Design Models and Their Value in Education

PRN Childs*, JH Downie**, and T Katz**
* School of Engineering and IT, University of Sussex. ** School of Engineering, University of Brighton.

ABSTRACT

There are a number of models of the design process that are in relatively common use in education. Within industry the use of a unified design model seldom occurs and most companies and individual designers tend to develop their own although these often have common themes. The design educator faces the challenge of assisting students to develop their design skills and yet be employable within a range of industries. Methods used to achieve this aim often include the presentation of the more common design models. However when models are presented at the early stages of their education students have not usually yet attained the interdisciplinary skills demanded by the design process. This paper reviews the approaches adopted at two universities to address the issues of the complexities of design models in education and suggests some approaches to teaching design methodology, which are perceived by the students to be helpful and not simply yet other design constraints.

1. INTRODUCTION

There are a number of design models which are highly familiar to design educators including those of Pugh (1990), Pahl & Beitz (1988) and March (1976). The principal phases for two of these are illustrated in Figures 1 and 2 and for comparison the concurrent engineering model proposed by Chatwin (2001) is shown in Figure 3. The models shown in Figures 1 and 2 have been widely used in education.

Pahl & Beitz (1996) divide their model, see Figure 1, into four phases: (1) product planning and clarifying the task; (2) conceptual design; (3) embodiment design; (4) detail design. The approach acknowledges that because of the complex nature of modern technology it is now rarely possible for a single person to undertake the design and development of a major project on their own. Instead a large team is involved and this introduces the problems of organisation and communication within a larger network. The aim is to provide a comprehensive, consistent and clear approach to systematic design.

Noting that design is an activity, Pugh (1990, see also SEED 1985) used the term ‘Total Design’ to refer to the systematic activity necessary from the identification of a market need to the commercialisation of the product to satisfy the market need. Design is regarded as having a central core of activities, see Figure 2, consisting of the market potential, product specification,
conceptual design, detailed design, manufacture and marketing. Design is an activity and Total Design is a framework of increasing thoroughness introducing systematic design procedures. Pugh notes that unless a product is subject to the rigors of Total Design it is likely to fail.

Figure 1: The design process proposed by Pahl & Beitz (figure adapted from Pahl & Beitz (1996))
Prior to formal university education most students have already designed; informally with childhood toys, games, construction kits and more formally through such school projects as furniture, vehicles and toys. As such they have an intrinsic experiential based view. This experience can be exploited by helping students to declare and analyse their own design methodology: an approach adopted at the University of Brighton in the early months of the Product Design BSc. In this programme, developed with the help of both Visiting Design Professors and industrial advisors, rival methods are compared and discussed between groups and the limitations of their first design approaches usually becomes apparent. The problem here is to ensure that although students are immersed in the excitement of the task, they make the effort to evaluate their activity before attacking a subsequent assignment. At Brighton the design activity and formal design models are gradually 'revealed' and then reinforced throughout the course through project-based work. Product design specifications are the key to managing this activity. A good approach to cutting out the superfluous aspects is to undertake a full product design specification and then identify the non-critical inputs. This broadens the student’s perspective and helps to define the boundaries of the design space.
The aim is to develop an holistic design approach through application of the SOLO taxonomy (Moon (1999)). As the students develop, they can firstly identify a single “correct” process, then accept other design models as feasible. They next need to evaluate how these relate and finally choose and adapt appropriate models for new situations.

The strategy adopted at the University of Sussex for the teaching and learning of design is comprehensively based on Pugh’s Total Design model. This occurred following the development and subsequent adoption of a design learning policy that was worked out in conjunction with the University’s group of Visiting Professors in the Principles of Engineering Design. Pugh’s model is viewed within the curriculum as the main trunk of engineering purpose and the traditional engineering disciplines such as thermodynamics and mechanics are ‘subject’ to design and form part of the engineer’s toolbox. The adoption of the Total Design approach by students is encouraged by a design course in the first year including a case study on a hand held machine tool such as a cordless electrical screwdriver, router or chainsaw (see Childs and Simons (1999)). This is followed up in the second and third years by extensive design studies undertaken by the students and an introduction to the principles of concurrent engineering, Figure 3.

* Concurrent Engineering

- Definition of product need: Marketing information
- Conceptual design and evaluation, Research, Product Champions
- Design analysis; codes/standards review; physical and analytical models
- Prototype production; testing & evaluation
- Production drawings; Instruction manuals
- Material specification; process and equipment selection; safety review; environmental impact
- Pilot production
- Production
- Inspection and quality assurance
- Packaging; marketing; and sales literature
- Product Supply (JIT)

* Increasingly not a single organisation but a supply-chain facilitated by the Internet and e-commerce

- Design & Prototyping
  - Computer Aided: Design (CAD, ECAD); Engineering (CAE)
  - Design Plant & Processes
    - Computer Aided: Manufacture (CAM); Process Planning (CAPP)
  - Control of Operations
    - Computer Integrated Manufacture (CIM)

* R&D
* Research
* R & D

Figure 3: Concurrent engineering (figure courtesy of C Chatwin 2001)
2. MODEL STRENGTHS AND WEAKNESSES

The merits in the use of the standard design models are that they provide a framework within which students can work and undertake projects, and in this context their education can be managed. Students who do not know where to start can be guided by the strong messages of the need for market testing and detailed specification. The models also serve to reinforce the iterative process of design, where initial ideas are reworked or discarded in the development of a more robust solution.

A merit of Pugh’s model is that it is possible to cut out the superfluous design inputs. Of course this requires experience in order to identify which items are superfluous. Herein lies the quandary facing the educator. The experienced designer has the know-how and therefore does not necessarily need the explicit help of the model or methodology. The inexperienced designer does not have sufficient background skill to use the model effectively and is lumbered with a cumbersome exhaustive approach that can dishearten and wear down even the most enthusiastic. Some educational establishments will implicitly limit design to a formalised discipline.

However research on creative thinking is beginning to demonstrate that creativity involves the deployment of a large number of psychological abilities (see Section 3) and the place for systematic discipline is not clear. This calls into question how we introduce and use the models within education and also the validity of the models in the first place. There are however, countless counter-examples to illustrate the need for detailed disciplined design consideration and there are many designs where failure would be catastrophic and which illustrate the folly of merely relying upon intuitive design.

Design models and methodologies encourage us to undertake careful marketing and specification. Because of their sequential presentation, ‘design starts with a need’ or ‘design starts with an idea’, they inherently encourage us to undertake tasks sequentially. This is not necessarily the intention of the models and indeed this approach is countered within the descriptions and instructions given by the proponents of the model who instead encourage an iterative feedback working methodology. However design lecturers will ‘bang the drum’ of specification enforcing the rigorous undertaking of this task – some designers and students will just want to get on with the global design task.

A criticism of the Pahl & Beitz and Pugh design models is that they tend to be encyclopaedic with consideration of everything possible. As such, though, their use can be viewed as a checklist against which a personal model can be verified. A further criticism of design models is that they are too serialistic as opposed to holistic and that because of the serious manner in which the models are portrayed and documented they have the tendency to put the intuitive and impulsive designer off! One approach to challenge the primadonna or instinct-based solution to a design problem is to demand that a student or designer justify that their solution is the best possible. In other words as assessors we require persuasion that instinct based solutions are indeed the best and in these cases we could use the standard design models in checklist mode to evaluate the quality of the design.
Product design history is littered with successful and failed-product case studies. One example, the Lotus bike frame by Mike Burrows, was summed up by the designer by ‘it just looked right’. The process involved little calculation and lots of designer flare. The mechanical stress input on Pugh’s model was satisfied, not by detailed design calculations but by intuitive design. This approach is attractive to many students and practitioners as well as observers. Burrows observed however that the method worked for him for a cycle frame but would not work for an aircraft wing. Had design models been more widely adopted it is quite possible that they would have killed off a substantial number of innovative products. It is fair to say that the Pugh and Pahl & Beitz models have not been adopted or welcomed widely.

A further criticism is the tendency for each design discipline to adopt its own design model: electronic, architectural, mechanical, fashion, ceramics, furniture etc. There appears to be a design model for each sector of the product design spectrum. This suggests that an empirically based model refined for each discipline is more relevant and useful than a general model.

3. DISCUSSION

A common viewpoint reported by design educators is that we must learn to walk before we can run. Is this right? Toddlers after all run and stumble before they learn sufficient control to walk but we do not teach them the fundamentals of bipedal locomotion dynamics as a preparation. The educational metaphor of building strong foundations may be valid but in design especially, these foundations do not consist of independent ingredients. The human has the identifiable ability to design and scheme from about age two. Frequently, however, we do not do it very well. To qualify this further, sometimes the design is not to its full potential. As a result of our development each person has their own individual design model which they will use implicitly. Recognising this, the encyclopaedic models of Pugh and Pahl & Beitz can then be used in terms of their value as checklists and aids to reflection.

In some design activity we do the task and then reflect. Learning and development only takes place when the mind engages on the task. This approach fits the design model, but the external design model has not helped us do the design, so its benefit is chiefly as a focus for improvement.

In product design education we hope to provide development of fundamental skills and intentionally, come the final year, the individual flare of a student re-emerges and design models become implicit.

The use and acceptance of design models is a function of the approach adopted within a university. Are the lecturers unified and do they adopt and use a single model? This is unlikely and not wanted, if we wish students to develop beyond the level 1 of the SOLO taxonomy. Also, it is not the experience of the two universities represented in this article. The acceptance of specific design models per se is limited, with understanding of them possibly even more so. This may be an inevitable function of the staff utilised for design education, being sourced from existing academic disciplines, research staff and contract educators and the re-definition occurring in academic circles in responding to applicants’ demands.
The models do not naturally encourage or accept the ‘non-scientific’ inputs of personality, spirituality and ideology. If these inputs are ignored it will be to the detriment of the design process and their acceptance as important human factors is yet to be made. To some people their spirituality is the most important aspect of their life. Ignoring this affective domain also makes learning unbalanced and problematic (Katz (2000)), as engagement in learning is essentially an emotional affair. Technical disciplines at universities have historically focused almost exclusively on developing skills and knowledge, with critical thinking thrown in.

In the preface to Stuart Pugh’s text on Total Design he pointed out his aim to add to a designer’s understanding by introducing his Total Design model. However once a product is released, in this case Pugh’s design model, control over its use and meaning is usually lost. This is the case with Pugh’s model. How people view and use it now may be outside the scope originally envisaged by its originator. Furthermore it is surrounded now by competitive models clamouring for adoption.

The inherent difficulties experienced in the use of competing design models combined with the periodic emergence of new design methodologies adds richness to the domain and requires us to question the validity of existing models. Artists and scientists rarely know how their ideas actually arise. As educators we may claim that we aim to encourage creativity. ‘Creation’, the root of the word creativity, means to bring into being or form out of nothing. This is strictly impossible barring supernatural intervention. Redefinition of creativity in terms of mental processes and the production of new ideas causes new problems because there is no satisfactory definition for novelty (Boden (1992, 1994)). For example randomness can ‘create’ or ‘beget’ novelty.

Recognising that creativity is not a single ability or talent, any more than intelligence is, informs us that creativity is not confined to the chosen few. Our design methodologies must therefore not restrict design to only be undertaken by those who conform to certain hurdles or constraints. Current understanding of creativity is that it requires the deployment of a large number of psychological abilities such as noticing, remembering and recognising (Boden (1992)). Boden describes an understanding of creativity in terms of conceptual spaces. When maps are generated they describe an indefinite number of possibilities and constraints for connecting locations. Likewise in creativity, except that the maps in question are imaginary and cognitive, and are generative systems that guide thought and action in some paths but not in others. So design methodologies must exploit, encourage and allow this process to occur.

So do the Pahl & Beitz and Pugh models allow this? This is unknown. They do not stop creativity occurring and there are many examples where design has been carried out aided by the methodological processes encouraged. There is great strength in their use to ensure that the creativity is implemented as feasible products. However, the hunch eluded to here is that our understanding of the mental process, not just the product creation process, will be the driver in the development of design methodologies that allow us increasingly to exploit the creative process and therefore even better models will in due course emerge. The design lecturer and course designer would therefore be advised to add to their understanding of the mental process and the outcomes of psychological and artificial intelligence research and to integrate this understanding within their approach to design education.
4. CONCLUSIONS

It is evident that the universality of the design models developed by Pugh and Pahl & Beitz is not accepted. Whether the models should be introduced early or late within a degree is not obvious and either approach has been demonstrated to allow the personal development of product designers and engineers. Practice at one university has however clearly demonstrated the value of the models to calibrate or verify either an instinct-based solution or an individuals own design model.

Consideration of the outcome of research findings in psychology, and specifically understanding of the creative process, calls into question whether the design methodologies of Pugh and Pahl & Beitz are sufficiently developed. It is envisaged that as our understanding of mental processes of creativity advances then new design methodologies will emerge that allow us to exploit our creativity more fully. Also, the ability of students to develop their own flexible approach, having come to terms with a number of diverse models, is an important part of their cognitive, affective and professional development.

Finally a self-critical point – has the level of planning and organisation we demand of students following the standard design models been applied to our design of product design and engineering degrees? We suspect not and indeed quirks and inadequacies are very obvious in most academic programmes; these can invariably be identified as originating from poor or non-existent specification and lack of control. Perhaps we all apply our own implicit models with less rigour than is warranted!

REFERENCES

(3) Chatwin, C. Personal communication, University of Sussex, 2001.