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The Importance of Design Methods to Student Industrial Designers*

Lance N. Green
University of New South Wales, Sydney, NSW 2052, Australia
Elivio Bonollo
University of Canberra, University Drive, Canberra, ACT 2601, Australia

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.

INTRODUCTION

Following graduation, it can take a considerable period of time for a designer to develop confidence and professional competence in industrial design. Many professionals would agree that it can take at least 10 years. This length of time is needed for the designer to build a database of experience and it is this experience that the designer accesses during the process of designing. This is the way it has been, because the process of design has not basically changed over the years, and it has come to be accepted that a long period of apprenticeship to the design profession is essential after graduation. However, this suggests that the decision-making process of design is based upon experience and intuition.

For many years, designers involved in research sought to place the design process on a more systematic and rigorous foundation. However, this proved to be problematic and a large percentage of the effort in developing methodological techniques was unsuccessful. Designers generally repudiated methodological techniques because they believed they constrained design thinking and impaired creativity. As a consequence, formal design methodologies have not achieved wide acceptance by educationalists in industrial design. It has been shown that practitioners who were not taught design methods generally fail to include them into their professional design work [1].

But the debate does not consider the situation of the student designer who:

> *… is expected to plunge into designing trying from the very outset 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 means* [2].

The above description by Schon represents a chaotic situation. The student has no database of experience, little knowledge of marketing, engineering, manufacturing, the process of drawing, or even an understanding of the design or product development process. Frost has stated that it is *little wonder that most students are scared witless by design and exhibit excruciating pencil-phobia* [3].

The student faces this predicament because the context of industrial design education is centred on practice in design until such times as the student builds a substantial body of project experience. In this way,

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the student gradually gains a level of confidence and competence in the design process. But many do not.

In this article, the authors consider the circumstances of the student designer in contrast to the experienced designer, and deliberate on the process and intuition employed by the experienced designer, arguing the need to support the student designer by emphasising the design process and methods that can clarify thinking and decision-making.

THE PROCESS OF DESIGNING

A typical design process applied to a product development might include consideration of thousands of issues associated with cost, assembly, appearance, usability, manufacture, sustainability, export, competitiveness, standards and patents, among many others. Little wonder that it takes a considerable period for a designer to develop the expertise that facilitates the integration of issues and associated decision making. The designer essentially manages the process of design and effects the role of both designer and manager. Management aspects include the context of the product, client requirements, the validity of the brief, plus 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.

A number of designers and writers have written about *designing* and unanimously refer to the complexity of the process and the difficulty associated with many problems that are ill-defined. Talbot argues the following:

> *Industrial 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 variable and constraints some initially known and others revealed during the design process* [4].

The outcomes of the design process never evolve to one unique and correct answer; 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 stated the following:

> *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* [2].

An industrial design project may include responsibility for the design of the *user interface* and product function and emotive aspects, such as *product appeal* (visual, tactile and style), together with perceived quality and value. In addition, the designer has to work 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. Such design problems are usually ill defined (as opposed to well-defined problems that can be solved using well understood procedures and have clearly identifiable, correct solutions).

The designer generally follows an established process. While approaches vary, the product development process (PDP) can be used to describe the way in which the designer moves though the project. The stages in this process are as follows:

- Product planning;
- Task verification;
- Conceptualisation;
- Embodiment;
- Detailed design;
- Communication;
- Preparation for production.

The designer will move through the stages of the process, not necessarily in a sequential manner, and may iterate between the stages refining the stage outcomes until the optimum result is achieved. For example, when involved in the *product planning* stage, the designer may seek information in the *preparation for production* stage regarding manufacturing cost and facilities for production. Similarly, when preparing detail designs, the designer may go back to the *task verification* stage to verify the considerations outlined in the brief.

The graduate designer usually gains employment in an industrial design consultancy where engagement in projects, ranging from the design of toothbrushes right across the spectrum of products to motor vehicles, facilitates the building of a foundation of experience. The novice designer, starting from an elementary understanding of design gained at university, will then engage in projects under the watchful eye of an experienced designer. The novice quickly consolidates understanding of design and inexorably gains experience in countless issues associated with materials, manufacture, engineering, marketing, sustainability, recycling, legislation, standards, patents, specifications, costing, prototyping, communication and project management. Thus, the novice designer will proceed to an experienced designer over a period of perhaps 10 years.

In moving through the stages of the product-development process, the designer will employ certain procedures and tools to arrive at effective stage outcomes. In the *product planning* stage, the designer may carry out analysis of the features of competitor products. This might be done employing a formal *features analysis* method or may employ a *benchmarking* method. Similarly, in the *task verification* stage, the designer may employ *objectives trees* or *morphological analysis*. However, experienced designers do not necessarily employ formal methods. In many instances, their experience enables them to make a considerable number of mental iterations that may reflect upon, for example, competitor product features and arrive at conclusions that are uncannily accurate and conclusive.

Eder, writing about engineering designers, explained that certain methods are accepted by industry, examples include Total Quality Management (TQM), Quality Function Deployment (QFD) and Taguchi [5]. He further laments that such methodologies are used only in a small fraction of industry. Frost responded to Eders' comments by arguing that much design in industry is incremental and not original and, therefore, not requiring methodological approaches [6]. Maffin considered the low use of methods in industry and argued that much design in industry is non-original and that design is based on established concepts and does not require elaborate exploration [7].

These comments by engineering academics apply equally to the field of industrial design. While 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 do not necessarily include Osborne's idea-generation techniques. Nor do they necessarily establish a brainstorming committee. 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.

DESIGN METHODS: THE CURRENT SITUATION

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 methodologies evolved from the introduction of new systematic design methods that were 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 [8].

The design methods introduced in the 1960s and 1970s 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) and design for X (DFX). Although these were adopted by certain sections of industry, the adoption by the design industry was generally minimal. Various authors have written about the low level of adoption by industry of the aforementioned methods. Huang and Mak refer to other reports by Wright (1996), Norell (1993), McQuater (1996), Dale and Shaw (1990), and Pandey and Clausing (1991), and the general conclusions point to a low incidence of usage in industry [9]. 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 [1].

Research by Spring McQuater, Swift, Dale and Booker has shown the following:

> *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 those techniques that have direct application to design such as QFD, design of experiments, fault tree analysis and failure mode and effects analysis (FMEA)* [10].

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 engaged under the pressure of deadlines, it is difficult to introduce new ways under these circumstances [11].

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

- The designer, over time, has developed a database of expertise that facilitates effective design decision making;
- Many methods are cumbersome, requiring significant input data and paperwork and, as a result, are time consuming;
- Formal design tools were not taught at universities in the past and currently.

It follows, then, that methods and processes are not included in the curriculum of many university and college courses. Certainly, CAD and modelling is widely taught, but methods like VA, QFD or 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/she does not know how to do, in order to get the sort of experience that will help him/her learn what designing is [2].

A STRUCTURED SURVEY

In 2004, the writers initiated a survey of industrial design programmes in Australia, Singapore, the UK, Korea and New Zealand. The purpose was to determine the effectiveness of various aspects of students' approaches and the methods they used as they progress through their final-year major projects. Large numbers of questions were posed firstly to understand the capability of student designers in such areas as time management, conceptualisation and idea generation skills, and secondly to understand the design methods employed by student designers. A small section of the nature of typical questions in the survey is included in Table 1 and the responses requested relate to the

Table 1: Example indicating the nature of questions posed in the survey of industrial design courses.

	least utilised				highly utilised	
	1	2	3	4	5	N/A
Anthropometric analysis				X		
Benchmarking		X				
Brainstorming			X			
Computer-Aided Design					X	
Computer-integrated manufacturing						X
Concept selection (Pugh)	X					
Concurrent engineering	X					
Cost analysis	X					
Design catalogues			X			
Design by drawing					X	
Design drawings (engineering)		X				
Design for assembly (DFA)		X				
Design for disassembly (DFDA)		X				
Design for environment			X			
Design of experiments (Taguchi)	X					
Features analysis		X				
Function analysis	X					
Pareto analysis	X					
Quality-function deployment	X					

extent to which the method is utilised.

The results of the survey are currently being analysed; however, there is a clear indication that many optional methods are utilised to a limited extent in major projects. In addition, knowledge of the formal design process is not really understood by the student 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, patent searching, features analysis, concept selection, function analysis, among many other of the more rigorous techniques, are least utilised. The early results of the survey indicate that methods are not widely taught in many industrial design programmes and that students are not confident with time management, the generation of ideas and an understanding of the product development process (PDP) and its potential role in guiding their project work.

The minimal use of design methods to assist the student designer may not seem to be a major issue to many teachers of industrial design. Yet what is overlooked is the complexity of current design considerations. For example, the traditional studio incorporated a relatively limited span of consideration. Technical considerations would have included design and drawing, and processes would have included critique and discussion. Earlier studios had a greater emphasis on art and drawing; hence, the broader considerations, namely financial and socio-cultural, would not have figured greatly. Factors that have broadened the focus of the current studio are globalisation, technology, developments in process and cultural considerations. Figure 1 shows the developmental trends in this regard.

Design is the key to international competitiveness of organisations and the key consideration of international design is to consider diversity. Despite the globalisation of markets where, for some time, the trend has been to internationalise products, there is – and will be – a trend towards the accommodation of the diversity of culture and race.

Acceptance of products for international consumers can only be successful if they operate on a cultural level, supported by effective communication, which is important as it makes it possible for cultural acceptability and recognition. There is cultural diversity in most countries and these represent market segments (niche markets). Thus, it is possible to identify these segments, develop products and market them appropriately to a segment. Understanding the culture, lifestyle, people and language of a country that a designer seeks to develop the product for is essential in the modern studio approach. Indeed, Pallasmaa stated the following:

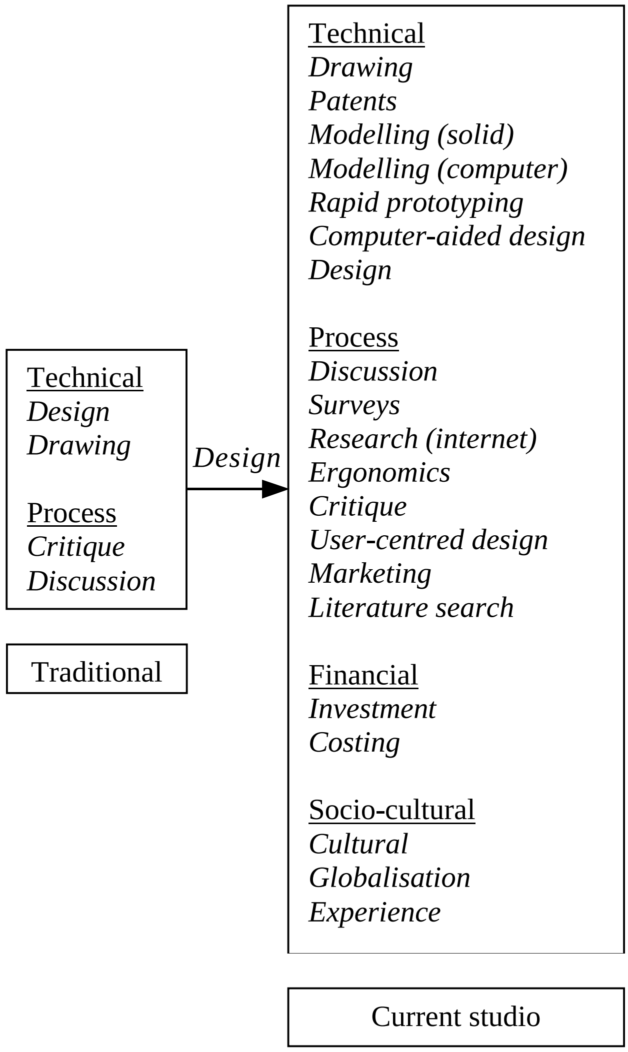

Figure 1: The developmental trends.

> *Culturally-adapted architecture is not merely a matter of visual style but integration of culture, behaviour and environment. To deny cultural differentiation is foolish* [12].

Local factors, such as price constraints, differing distribution facilities, regulations and cultural differences, have a great deal of impact on product consumption. An educational programme cannot teach about such issues relevant to all countries. However, if these issues, among others, are highlighted, then an awareness of regional factors will grow in the student.

Technical issues, including solid modelling, computer modelling, Computer-Aided Design and rapid prototyping, all require a high level of expertise in the student, but this was not the case 20 years ago. Similarly, current approaches included in the process of design are considerations in marketing, user-centred design and the use of the Internet to search for information.

All of these factors present a very different environment for the student designer. Greater quantities of information to be processed, decisions associated with cultural, functional and competitive aspects of the product need to classified and decisions synthesised. The use of design methods in these circumstances provides some structure and resources to support the studio in what is now a complex studio design environment.

THE EXPERIENCED AND STUDENT DESIGNER

Ahmed, Wallace and Blessing have described the differences between experienced and novice designers in engineering design in the aerospace industry [13]. 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 tended to be more aware of trade-offs in decision making, questioned data, did not need to gain an understanding of how things worked, 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.

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. While 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 the PDP is *Product Planning* where the market environment of the product is considered, 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 a 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 think about *product planning*. 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, the *product planning* phase and can articulate these to the student. But the student may not make the connections and has no real foundation of knowledge to summon. Therefore, the student designer can only benefit from structure and method.

The *task verification* 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, while 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. *Objectives trees* applied to design objectives can help to better understand the competing objectives and their relative importance. A *Pareto analysis* can clarify a variety of considerations.

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 options 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 *embodiment* 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 the evaluation of the design concept.

The student designer who has used a formal approach to the PDP and design methods may, during the progression from a novice designer to experienced, rely less and less on a structure and methods. Eventually, the student designer 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 here 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 more transparent the basis of design decision-making. The expertise associated with certain methodological approaches can lead to the designer attaining considerable expertise in focused areas. Examples of this are QFD, FMEA and design of experiments.

CONCLUSION

The literature reviewed showed that 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 is no unique right answer [2]. The student designer faces a paradox where he/she does not really understand what *design* is, but must embark upon it in order to gain experience. Hence, a situation exists where design, as viewed by the student, is an ill-defined process that addresses ill-defined problems. Little wonder, then, that 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 effectively utilises intuition that has been developed over time [13].

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

What is not fully appreciated by many teachers of industrial design is that the span of considerations dealt with by the student within the studio has widened significantly. These include not only complex technical tools, like CAD, rapid prototyping and modelling, but also factors associated with globalisation, such as cultural diversity, competition and marketing. The student is faced with a plethora of available information and the use of methods may assist to classify and synthesise the information.

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 [14]. 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 the utilisation of systematic techniques.

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BIOGRAPHIES

Lance Green is Director of postgraduate programmes in industrial design at the University of New South Wales, Sydney, Australia. From 1994 until 2000, he has supervised the undergraduate and postgraduate programmes in industrial design. In 2000, he relinquished supervision of the undergraduate programmes to focus on the postgraduate area.

Prior to his present role, he has occupied senior positions in Australian industry such as: General Manager of Poly Industries (product design and plastics manufacture); Technical Director at Plastic Processors (plastics and health-care manufacturing); Research & Development Manager, Baxter Healthcare (Aust) (R&D Healthcare Products); Divisional Engineer at Rheem (Aust) (product and process development for packaging group); and Technical Manager for Advance Industries (product and process development of plastics and packaging products).

Lance is a Chartered Engineer and holds a Bachelor degree from the New South Wales Institute of Technology, a Masters Degree in Design from the University of Technology, Sydney, and a Masters Degree in Higher Education from the University of New South Wales. He is a Fellow of the Design Institute of Australia and a Fellow of the Institution of Engineers, Australia.

Professor Elivio Bonollo is Pro Vice-Chancellor (promoting international relations) and Professor of Industrial Design at the University of Canberra (UC), and formerly Dean of the Faculty of Environmental Design (1997-1998) at the UC. He is also Director of the National Institute of Design, a collaborative design partnership between the UC and the Canberra Institute of Technology. He was Professor and foundation Director of the Centre for Industrial Design at Monash University (1989-1996), and before this Senior Lecturer in charge of Industrial Design at the then Royal Melbourne Institue of Technology (RMIT) (1979-1989). He is the principal author of the original industrial design degrees at RMIT and Monash University.

He is an active researcher and publisher in the field and currently the UC project leader for an AusIndustry $1M Collaborative R&D Start Grant with Caroma Industries in Sydney, Australia. This project is concerned with the design and development of water saving systems for water closets and related plumbing. His current overseas appointments include External Examiner in product design at Temasek Polytechnic, Singapore, and Visiting Professor in the Faculty of Engineering at Ubon Ratchathani University, Thailand.

Livio holds a Bachelor Degree in engineering, a Master of Engineering Science and a PhD from the University of Melbourne, Australia. He is a chartered engineer and a member of The Institution of Engineers, Australia and a Chartered Engineer and member of The Institution of Electrical Engineers, London, England, UK.