THE PRESENTATION AND TESTING OF A DESIGN PROCESS MODEL EMPLOYED BY STUDENTS IN FINAL-YEAR, MAJOR PROJECTS IN INDUSTRIAL DESIGN

Lance Green
Industrial Design Program, The University of New South Wales, Sydney Australia

ABSTRACT
An initial study surveyed academics involved in teaching industrial design in Australia, and overseas. The study sought to determine the approach of students, in various industrial design degree programs, to their final-year projects and the extent to which design process and design methods were incorporated in their project reports and documentation. These findings, together with teachings from the literature concerning how students go about design in the studio and the needs associated with project activity, led to the proposal of a generic model, entitled the Major Project Development Model "MPD Model". The operational criteria in the MPD Model guided the development of a computer-integrated system of design methods allocated to the respective phases of the process. This system, called the "MPD System", was designed to support and enhance student design work in major projects. The model and system were tested in use by a cohort of students during 2004. These results were contrasted against a cohort in 2003 that did not employ the model and process. The results, obtained from the use of this model and process, are presented. In addition, a model describing the relative complexity of projects has been developed and tested and the results included in this paper.

Keywords: process/methods; integrated product development methods and tools; complexity of design activity; industrial design education; management of innovation, design and NPD

1 INTRODUCTION

This study applies to final-year projects executed by two cohorts, that is a cohort of 30 students in 2003 and a cohort of 30 students in 2004. The demographics of each cohort were similar; for example age, gender proportion, and academic performance at both high school and over the period of their university study. The principal difference was that the 2004 cohort used the MPD Model and System; the 2003 cohort did not.

The study used a model developed by the author for final-year, industrial design student projects. This model based on the research of a number of authors, namely: Archer (1966); Cross (2000); Cross and Roozenburg (1992); Maffin (1998); Bonollo and Lewis (1996); Baxter (1995); Eder (1998); Green and Bonollo (2002); more accurately reflects the steps and process carried out by students as they progress through year-long, final-year major projects in industrial design. The model was also informed by findings from an initial structured survey that revealed the approaches of students during major projects. The model, termed the Major Project Development Model (MPD Model), includes seven phases. The phases, their description and applicable design methods are listed as follows:

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

2 TASKS ASSOCIATED WITH THE MPD MODEL

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.

A proposed instrument for analysis of tasks has been developed. This instrument and methodology avoids the chaos of assessment of projects by providing a rationale for assessment with evaluation criteria that reduces the subjectivity and confusion. The relative importance of a task is allocated a *weighting* based on a range of 1 to5. 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 a 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 was compared across a range of reports in order to understand the relative degree to which the task has been accomplished. Therefore the score of a particular, task multiplied by its weighting produces a definitive score. The respective scores for each task are summed to arrive at a definitive score for the individual project. Then the scores for the 30 projects of the respective cohort are summed and an average for the cohort established.

3 THE "MPD SYSTEM" (COMPUTER_BASED DESIGN METHODS)

The design-teaching/learning instrument used by students in the study is called the "MPD System" which consists of a computer-integrated suite of design methods based on the "MPD Model". The MPD System consists of a suite of computer files (design methods), 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 specified in the MPD Model 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. Forty-three (43) design methods are assigned to the various phases of the system.

4 APPLICATION OF THE MPD MODEL AND SYSTEM

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

The studio is a creative place where a right-brained approach, based on visual, holistic, parallel, synthetic, diffuse and intuitive thinking, is emphasised. The introduction of a greater level of methodical thinking, that is a left-brain approach with its emphasis on verbal, analytic, linear, serial and focused thinking can lead to more comprehensive consideration of issues, particularly in year-long major projects. The MPD Model and System links the left and right brain approaches in the studio and the Model is intended to act as a connecting bridge or instrument to facilitate dual-brain processing in the studio. Seven stages, commencing with *Product Planning* apply to the model and system. In this stage the student would understand the outcomes required and may conceptualise in a right-brain mode using methods such as idea generation or brainstorming.

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 remaining five phases namely concept generation, evaluation, detailed design, communication and preparation for production are also included in the project. 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.

5 A MODEL FOR MEASURING THE COMPLEXITY OF PROJECTS

The notion of *complexity* is difficult to measure and define with precision. A number of researchers have explored the field of complexity, namely: Moody *et al* (1997), Burns *et al* (1996), Bonollo and Lewis (2002), Samuel and Weir (1997), Clark and Fujimoto (1991) and Griffin (1993). 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 earlier researchers, namely those listed above. Ten categories of assessment are proposed and these are listed as follows:

1. **Complexity of the market**: complexity and diversity of the market segment, strategic implications, intensity of competition, patents, economic considerations, among others;
2. **Scientific considerations:** Noise, light, power, sound, energy, physics, chemistry, corrosion, galvanic action, solar energy, GPS navigational systems, communications technology.
3. **Regulatory issues:** 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:** Anthropometric factors, human scale, usability issues, prototyping models, experience-based considerations, task analysis, universal design, experience-based design.
5. **Health and safety considerations**: Human factors, issues associated with the body, e.g. physiology, anatomy, circulatory, cardiac, sports injuries, sound, hearing loss.
6. **High level of aesthetic requirements**: Issues associated with emotional response, relationship to art and high design, where the predominant function is visual, where issues of finish (texture, colour, resolution of detail) are subtle but critical.
7. **Sustainability considerations**: 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**: Number of manufacturing technologies involved, complexity of processes, broad consideration of design-for-assembly and disassembly, materials research, manufacturing cost issues.
9. **Political/global/racial/cultural considerations**: 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 and trading blocs.

10. **Engineering/production design considerations**: 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).

A weighting over a range 1 to 5 is applied 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 project process.

In comparing projects in the ten categories of assessment, the range of projects were considered and the extent to which a student, in a particular project, has executed these. A scoring instrument was developed that enabled an across-the-board consideration of a range of projects. A total of 60 projects were measured by application of the complexity model and the scoring instrument. The instrument includes the ten categories of assessment, the respective weightings and a range of possible scores. The product of the score and the weighting factor for each category is determined and the overall sum tallied to arrive at a complexity score for each project.

6 RESULTS

6.1 *Tasks and methods employed by the 2003 and 2004 cohorts*

The respective scores for the tasks and structure included in the 2003 and 2004 cohort project reports were contrasted and the results show a considerable difference between the scores achieved by the respective cohorts. The 2003 cohort achieved an average score, across the 30 projects, of 498 and the 30 projects of the 2004 cohort, 736. The 2004 cohort clearly demonstrated a greater awareness of the use of design methods and knowledge of the major project development process. These findings were tested by comparison of the scores obtained by the two cohorts across the board. It was found that the difference between the cohorts was significant and not a chance event.

Because the two cohorts are similar academically, each group having 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 influenced by 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 the MPD System which provided a suite of computer-based design methods to categorise of information, enable a breadth of consideration of issues and encourage creative thinking.

6.2 *Complexity of the projects undertaken by the 2003 and 2004 cohorts*

The relative complexity scores for the projects of the 2003 and 2004 cohorts were contrasted and clearly show that the average complexity of the projects produced by the 2003 cohort was qualitatively less than the average produced by the 2004 cohort. These findings were tested by comparison of the scores obtained by the two cohorts. The 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. The validation of this model clearly is a significant development in this study. The principles can be adopted and integrated into the assessment process to arrive at a more comprehensive evaluation of student application in major projects.

7 CONCLUSIONS

The study has indicated that the MPD Model and System has contributed to more comprehensive project outcomes. In addition, the complexity model has been tested and the results indicate that it is an effective instrument in classifying projects. However this is one study and a longitudinal study would be more definitive in confirming the effectiveness. It is important to note that the above models have gained universal acceptance in the programme at the University of New South Wales both in terms of the students whose surveyed opinions have been very positive and staff who believe it provides a structure and methods for major projects.

REFERENCES

[1] Archer, B.L. (1966) Systematic Method for Designers, Design Council, London

[2] Baxter, M. (1995) Product Design: a practical guide to systematic methods of new *product development*, Chapman and Hall

[3] Bonollo E and Lewis B, *The Industrial Design profession and Models of the Design Process*. Design & Education Volume 6, Number 2, December, 1996.

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

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

[6] 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

[7] 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.

[8] Green, L. N. and Bonollo, E. (2005) *Complexity in Student Major Projects.* 4th Asia-Pacific Forum on Engineering and Technology Education, Bangkok, Thailand 26- 29 September, 2005.

[9] Green, L. N. (2003) *Design Methods in the Industrial Design Studio.* The Learning Community. First explorations of the Research-Teaching Nexus at UNSW.

[10] Griffin, A., (1993) "Metrics for measuring product-development cycle time" Journal of Product Innovation Management Vol 10 pp112-125

[11] Lewis B and Bonollo E, (2002) An analysis of professional skills in design: implications for education and research. Design Studies (23) pp385-406.

[12] Maffin, D. (1998) Engineering Design Models: context, theory and practice, *Journal of Engineering Design*, Vol. 9, No. 4

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

[14] 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

Dr. Lance GREEN
University of New South Wales
Faculty of the Built Environment
Sydney, 2052 Australia
l.green@unsw.edu.au
+61 408 161 239