291	111	FALSE
-0.9	0.260	104	FALSE
-1.2	0.188	88	FALSE
-1.2	0.188	88	FALSE
-1.2	0.184	87	FALSE
-1.3	0.179	86	FALSE
-1.7	0.094	63	FALSE

2004 NORMAL DISTRIBUTION

2.1	0.048	258	FALSE
1.7	0.096	246	FALSE
1.6	0.118	242	FALSE
1.3	0.162	235	FALSE
1.1	0.219	227	FALSE
0.7	0.308	215	FALSE
0.7	0.308	215	FALSE
0.6	0.341	210	FALSE
0.5	0.346	209	FALSE
0.5	0.346	209	FALSE
0.5	0.346	209	FALSE
0.3	0.376	203	FALSE
0.3	0.380	202	FALSE
0.3	0.387	200	FALSE
0.1	0.397	195	FALSE
-0.2	0.394	187	FALSE
-0.3	0.387	184	FALSE
-0.3	0.380	182	FALSE
-0.4	0.367	179	FALSE
-0.5	0.352	176	FALSE
-0.6	0.334	173	FALSE
-0.6	0.328	172	FALSE
-0.7	0.322	171	FALSE
-0.7	0.315	170	FALSE
-0.9	0.257	162	FALSE
-1.1	0.219	157	FALSE
-1.2	0.197	154	FALSE
-1.5	0.130	144	FALSE
-1.5	0.124	143	FALSE
-1.8	0.082	135	FALSE





APPENDIX 45: Statistical Analysis of Design Research verses Product Research (Complexity) Scores, 2003 cohort, examined reports

In this analysis the complexity scores associated with Design Research verses Product Research determined in the examination of the 2003 reports are tested for the significance of their difference. The results from the TTEST particularly suggest the results are correlated, and significant p<.05.

DR	PR
95	79
95	108
79	106
24	39
22	64
66	94
108	126
52	78
31	73
64	85
117	165
70	79
82	132
101	143
65	101
52	87
63	109
28	60
58	87
67	105
51	73
24	63
33	55
45	66
106	140
66	89
59	69
50	75
61	73
64	59

Correlation 0.855 Significance = 0.000571

APPENDIX 46: Statistical Analysis of Design Research verses Product Research (Complexity) Scores, 2004 cohort, examined reports

In this analysis the complexity scores associated with Design Research verses Product Research determined in the examination of the 2004 reports are tested for the significance of their correlation. The results from the TTEST particularly suggest the results are correlated, and significant p<.05.

Design Research	Product Research
82	127
70	103
82	105
79	121
84	131
89	93
66	96
50	93
80	122
73	122
73	98
49	86
86	117
41	103
86	124
103	143
73	84
95	132
105	137
75	104
82	127
109	149
82	133
72	98
101	134
66	118
66	110
78	76
80	129
69	103

Correl= 0.688 Ttest= 6.47783E-11

APPENDIX 47: THE MPD SYSTEM