Philosophy of design: a meta-theoretical structure for design theory

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This paper focuses on the structure and dynamic of theory in design research. Problems with existing theory are explored, and a new meta-theoretical method is suggested for assisting the critical analysis, comparison and formulation of design theories and concepts. This meta-theoretical method contributes to building a simplifying paradigm of design research by providing a means to clarify the existing state of design theory in the field, to assist with the establishment of coherence and compatibility between concepts in disparate theories, to validate theory and concepts, and to uncover 'hidden' aspects of design theories.

Keywords: philosophy of design, design theory, epistemology, ontology, design philosophy

This paper is a contribution to the study of Philosophy of Design. In it, a critical overview is taken of the structure and dynamic of design theory. This overview leads to a method to assist with the critical analysis of design theories and their associated concepts. If we consider 'design theory' as an artefact to be designed, this paper's role is in the part of the design process often called 'problem analysis'. Underpinning what is presented in this paper is an assumption that the act of designing by human agents is central to the academic study of design. This theoretical standpoint, that what is described as design always implicates humans, together with the understanding that any theories, theorising or theory interpretation has meaning only in a human context, is the basis for the analyses presented below.

Philosophy of Design is different from *design philosophy*. It is the disciplinary equivalent of Philosophy of Science, or Philosophy of Technology—whereas design philosophy is associated more with the philosophical study of design method. Appropriate questions in Philosophy of Design are, for example; 'What, in general, is design?', or 'What are the

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0142-694X/00 $ - see front matter *Design Studies* **21** (2000) 293–313
PII: S0142-694X(99)00012-5

characteristics of a valid theory of design?', or 'What are the characteristics of a theory of objects being designed?', or perhaps, 'How might a theoretical design concept be tested for coherency with other concepts?', or even 'Should a theory of objects be part of design theory?'.

The term *design philosophy* has also been used to describe the study of such questions. The historically intimate connections between design philosophy and the study of design methods[1,2] has, however, limited the scope within which philosophical issues relating to design have been considered[3]. Design Philosophy is not, therefore, a suitable title for the philosophical study of all aspects of design theory because theories related to design, and the concepts associated with them, cover a wider range of issues than the methods, methodologies and techniques of design. The term, *Philosophy of Design* is used in this paper to describe this wider philosophical inquiry.

In alignment with this philosophical perspective, the capitalised *Design Theory* is used here to refer to the sub-discipline in which the role, validity, coherence and utility of theories and concepts pertaining to design are researched. In this respect, Design Theory encompasses several other sub-disciplines such as; Design Science, Science of Design, Design History, Design Methods, Design Methodology. This is contrary to views expressed elsewhere[4–7] that *design science* (or the *science of design*) completely encompasses design theory and the theory of technical objects, for example, in Hubka and Eder's[8] comprehensive development of a theory of technical systems. From the above human-based position on design theory, the scientific viewpoint is but one paradigmic perspective within which theorising about design may occur. Theorising about design goes beyond the paradigms within which design is practised, and beyond those theoretical outlooks by which its practice is researched, for example:

- Coyne and his associates[3,9–13] have written extensively on the application of a variety of post-positivist outlooks to design research.
- Sargent[14] proposed a meta-theoretical argument that there cannot be a unifying design science because there appears to be an incommensurability of viewpoints in design research
- Broadbent[15] discussed theory building in the study of design
- Thomas and Carroll[16] explored how design might be best conceived of in terms of an individual's psychological perspective
- Daley[17] analysed the role of objects in theories of creativity
- Dilnot[18] investigated the limitations of definitions of design that excluded its social context
- Liddament[19] drew attention to the limitations that computationalist per-

1 **Cross, N** 'Science and design methodology' *Research in Engineering Design* Vol 5 (1993) pp 63–69
2 **Cross, N** (ed) *Developments in Design Methodology* John Wiley, UK (1984)
3 **Coyne, R and Snodgrass, A B** *Problem Setting within Prevalent Metaphors of Design—Working Report* Faculty of Architecture, University of Sydney, Sydney (1992)
4 **Simon, H A** *The Sciences of the Artificial* 2nd edn, MIT Press, Cambridge, Ma (1984)
5 **Suh, N P** *The Principles of Design* Oxford University Press, New York (1990)
6 **Altschuller, G S** *Creativity as an exact science* Gordon and Breach Science Publishers, London (1984)
7 **Dixon, J R** 'On a research methodology towards a scientific theory of design' in **S L Newsome, W R Spillers and S Finger** (eds) *Design Theory '88*, Springer-Verlag, Berlin (1988)
8 **Hubka, V and Eder, W E** *Theory of Technical Systems* Springer-Verlag, Berlin (1988)
9 **Coyne, R D** 'Objectivity and the design process environment and planning B' *Planning and Design* Vol 19 (1990) pp 361–371
10 **Coyne, R D and Yokozawa, M** 'Computer assistance in designing from precedent' *Environment and Planning B: Planning and Design* Vol 19 (1992) pp 143–171
11 **Newton, S and Coyne, R D** 'Impact of connectionist systems on design' *Knowledge Based Systems* Vol 5 No 1 (1992) pp 66–81
12 **Coyne, R D, Snodgrass, A and Martin, D** *Metaphors in the design studio—Working Report* Faculty of Architecture, University of Sydney, Sydney (1992)
13 **Coyne, R D and Snodgrass, A** 'Is designing mysterious? Challenging the dual knowledge thesis' *Design Studies* Vol 12 No 3 (1991) pp 124–131
14 **Sargent, P** 'Design science or nonscience' *Design Studies* Vol 15 No 4 (1994) pp 389–402
15 **Broadbent, G** 'Design and Theory Building' in **N Cross** (ed) *Developments in Design Methodology*, John Wiley, UK (1984)
16 **Thomas, J C and Carroll, J M** 'The psychological study of design' *Design Studies* Vol 1 No 1 (1979) pp 5–11

spectives place on the development of design theory, particularly in terms of ontology, epistemology and methodology

- Galle[20] explored how the definition of 'designing' is influenced by the inclusion of human design agents into its explanation (and helpfully clarified the language of 'brief', 'representation' and 'artefact')
- Oxman[21] created a new perspective on design education by focusing on the dialectic nature of designing, the associated theories of cognition and the epistemology of knowledge structures

All aspects of research into design involve conceptual abstraction and symbolic representation. In each of the above examples, the theoretical abstractions of Design Science and other paradigms of design research are subject to scrutiny, and, therefore must lie at a lower level of theoretical abstraction than the analyses of them. In terms of sub-disciplinary structure, this overarching role of Design Theory implies that it should be viewed as being higher up the sub-disciplinary 'tree' of Design Research. Abstractions and representations are fundamentally grounded in human values[22–28], whether based on paradigmic assumptions[25,26,29], metaphors[6,9,10], or reified conceptual frameworks[30], and form part and parcel of theory-making about design[31]. Taking a human-centred perspective on design research, therefore, also implies that Design Theory subsumes most, if not all, sub-disciplines associated with the study of design (theoretically, at least).

1 *Confusion, conflation and multiplicity in Design Theory*

The development of theories of design research has occurred in a piecemeal fashion, and four serious criticisms may be made:

- That there exists a substantial amount of *confusion* with respect to the underlying basis of many theories, concepts and methods.
- That in developing and validating theoretical aspects of the study of design, many writers are unjustifiably *conflating* concepts drawn from a range of sources.
- That there exists an unnecessary *multiplicity* of design theories and concepts.
- That the terminology of design research has become unnecessarily and unhelpfully confused and imprecise by dint of the above points

In 1992, I attempted to collect together a glossary of the main theoretical terms of the design research literature[32], and found that it was an almost impossible task to do justice to the different variants of major terms: there are almost as many different definitions of *design* and *design process* as there are writers about design. Since the earliest attempts at formulating theories of design there have been many arguments between proponents

17 **Daley, J** 'Design creativity and the understanding of objects' *Design Studies* Vol 3 No 3 (1982) pp 133–137

18 **Dilnot, C** 'Design as a socially significant activity: an introduction' *Design Studies* Vol 3 No 3 (1982) pp 139–146

19 **Liddament, T** 'The computationalist paradigm in design research' *Design Studies* Vol 20 No 1 (1999) pp 41–56

20 **Galle, P** 'Design as intentional action: a conceptual analysis' *Design Studies* Vol 20 No 1 (1999) pp 57–82

21 **Oxman, R** 'Educating the designerly thinker' *Design Studies* Vol 20 No 2 (1999) pp 105–122

22 **Dewey, J** *How we think: a restatement of the relation of reflective thinking to the educative process* D.C. Heath and Company, New York (1933)

23 **Dewey, J** *Art and Experience* Capricorn Books (1959)

24 **Feyerabend, P** *Against Method* New Left Books, London (1975)

25 **Kuhn, T S** *The Structure of Scientific Revolutions* Chicago Press, Chicago (1962)

26 **Guba, E G** 'The Alternative Paradigm Dialog' in **E G Guba** (ed) *The Paradigm Dialog*, Sage Publications, London, (1990) pp 17–27

27 **Lincoln, Y** 'The Making of a Constructivist' in **E Guba** (ed) *The Paradigm Dialog*, Sage Publications Inc., California (1990)

28 **Kitchener, K S and Brenner, H G** 'Wisdom and Reflective Judgement: knowing in the face of uncertainty' in **J R Sternberg** (ed) *Wisdom: its Nature, Origins and Development*, Cambridge University Press, Cambridge, (1990) pp 212–229

29 **Smith, J K** 'Alternative research paradigms and the problems of criteria' in **E G Guba** (ed) *The Paradigm Dialog*, Sage Publications, London, (1990) pp 167–187

30 **Nideau, R L** *Mind, Machines and Human Consciousness* Contemporary Books, Chicago (1991)

31 **Stegmüller, W** *The Structure and Dynamics of Theories* Springer-Verlag, New York (1976)

32 **Love, T** *Social, Environmental and Ethical Factors in Engineering Design Theory: a Post positivist Approach* Praxis Education, Perth, Western Australia (1998)

of different concepts and theories in which reconciliation happens by the proponents realising that they were using the same words or concepts differently. Several researchers have pointed to the problem that few of the definitions of terms associated with design research have been explicated satisfactorily, for example:

- Ullman[33] claimed that 'As research results have been published, it has become obvious that the term "design" has different meanings to different researchers... the field lacks a commonly accepted description of design methods, types and theories'.
- Pugh[34] considered the study of the activities, philosophies, processes and products of design to be confused.
- Roozenburg[35] pointed to the philosophical terminological and conceptual confusion surrounding the abduction–deduction–induction aspects of innovative design thinking.
- Eder[36] reported that a workshop aimed at developing a glossary of words and concepts relating to the science of engineering design found problems where the same words were used with different concrete meanings, at different levels of abstraction, and where their meanings were dependent upon cultural context.
- Hubka and Eder[8] noted the difficulty of clarifying definitions when creating novel theory.
- Parnas and Clements[37] argued that, in software design, precise definitions are often not provided, and that 'there are many terms used for the same concept and many similar but distinct concepts described by the same term'.
- Talukdar, Rehg and Elfes[38] claimed that neither practitioners nor researchers agree on what constitutes design activity. They noted that Finger, Director of the Design Theory and Methodology program of the US National Science Foundation, asked design researchers for their definitions of design activity and received twelve different classes of answer.
- French[39] commented that there are as many ways of producing block diagrams of design process as there are of 'tribal lays'.

In 1984, Cross[2] identified four overlapping themes which also represent the chronological development of research into design:

(1) The management of the design process
(2) The Structure of Design Problems.
(3) The nature of Design Activities
(4) 'Reflection' on the fundamental concepts of design

Two other themes that can be added to Cross' list are:

33 **Ullman, D G** 'A taxonomy for mechanical design' *Research in Engineering Design* Vol 3 (1992) pp 179–189

34 **Pugh, S** 'Engineering design—unscrambling the research issues' *Research in Engineering Design* Vol 1 No 1 (1990) pp 65–72

35 **Roozenburg, N** 'On the Logic of Innovative Design' in **N Cross, K Dorst and N Roozenburg** (eds) *Research into Design thinking*, Delft University Press, The Netherlands (1992)

36 **Eder, W E** 'Report on workshop W3' in **V Hubka and W E Eder** (eds) *Schriftenreihe WDK 7 Results of ICED 81 (Rome)*, Heurista, Zurich (1981)

37 **Parnas, D L and Clements, P C** 'A rational design process: how and why to fake it' *IEEE Transactions on Software Engineering* Vol SE-12 No 2 (1986) pp 251–257

38 **Talukdar, S, Rehg, J and Elfes, A** 'Descriptive Models for Design Projects' in **J S Gero** (ed) *Artificial Intelligence in Engineering Design*, Computational Mechanics Publications, Avon, UK, (1988)

39 **French, M J** *Conceptual Design for Engineers* 2nd edn, Design Council, London (1985)

(1) Knowledge about the environment in which designing takes place
(2) The knowledge needed for designing, i.e. knowledge about objects and design processes (Hubka and Eder[40])

Together, these themes can be viewed as different paradigms under which design researchers have investigated design activities, and proposed theories and models to represent them. In 1993, Cross[1] reported on theoretical developments over the ten years since his earlier review. This later review implies that a sequential Kuhnian-style development of different sub-paradigms of design theory, in which the same terms and concepts have been used differently, has become the concurrent development of theory across all paradigms. This would provide one explanation for both terminological and conflationary confusion in the field.

Dixon[7] confronted the confusion in design theory by regarding all design research as being in a *pre-theory* stage. He suggested, from a positivist scientistic position, that, as a matter of urgency, attempts are made to establish scientifically testable theories of design. Dixon's outlook on the establishment of theories of design may be subject to challenge by postpositivist academics (for example, Berger and Luckman[41], Coyne[9], Coyne and Snodgrass[3], Coyne Snodgrass and Martin[12] and Margolis[42]), but his analysis of the potentially impossible difficulties in establishing a general theory of design and his critique of attempts made so far, were valid from either a positivist or post-positivist perspective.

It is difficult to prove that it is commonplace for theoretical aspects of the study of designing to be supported by conflating concepts inappropriately. It is perhaps more fruitful to indicate how conflation may lead to the development of erroneous threads of theory or to faulty conclusions. The simplest case of conflation follows the sequence:

'A is related to B' and 'B is related to C' therefore 'A is related to C'

The validity of such an inference requires the correct identification and use of the characteristics of the abstract entities (in this case A, B and C) and their relationships. A popular example of inappropriate conflation is that of cat and dog equivalence:

'A cat has four legs' and 'a dog has four legs' therefore 'a cat is a dog'

The construction of theory in the study of design sometimes brings forth similar problems with conflation, for example,

'Designers think' and 'cognitive psychologists study thinking', therefore, 'research into design lies within the discipline of Cognitive Psychology'

40 **Hubka, V and Eder, W** 'Design knowledge: theory in support of practice' *Journal of Engineering Design* Vol 1 (1990) pp 97–108

41 **Berger, P and Luckman, T** *The Social Construction of Reality* Penguin Books, England (1987)

42 **Margolis, J** 'The Technological Self' in **E F Byrne and J C Pitt** (eds) *Technological Transformation: Contextual and Conceptual Implications*, Kluwer Academic Publishers, Netherlands (1989) pp 1–16

The issue of conflation is not simply a matter that the logic which has been used is faulty. It is that two or more ideas have a similarity in some of their aspects which encourages their unjustified co-association and improper conflation into some larger conceptual whole. This combined conceptualisation may then, in its turn, be used as a faulty basis for the formulation of further theory, or to draw incorrect conclusions from. Whilst such obviously muddled thinking is fortunately rare, the study of design and its associated theory is conceptually challenging, and in theoretically difficult situations unjustified conflation can easily go unnoticed by both author and critic alike.

Since the 1950s, the volume of design research literature has increased from a handful of books in the 60s to the current level of several hundred books, articles and conference papers written each year. When Cross[1] identified the four sequential themes in design research mentioned earlier, he suggested that the development of each was necessitated by the failure of its predecessor. The increase in the literature has resulted in the number of theories and concepts in design. This high level of multiplicity of concepts and theories in design research has several aspects:

- Theories are speculatively proposed
- Theories are generated from within a wide variety of paradigms.
- Theories and theoretical developments are not subjected to sufficient critical epistemological and ontological attention.
- There is little agreement on the most fundamental aspects of theory, for example, 'What *is* meant by *design*?'
- Some useful theories that would help with the integration of Design Theory are ignored, partly because they are 'not invented here', or perhaps because they lie outside what is seen as the province of the study of design.

This problem of unbridled abstraction, and its associated language needs, threatens to overwhelm design research, and the protocols of academic research add to the problem. Whilst developing their own theories, contemporary design researchers are supporting their work by analysing the work of earlier theorists, each of whom has been trying to provide theories of and about design, or critique the theories of those before them. The next generation of theorists will in their turn be attempting to provide overviews of and theories about current work. This continuous production of new abstractions by each new generation of design researchers, and the requirement for terminology that differentiates each new abstraction from earlier ones, appears to be never ending. The Indian literature of the Vedas provides a parallel to this situation in describing how the earth is supported:

'...on elephants, and they are supported on more elephants, and they on other elephants. Elephants on elephants for ever....'

This is *temporally*-based conceptual development, in which new concepts and new terms are needed as time goes by to describe patterns in the theories of previous generations. What is needed is some means of structuring existing concepts and theories to bound the unnecessary growth in abstractions and terminology so that it is clearer to design researchers which concepts, theories and theoretical strands are pragmatically more useful or better justified, and what their relationships are to each other. This is an important step in any move toward the development of the 'simplifying paradigm of design research' that Cross[43] has identified as important for the field.

The meta-theoretical method proposed in his paper is intended to hasten this process. The method provides a bounded structure for the development of theories that reduces the need for new language and new concepts to explicate the work of previous theorists. This simplification provides an underlying structure that enables the main focus of conceptualisation to be directed towards theorising about the activity of designing, the knowledge needed, the tools used, the information available, the management of the process, the environment, and the specifications of products being developed.

2 *Critical analysis and design theory*

Critical analysis provides the basic tools for clarifying design theory because its purpose is the clarification of relationships between individual concepts and theories, and between these individual concepts and theories and their underlying assumptions. Critically analysing the concepts and theories associated with design is not easy, however. In some cases, the researcher finds that an author has defined a concept to have a particular meaning, and then used it later in the same text with a subtly different meaning. In other cases, authors confuse metaphoric meaning and literal meaning of terms. In another case still, a term may have been applied simultaneously to different concepts, processes or activities. In many texts these problems are compounded by confusion about the epistemological relationships between proposed ideas, and existing concepts and theories. For example, it is clear that the study of the geometric properties of a particular element of a design, such as a crankshaft, is different from trying to understand the cognitive mechanisms by which a designer chooses such a shaft. Confusion arises in the literature, however, because the same words and similar concepts are used in theoretically different circumstances. The following not untypical sentence illustrates how ill-defined an apparently coherent phrase may be:

43 **Cross, N** 'Research in design thinking' in **N Cross, K Dorst and N Roozenburg** (eds) *Research in Design Thinking*, Delft University Press, Delft (1992) pp 3–10

'The design of the shaft depended on the decision making processes used by the designer.'

To be clear about the meaning of the sentence as a whole requires correct understanding of the potential meaning of each element in that sentence. This is not straightforward. For example, in the case of 'decision making processes':

- 'Decision making processes' may refer to decisions based on basic models of shaft behaviour, for example: models of force, stress or dynamics
- 'Decision making processes' may alternatively mean that the design is defined by the results of higher order methods which use the output of, for example stress behaviour, to optimise shaft geometry
- Or, perhaps, it is the designer's *internal cognitive* decision making processes that are being referred to
- Perhaps 'decision making processes' refers to a process based on a wider internal perspective (or world view) of the designer that includes their personal habits, values, beliefs about the world, the effects of the designer's environment, etc.

In the case of 'the design of the shaft':

- 'The design of the shaft' may mean the activity of designing the shaft
- 'The design of the shaft' may refer to an engineering drawing of the shaft (or some other communication or representation)
- Perhaps 'the design of the shaft' refers to an actual shaft

By taking combinations of the possible meanings of each of the above two phrases in the above sentence it is possible to see how easily confusion is brought into any discussion about designing, and how difficult it is, at present, to clearly and unambiguously critically analyse even small amounts of design literature. The meta-theoretical method proposed in this paper provides a means of resolving such conceptual tangles.

The semantic and conceptual confusion in design research is compounded by theoretical constructs at different levels of abstraction having many similarities. There are several reasons that may be advanced to explain this. From a Kuhnian perspective, researchers (often with little experience of designing products) have a restricted range of conceptual tools, which when applied to research into design at *any* level of abstraction produces similar sorts of analyses. This is clearly true when a systems approach is applied. Both designing and researching are human activities that are undertaken within particular cultural and environmental ecologies which is likely to result in a uniformity of conceptualisation and language. This

argument is supported by existence, in the areas of History of Technology and Design History, of research into the culturally based reasoning behind the development of particular artefacts or technologies (see, for example, Margolin[44]).

Popper[45] addressed the problem of theoretical confusion and validation with his analysis of the relationships between the following three worlds:

- World 1—Physical and material objects
- World 2—The subjective world containing minds and their contents
- World 3—The objective world of theories, knowledge and problems

He argued that confusion arises when concepts from different worlds are conflated, and that it is better to regard the analyses of each world as incommensurate. Phillips[46] discussed Popper's three world concept with reference to research into educating native speakers of English to speak Russian. He asked how a pedagogical theorist could validate a particular *theory* of language learning by testing a student. It is clear that the *linguistic skills* and *learning skills* of a student could be tested by observing them answer, in Russian, questions which are competently phrased in Russian. The internal subjective workings of the students mind, however, cannot be proven by these observations, and, more importantly, the information does not indicate the workings of the learning *theory* in question. If the researcher asked for *subjective* details from the student it is not obvious how the researcher could prove them or use them to validate theoretical aspects of the learning theory. For example, how could the researcher prove that the student was actually conversing in Russian rather than using two acts of translation and thinking in English? Phillip's example illustrates at least one of the problems facing design theorists who are attempting to formulate well justified theory about the internal creative processes of designers. (The reviewers of this paper have commented that this argument is somewhat similar a position taken by Klaus[47] on the relationships between 'theory', 'method' and 'object'.) Clearly, any theories about designing must comport well with our material and subjective worlds, but the real test of theories lies in their validation and coherency with respect to other well supported theories that are drawn, not only from the field of design, but from the widest range of relevant theoretical constructs across all disciplines. The proposed meta-theoretical method below provides a theoretical structure for validating design theories and concepts in this manner.

44 **Margolin, V** 'Design history or design studies: subject matter and methods' *Design Studies* Vol 13 No 2 (1992) pp 104–116
45 **Popper, K** *Unended Quest* Open Court, Illinois (1976)
46 **Phillips, D C** *Philosophy, Science and Social Inquiry* Pergamon Press, Oxford, UK (1989)
47 **Klaus, G** *Kybernetik in Philosophischer Sicht* 4th edn, Deitz-Verlag, Berlin (1965)

3 *Meta-theoretical analysis*

Theories, concepts, assumptions and human values are studied and analysed as *theoretical abstractions*. They are World 3 entities in Popper's

terminology. Although the practice of studying, generating, using and criticising such abstractions is not commonplace in the contemporary disciplines of science and technology, such epistemological and ontological analysis is widely used in other disciplines and dates back to the earliest Greek philosophers. Whilst not at the forefront of academic consciousness, the structuring of abstractions is a basic tool in most disciplines. It can be seen perhaps most clearly in Mathematics—where theorems depend on axioms (both abstractions), and in Philosophy—especially in the field of Logic which is concerned with the manipulation of abstract entities and the verification of logical relationships between them.

Disciplines that involve practical human action, particularly the Social Sciences such as, Anthropology, Ethnography and Sociology, have a significant focus on the epistemological and ontological analysis of their theoretical abstractions because their theoretical foundations are not amenable to Cartesian validation. This lack of Cartesian validation means that the development of empirical research programs requires a critical identification of the assumptions and implications of abstractions reaching back to an understanding of the ontological and epistemological bases of such research The development of Grounded Theory by Glaser and Strauss[48] and its methods of validation are a typical case. A human-based perspective on design research implies that it should be viewed in the same light as these other disciplines that involve research into human action and, in consequence, needs a similar level of attention to epistemological and ontological issues relating to theories involving humans in design.

There are many different means by which similar attention to epistemological and ontological clarity could be brought to design research, and some are more appropriate than others. In this paper, a meta-theoretical approach is used because it is just post-positivist and aligns well with Science and with a constructivist approach to human knowing. The approach is *meta*-theoretical because the analysis of a particular set of theories can only be done at a higher level of abstraction, and because concepts and theories exist in meta-level relationships to each other. The basis of meta-theoretical analysis is that it provides a means to analyse, relate, position and validate concepts and theories that are in and from different theories and theoretical stances.

3.1 *Metaphors of design as meta-level abstractions*

It is not just the 'hard' theories of engineering design that are abstractions in the sense used above. It applies to metaphors and other mental constructs also. Metaphors are used to describe phenomena or patterns of mental constructs as if they were something else—something more familiar—and may be used consciously or unconsciously. This is relevant to design research

48 **Glaser, B G and Strauss, A L** *The Discovery of Grounded Theory: Strategies for Qualitative Research* Aldine, Chicago (1973)

because attempts to describe the process of design have been generally metaphoric in nature, and this is especially true of general theories of design. These metaphors are useful in that they enable the grouping of concepts at lower levels of abstraction into memorable patterns. Such groupings or meta-abstractions allow us to place concepts relative to each other, describe relationships between them and fit new concepts into an overall theory. Each metaphor, however, is both limited in its scope and limiting for its users. Whilst metaphors provide a basis for checking the internal consistency of a grouping of concepts they also exclude other ways of describing and analysing phenomena and are limited by them not being literal descriptions. This in turn may cause difficulties in including new insights and information. Coyne and Snodgrass[3] used this metaphoric view of design to discuss the limitations of the overarching metaphors of design process in how design problems are formed and addressed. A lack of clarity about abstractions, meta-abstractions and metaphors along with an unconscious use of metaphors or meta-abstractions of design is likely to result in semantic difficulties and theoretical confusion.

3.2 *The use of meta-theoretical analysis*

Abstractions are closely tied to human assumptions (which in their turn, are also abstractions) about how the world is. Every theory or concept is dependent upon a variety of other abstractions at different levels of abstraction than itself, and for its validity it must be seen to be coherent with them. Abstractions relating to any situation lie in a meta-theoretical spectrum in which the lowest level of this spectrum refers to the sensual 'concrete' world as experienced through our senses, and the most abstract higher levels refer to the ontological world of assumptions about reality, personal values and value systems. In between lie all other abstractions, each grounded in human experience and conceived on the basis of our ontological assumptions about existence.

To give an example of this hierarchy, consider the concept of *stress* as an abstraction in engineering mechanics. Contrary to the beliefs of many engineers, stress does not exist as a physically perceivable phenomena (except, perhaps, mental or psychological stress!). It is a theoretical abstraction depending for its meaning on the lower level abstractions of force and area. Usually *stress* is defined as the *force* transmitted per unit *area*. The abstractions *force* and *area* in their turn depend for their meanings on our more concrete conceptualisation of our observations of the movements of physical objects.

The metaphor or paradigm within which we can conceive mechanical stress also, however, depends upon the human values espoused in higher level abstractions about existence such as:

- Assumptions about the consistency of the universe
- Assumptions that the world can be mathematically modelled
- Reliabilistic beliefs about the constancy of the world and our perceptions of it (see for example Levin[49])
- A religious belief system which allows us to make such models without fear of divine retribution.

The abstraction 'stress', therefore, lies in a hierarchy of abstractions. It depends upon both lower and higher level abstractions. It not only depends upon these other abstractions and its coherency with them for its meaning but it is validated (or not) by them.

To summarise, theories and concepts are abstractions (Popper's World 3 entities). These abstractions lie within a co-dependent hierarchy. At the lowest level of abstraction is the direct perception of reality, where information is available to each individual through their perceptive senses. The highest level of abstraction is concerned with the beliefs and values associated with fundamental issues of existence. Between direct perceptions of 'reality' and beliefs about 'what is fundamental about existence' we have the everyday abstractions which are the stock in trade of communication, reflection and theorising in such diverse occupations as journalists, artists, scientists, technologists and academics.

4 A meta-theoretical structure for Design Theory

One simple solution to problems of confusion and conflation of the concepts, theories and terminology in design research is to take a meta-theoretical perspective, use a critical framework for analysis, and create a structure that enables elements of different theories and concepts to be located relative to each other. The most obviously useful method is to use a meta-theoretical structure based on levels of abstraction because it offers a means of classification that is hierarchical and relatively independent of the domain-based meanings associated with each theoretical element. This method provides a straightforward means of clarifying and externalising many of the hidden dependencies between abstractions in Design Theory.

The meta-theoretical taxonomy proposed below also offers an opportunity for using rationalist methods to inspect and critique the theoretical frameworks that research is undertaken within, and to explore the bounds that particular individual and culturally formed realities place upon theory-making. In this meta-theoretical taxonomy, the levels of abstraction or meta-theory are based on a hierarchical form. The lowest level of abstraction refers to an individual's direct, sensual interaction with the world. The highest level is concerned with human values, assumptions about existence

49 **Levin, M** *Reliabilism and induction, Synthese* Vol 97 No 3 (1993) pp 297–334

and the implications of those assumptions. Thus the taxonomy ranges from 'our perception of reality' to our questioning 'What is reality?'.

It is emphasised that although this taxonomy was developed as a basis for categorising different theoretical abstractions about designing, the focus is not on the *content* of the abstractions or theories. This is a taxonomy of abstractions and theories in terms of their theoretical *behaviour*, that is a study of *theory qua theory*. The relationships which are important in this taxonomy are those of theoretical and conceptual definition, and necessary assumption. To give an example, the meta-theoretical level of 'Theories relating to mechanisms of choice' is concerned with choices about particular theoretical elements that each have particular behaviours. At root, the description of these elements and their behaviours depends on empirical experience (level 1). These theories about choice also depend (however unconsciously to users and theorists) on various privileged assumptions at higher orders of abstraction, such as assumptions, and presumptions about design method and process, or even more abstractly, about what designing is, or more abstractly still, about what the world is.

4.1 *Meta-theoretical structure for classifying abstractions of design theory*

Each level in the following hierarchy contains: the number and name of the abstraction level, a short description and illustrations or examples.

(1) *Direct perception of realities*—This is the level at which we 'sit on chairs', 'watch sunsets', 'hear the sound of a bird'...—*'The woodworker feels the movement of the hammer as the nail is driven.'*

(2) *Description of Objects*—The level that encompasses simple descriptions of objects, processes and systems—*'a vacuum cleaner', 'a car body', 'a groyne', 'a typeface', 'a database'… 'The woodworker uses a "claw hammer" rather than a "chisel".'*

(3) *Behaviour of Elements*—The level at which the behaviour of elements which may be incorporated into objects, processes and systems is described. *For example, 'a camshaft rotates at 600 rads/sec', 'headline type needs to be set closer than body text', 'the lower windows need to offset the visual weight of the portico', 'the melody returns to the tonic'. 'The hammer is made up of two parts; a head and a handle… The correct angle between the handle and the face of the hammer head is necessary for nails to be hammered in straight.'*

(4) *Mechanisms of Choice*—The level of descriptions about the way that choices are made between different objects, processes, or systems, and how solutions are evaluated. *For example, 'Why does a woodworker choose a claw hammer rather than a sledge hammer for hammering a small nail?'*

(5) *Design Methods*—The level in which theories about and proposals for design methods and techniques are described—*The theories about designing wood artefacts. 'How does one design a chair?'*

(6) *Design Process Structure*—The level that includes the theories about the underlying structure of design process, and the influences of domain, culture, artefact type and other similar attributes and circumstances. *For example, 'What are the processes underlying the design of Polynesian catamarans?'*

(7) *Theories about the Internal Processes of Designers and Collaboration*—This level includes the descriptions of theories about the reasoning and cognition of individual designers, of negotiated design in collaborative design teams, and of cultural design effects on designers' output. *For example, 'How did Mackintosh design furniture?' 'What communication is necessary between the different designers of timber framed housing?'*

(8) *General Design Theories*—This is the level that is concerned with the details of those general theories which seek to describe the whole activity of designing and its relationship to the objects involved. *For example, 'The activity of designing a boat, or a turbine, or a comic strip can be described as follows....'*

(9) *Epistemology of Design Theory and the Theories of Objects*—This is the level that contains those analyses and discussions about the critical study of the nature, grounds, limits and criteria or validity of design knowledge—*'What is a theory of design?', 'What does it include and exclude?', 'On what assumptions is this theory based?'*

(10) *Ontology of Design*—The philosophical study of the ontological basis for design theory and the activity of designing. It is at this level where human values, and the values and fundamental assumptions of researchers, are included in critiques of theory. *For example, 'Which human values and assumptions effect the design of new legislation for narcotics?', 'Are the methods of evaluation used to choose between different design alternatives consistent with the ethical proscriptions of the relevant professional bodies?', 'What is reality?', 'What is existence?'.*

The above taxonomy has been structured hierarchically in a manner which separates different groups of abstractions, as found in the literature on design research, into a dependent sequence. Abstractions in levels 2–10 provide theories and patterns of concepts at lower levels. Abstractions in levels 1–9 of the taxonomy are based on assumptions drawn from following levels. Abstractions at higher levels provide assumptions for preceding levels. Clearly there is much interaction between research and theory generation done at each level of abstraction and other levels. Where new con-

cepts are proposed at any level, appropriate language is needed to separate its concepts from that of other levels of abstraction.

At first glance,

- Levels 2 and 3 relate to objects
- Levels 4–7 relate to design process
- Levels 8–10 relate to philosophical matters

On this basis it may be argued that the theory categories relating to objects (levels 2 and 3) and the theory categories relating to design process (levels 4–7) form two parallel but co-ordinated streams. This may be a useful identification of the foci of research effort, but in terms of theoretical relationships between abstractions the matter is different. Theories relating to *design process* apply to other *less abstract elements or entities* and their *behaviour*. It is levels 2 and 3 that contain the descriptions and details of behaviour of these entities, and hence, in terms of abstraction, there is a hierarchical dependence between levels 4–7 and 2–3. It is irrelevant that some of these level 2 and 3 entities or elements, particularly the non-physical ones, are difficult to conceive, or in human terms 'very abstract' because it is matters of theory structure and dynamics which are being addressed rather than cognitive difficulty.

The elementary verbal or literal 'descriptive tokens' of level 2 do not necessarily refer only to the physical. Complex theoretical abstractions may also be tokenised similarly; for example, different logic chip architectures may be given descriptive tokens and dealt with as abstractions in a similar manner to more physical phenomena. This tokenisation also applies to elements of design theories. This is as it should be, because meta-theoretical analysis is applicable to any abstraction or abstraction structure where the focus of the study is on theory-making qua theory-making.

In the above meta-theoretical structure, different sub-disciplines or fields of design research have a different balance of activity at each level. For example, the main theoretical abstractions relating to Engineering and Graphic Art, might well occupy predominantly different niches, or have different distributions in the above hierarchy. Both will be different to the distribution of the more abstract aspects of Design Science (or Science of Design) which would be found mainly in levels 9 and 10 (epistemology and ontology).

Phillips[46] evaluated several contributory postulations on the development of knowledge and noted the weight of academic opinion that all theory is unprovable in isolation but depends for its existence on a wider structure

or theoretical ecology (see also, Stegmüller[31] and Murray[50]). It should be expected that successful general theories of design would provide a complete range of coherent concepts at all levels. In addition, each individual concept or theoretical element should also, potentially at least, be a part of a general theory. For each theoretical element or theory to be coherent, and to stand up to the rigours of comparative and critical analysis, it must be a part of a web of theory that ranges from direct perception of reality to assumptions about existence itself. To repeat, theoretical elements and concepts should form coherent chains that are represented in all levels of the meta-theoretical hierarchy.

4.2 The use of the meta-theoretical structure

The above structure provides the means to improve conceptual and linguistic clarity by decomposing differing design theories and concepts into their relevant contributions at each of the different levels of abstraction. This decomposition provides a powerful means of comparing and contrasting different theories, concepts and metaphors of design theory by exploring the differences and similarities between related elements at each meta-theoretical level. The following simplified example shows how two metaphors of design (*Design as Information Processing* and *Design as a Creative Process)* can be decomposed into their contributions at each level of the meta-theoretical hierarchy to provide the conceptual detail that enables their critical analysis.

4.2.1 Design as Information Processing

Information processing is the most common theoretical perspective on design found in the contemporary literature of design research. This perspective is closely approximated by that of Suh[5].

(1) *Direct perception of realities*—Receiving and sending information. The effect on the user. Feelings of 'lack of information' or 'being overwhelmed by too much information' or 'wondering where to find appropriate information'.
(2) *Description of Objects*—Descriptions of information sources such as; books, computer files, expert knowledge. Descriptions of information types such as; 'fluid viscosity', 'Pantone codes', 'customer needs' and 'product specifications'. Descriptions of information flow processes such as; 'telephoning', 'DXF file transfer', 'interaction with stakeholders', 'human-machine interactions', 'design team collaboration'.
(3) *Behaviour of Elements*—The behaviour of elements of the designed artefacts are described in terms which allow for convenient information processing. For example, the use of mathematically based models rather than scale models.

50 **Murray, E L** *Imaginative Thinking and Human Existence* Duquesne University Press, Pittsburgh (1986)

(4) *Mechanisms of Choice*—The relevance of decision making methods and evaluatory techniques is dependent upon their communication efficiency, data integrity and data validation. The relevant fields of study which relate to the reasoning behind design choice would include; communication theory, artificial intelligence, cognitive psychology of decision-making, systems analysis and information processing.

(5) *Design Methods*—Design is seen as the codification, selection and management of information. The characteristic design method is the use of information selecting algorithms.

(6) *Design Process Structure*—The design of an artefact is seen as an information selection and management process. The underlying metaphor has the following aspects:

- The world can be codified in a form suitable for information processing
- This coded information can be categorised
- The correct information can be supplied to the designer
- The designer can use an information processing algorithm to 'design'
- A description of the designed artefact can be provided for manufacture
- The manufacture of the artefact can be achieved from the supplied information without ad-hoc interpretation.

(7) *Theories about the Internal Processes of Designers and Collaboration*—The designer is seen as a machine capable of rationally selecting and connecting together elemental information to satisfy a set of constraints. It is assumed that human expertise can be mathematically modelled. Interaction between design team members is seen as the communication of information.

(8) *General Design Theories*—'Design as information processing' lies within an atomistic and deterministic framework. It is presumed that design can be automated and that the human designer is only necessary to oversee that process.

(9) *Epistemology of Design Theory*—The test of whether particular design information, methods and theories are satisfactory is whether they transform and transfer information in the manner in which they were conceived.

(10) *Ontology of Design*—'Design as information processing' assumes that information is 'value neutral'. The universe is presumed to be consistent. It is assumed that it is possible to model reality exactly. 'Reality' is taken to be codifiable in such a way that information has the same meaning for any person using it. Cultural factors and human values are quantified.

4.2.2 Design as a Creative Process

Creativity that emphasises the intuitive internal creative processes of the designer forms the basis of this alternative metaphor of design research. This perspective has been unfashionable in engineering design research for some time. Amabile[51] noted that research into creativity has been mainly undertaken within Psychology, and even there it is relatively unrepresented. This creative perspective on the design process is exemplified by Glegg[52].

(1) *Direct perception of realities*—Observation through the senses—mainly sight in most disciplines. The representation of observations about bodily sensations and kineasthetics as 'feelings'.

(2) *Description of Objects*—Objects are typically described adjectivally rather than by using simple noun descriptions. Some examples are: a 'strong' red, a 'pretentious' vestibule, a 'convoluted' melody, an 'unnecessarily complex' mechanism, an 'elegant' solution.

(3) *Behaviour of Elements*—The main focus is on the *interrelationships* between elements. Although elements have intrinsic characteristics their properties are more commonly defined by other elements and external influences. To give some examples: from engineering design—'a gearbox may be *well matched* to an engine', from typographic design—'this subhead type is *more dominant* than the main headings', from graphic design—'the vertical line *divides* the picture *unequally'*, from architecture—'the low roofline *helps* the building to *blend* into the landscape', from pedagogical design—'group exercises *enable* students *to participate more fully* in their education.'

(4) *Mechanisms of Choice*—Where design is seen as a creative process the dominant mechanism of decision-making and evaluation is the use of 'feeling'. Studies of the 'correctness' of design decision-making based on feeling are usually historical and cultural. Such analysis depends also on an assessment of feeling and is usually justified by casuistic means. The type of questions which might be asked in this metaphor are; 'Which particular *outlook* should be used for designing in this case?' or 'How can Roman form and Jazz imagery be juxtaposed *satisfactorily'*, or 'How can a *successful compromise* be made in placing the camshaft?'. The answers to such questions depend upon human values and as such lie in the domain of 'feeling'.

(5) *Design Methods*—A range of methods have been developed to facilitate the designer's use of the right hemisphere of the brain. Such methods include associative and analogical techniques such as Synectics, Mind maps and Brainstorming. Many of these methods are also intended to discourage analytical thinking or use of the left hemisphere of the brain. Other methods provide guidance in specific

51 **Amabile, T M** *The Social Psychology of Creativity* Springer-Verlag, New York (1983)

52 **Glegg, G L** *The Design of Design* The University Press, Cambridge, UK (1971)

domains for visual creativity and manipulation of concepts. These techniques include concepts of visual balance, the flow of form, repetitive elements and geometrical transformations. All creative design methods necessarily depend on a sufficient base of experience residing within the designer(s).

(6) *Design Process Structure*—Design process models are often similar to more technically based process models. Many models use a systems based description of the form *analysis–synthesis–evaluation* with *evaluation* feeding information back into the other elements. Models based on a Romantic metaphor of design often omit the evaluation feedback loop, presuming that the individual genius of the designer is the measure of the quality of the design. The 'creative' aspect of the design process is seen as 'intuitive' or mysterious and is the most dominant aspect of the process; with all other process elements having a supporting role.

(7) *Theories about the Internal Processes of Designers and Collaboration*—Some theories are Romantic in style emphasising the creative genius of the individual. Whilst attempting to discuss creativity phenomenologically the underlying assumption is of creativity as a mysterious process. Other theories try to explain creativity as a function of particular biological and psychological processes. Descriptions of individual designer's creative processes refer to the designer's intuition, experience, feelings and style together with the domain's traditions. Collaboration between designers is seen as a process of trying to communicate nuances of feeling.

(8) *General Design Theories*—Design is seen as a creative activity. Other aspects of design process are subordinate to this.

(9) *Epistemology of Design Theory*—Assessment of the validity or coherency of design information, methods and theories is seen to be part of the intrinsic creative activity of the designer or design theorist. Domain based critics attempt to provide external comment on the completed works of designers.

(10) *Ontology of Design*—There are many ontological bases espoused by those who view design as a creative process. This metaphor of design includes human values, attitudes and assumptions. It does not depend on any particular world view except in the assumption that design is not deterministic, i.e. that it is not possible to reduce creativity to a set of algorithmic steps. It further assumes that design is an exclusively human activity which cannot be automated.

4.3 Using the results of the meta-theoretical decomposition

The above method of meta-theoretical analysis shows many differences between the two metaphors—in spite of the limited and sketchy nature of

the deconstructions. The method also indicates the theoretical or conceptual range of each metaphor and helps avoid the problem caused by proponents of a metaphor extending it by broadening its meaning without explaining the theoretical consequences. For example, *Information Processing* might be extended by claiming that 'everything can be expressed as information', or *Creativity* might be extended by insisting that every perception, action or thought is 'new' and hence a new creation. This technique of extending a metaphor may be useful temporarily for generating new insights, but it commonly leads to theoretical and terminological confusion in the literature. In both cases, these changes would grant greater powers to each metaphor, but if this increase in the range of a metaphor was given without the necessary analysis as to whether it was justified then it would simply be an example of theoretical 'double-speak'. The meta-theoretical method helps avoid this, and similar problems, because it shows the actual theoretical structure that is ascribed to a metaphor regardless of any transitional semantic reinterpretation of its title. Meta-theoretical analysis publicly lays bare the agreed underlying facets of any design theory so that when a metaphor, theory, concept, or other abstraction is proposed, or changed, it can be critiqued not only in terms of its own content but also in terms of its conceptual placement and its relationships. That is, the meta-theoretical structure provides the theoretical framework within which it is possible to not only ask, 'What do you mean by this idea?', but also to ask, 'What other concepts and theories is it related to and how?', 'What assumptions does it depend on?', 'What implications has it for the meanings of other concepts or theories?' and 'How coherent is it with other concepts and abstractions?'.

5 *Summary*

This paper lies within the field of Philosophy of Design rather than Design Philosophy. In the paper, the problems in Design Theory that are caused by widespread confusion and conflation and the unnecessary multiplicity of theoretical concepts are addressed via a meta-theoretical analysis, Popper's three world view and metaphor. A meta-theoretical method that assists with the move toward a simplifying paradigm of design research is proposed and an example of the use of this meta-theoretical method is given in which the underlying theoretical basis of *Design as Information Processing* is compared with that of *Design as a Creative Process*.

6 *Conclusion*

Confusion, semantic proliferation and lack of coherency in design theory may be reduced by the application of meta-theoretical analysis. The meta-theoretical method described above assists the critical and radical assessment of theories, concepts and other abstractions in Design Research. The

method is simple and straightforward to use, and provides a basis for limiting the generation of unnecessary terminology in design research. The meta-theoretical method also provides a structured means of identifying which elements of design theory might contribute to a truly 'simplifying paradigm' of design research, and which potentially simplifying paradigms are epistemologically inappropriate.

Acknowledgments

I am indebted to Dr. Jane Howarth of Lancaster University and to the late John Woollatt for discussing the philosophical aspects of design research with me. I thank the reviewers of this paper for their constructive advice and guidance. My thanks also go to the Engineering department of the University of Western Australia, and Drs. Laurence Spencer and Malcolm Hollick in particular, for their support.