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A. J. FULCHER & P. HILLS

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Towards a Strategic Framework for Design Research

A. J. FULCHER & P. HILLS

SUMMARY *Design research as an academic, intellectual field of study is new in comparison to engineering science research or research into the established natural sciences. This paper considers the current state of progress, describes the 'artificial' nature of design and the necessity for design research, and highlights the need for clearer macro goals and agreed methods of research. A methodology is proposed based on a foundational value system, which will first enable descriptive research profiles to be created from which prescriptive classifications can be attempted by deductive and inductive reasoning. The value system proposed is one in which national prosperity and improvement in the quality of life are achieved by industrial relevance and responsiveness. It is argued that meaningful classification must include a breadth and depth of parameters to reflect the value system and that such a classification will enable a more effective and efficient exploitation of the field.*

1. Introduction—The New Kid on The Block

Research into design is relatively new, although people have been designing in one form or another from pre-history. However, until the early 1960s and apart from a few lone voices in the UK, US and one or two European outposts, Germany was the principal centre of serious attempts to develop a deeper understanding of how designers work and how their efforts might be made more effective by structured approaches. Since then, enquiries such as those by Feilden [1] and Finniston [2] have sought to establish design as a means of improving national competitiveness in the face of international competition. These have led to the establishment of teams of design research workers in a variety of international locations. In the UK, this has led to the creation of Engineering Design Centres (EDCs) set up as a result of the Science and Engineering Research Council (SERC) initiative to stimulate and focus design research efforts. Similar independent and industrially funded centres exist elsewhere (e.g. Coverntry University Centre for Integrated Design) and there is further work occurring in university engineering departments even where no dedicated team is established.

The rationale for these activities is the potential benefit promised by improved design processes and tools. Within the field, it is recognized that the proper use of design is critical to an organization's ability to manufacture profitable products that meet market needs. However, the effectiveness and efficiency that are necessary are often found to be lacking in practice and there are all too many recorded case studies of poor design or design management that have resulted in commercial and physical difficulties. The recognition that design is crucial to corporate and national economic

A. J. Fulcher and P. Hills, Centre for Integrated Design, Coventry University, Room D54, 'D' Block, Priory Street, Coventry CV1 5FB, UK.

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success, coupled with realization that design in practice is less than optimal and a belief that new insights can improve the situation provides the incentive for design research.

The outcome of design research so far is an increasing volume of research papers, journals and conferences [3]. It is less clear whether or not the field of design research is approaching a maturity that will enable it to deliver much of its promised potential. Important questions remain unanswered. Is there convergence and agreement internationally on the research results to date? What theories have been tested and proven? What is the best methodology for design research? What are the major issues? Is a structure for research topics emerging? Is the research relevant to the needs of industry?

These are important questions to which there are no simple answers on a macro scale, although at a micro level it is possible to identify specific successes. This paper is intended to provoke thought at a macro level and to put forward ideas about how a classification system may enable design research to move forward with clearer objectives, shared methods and greater cohesion.

2. Growing Pains

Design research is in an adolescent phase. In comparison to the established natural sciences and even engineering science, boasting schools of research since the last century, design research has existed for perhaps three decades. Much has been done which can be commended (for an early but valuable review of progress, see Finger and Dixon [4, 5]), but mistakes have also been made and where these have been significant they have wasted effort and precious financial resources. Perhaps it is inevitable that in a new field such mistakes will be made. However, a clearer understanding of the field as a whole and a sharper definition of goals and agreement on methods could enhance performance. This has implications for the management of design research, both at a funding level and at a local level, as well as with the actual process of conducting research itself.

2.1 An Identity Crisis

Design research as it reaches adulthood has had an identity crisis. Indeed, it is uncertain whether or not the identity crisis has been resolved. Should design research be carried out in accordance with the discipline and methodology of orthodox engineering science? Or should it conform to research methodologies used in the social sciences, management research or industrial design? If the former, then there are important implications for the manner in which research is conducted, the way theories are proposed and experiments designed to test those theories. If the latter, the methods used will be different and the results of research evaluated against different critieria. Or should design research stand on its own two feet somewhere in the middle—a new pure form of applied research or a hybrid? This is a debate which has reached no obvious conclusion although individual researchers will certainly have made up their own minds and be conducting their research accordingly. This is not a trivial matter. Unlike orthodox scientific research, it is difficult to control all the variables in design research (as it frequently is in management or medical research) and this leads to experiments for which it is difficult to achieve unequivocally the same results in two nominally identical experiments. Consequently, this lack of agreement hinders progress in that conclusions accepted by some may be viewed as unsupported by others. For a deeper discussion of the philosophical foundations for design research, see [6].

2.2 Which Partner?

Design itself is a multi-faceted activity in which information, people and technology are interacting in a complex fashion in the context of an organizational structure. Consequently, design research makes alliances with other disciplines in order to bring fresh insights and deeper understanding as increasingly complex questions are tackled.

Computer science has already contributed much to the progress made, particularly in the provision of tools for modelling topology graphically, conducting analysis, enabling simulation and prediction and providing environments and representations in which researchers have been able to explore new avenues. Artificial intelligence (AI) is pushing the boundaries back further by offering tools with reasoning and decision-making capability and adaptability to particular situations. Blessing [7] discusses the relationship between AI and engineering design and concludes that a marriage is promising, even though the engagement and cohabitation periods have had their difficulties.

An additional partner is management science. The very fact that design, even in the most automated situations, inevitably involves people implies that the social sciences and in particular management science should have much to contribute. One view of design is that it can be considered as an exercise in management and management of resources in a state of constrained uncertainty. Uncertainty is introduced into the situation by the inclusion of people. No longer are we dealing with repeatable cause and effect, but rather cause followed by humanly manipulated effect where the human input is variable, leading to many possible outcomes. These difficulties are described in a management context by Gill and Johnson [8]. This is recognized by some design research establishments who have cross-fertilized their research staff with co-located researchers from social science or business schools.

However, as well as benefits, there are dangers in forming strategic alliances. Other disciplines will have different long-term goals and unless there is a very clear understanding of the objectives of design research, there could be a tendency for design objectives to be lost in the excitement of progress. Design research must produce tools and techniques which are practicably useful and usable by the majority of design practitioners as well as being sophisticated in their own right. This is particularly true where rapid progress is taking place in the associated field (as is the case with AI or knowledge-based engineering (KBE). Rapid progress is always important, but it must be in the right direction.

In short, design research needs to establish its own agenda to ensure that, when alliances with other disciplines are entered into, design priorities are maintained. This is important. Research needs stimulus. It is too important to be allowed to fly.

2.3 The Big Bad World

As previously stated, the Germans were among the first to look into the 'design' black box and analyze the processes involved. Notable contributions being made from Matousek [9], Hubka [10], Pahl and Beitz [11], etc. The very valuable work undertaken has formed a strong foundation for much subsequent research, but recently questions have been asked about the application of the design methodologies prescribed [3, 12]. There has also been a tendency for researchers to emphasize the need to apply the methodologies sympathetically to particular situations and individuals [13]. Hence, the processes prescribed become a set of guidelines to enable a particular organization to design its own processes according to the local environment.

Additionally, there is little evidence to support widespread acceptance of such structured approaches on a broad scale across industry. A recent report has shown that in a survey of over 200 experienced engineers in a wide range of engineering companies in the UK, 40% use no formal working procedures and 54% work to their own standards [14].

Why is this? Is industry really that slow to implement good ideas? Is the dissemination process inadequate? Or do the models lack the flexibility to cope with the real big bad world? One of the surprisingly few attempts to examine this issue in an industrial context [15] found that the neat structured plans envisaged for a particular design project were swamped by the noise created by the rest of the organization and environmental circumstances. This was in a situation where the company involved was explicitly committed to a structured approach and had senior management backing. If this is typical for a situation in which so many conditions were favourable, what chance is there for establishing the classical structures for design so often proposed in the literature in the lesser companies which form the majority?

Furthermore, industrially driven concepts such as concurrent engineering can complicate matters. Many prescriptive process models do not cater for time compression as a primary requirement, but rather focus on structuring the design process to optimize a technical solution in a sequential fashion rather than optimize business goals in a parallel fashion.

Such issues are challenging the design research community to think more broadly. It is no longer acceptable to regard design as a technical transformation of market need into manufacturing plans alone. Design research must enable that but do so in a context of real people, real organizations and real markets which are characterized by complexity, time pressure, limited resources and changing circumstances.

3. Signs of Maturity

Despite the complexities already described, there are signs that the field of design research is becoming mature.

3.1 Self-organization

The very fact that a 'community' of researchers around the globe is crystallizing is testimony to this fact. Evidence for this is the initiation of formal journals, shared newsletters, recognized centres of work, international and national conferences, and extensive mailing lists. It is expected that this self-organizing activity will continue, but would benefit by reinforcement of organization.

3.2 The Recognition of the Need for Agreed Terminology

A further evidence of maturity is the desire to communicate with common terminology. Several projects are under way (not necessarily in public as yet, but with design research centres) to collect and define terms accurately and so increase clarity of understanding and effectiveness of communication.

3.3 Self-assessment

There is an awareness of the need for self-assessment and a recognition that useable results must be demonstrated by the community as a whole. Discussions with researchers have shown that there is a common desire to work towards agreed objectives

and to coordinate effort. There is also a recognition that duplication of work takes place. However, as yet there is no unifying structure around which national and international research work can be coordinated.

4. A Proposition

We would contend than an agreed classification system will help to advance the cause of design research by:

- assisting in setting the right goals;
- clarifying methods in an agreed framework where some of the topics can be subjected to hard scientific processes, while others can be treated with softer scientific processes and evaluations;
- helping to identify the most suitable strategic partnerships for particular research topics;
- accelerating the emergence of design research field structures;
- identifying gaps and overlaps in research activity;
- acting as a navigation aid for researchers.

This paper will now go on to discuss the means by which such a classification is being developed. However, firstly, it may be useful to review the nature of design as compared to the natural sciences.

5. The Nature of Design and the Necessity of Classification

It is important to distinguish between the demonstrable truths of the natural sciences and the more subjective 'science of design'. This has implications for the methods used and the final results obtained and therefore needs careful consideration at the outset.

An attribute of the natural sciences is that they permit observation, measurement and classification, leading to definitive and exhaustive taxonomies. Design science, however, as pointed out by Simon [16], is not a science of the natural, but a science of the 'artificial', an investigation into what could or should be, not an analysis of what is. Consequently, any classifications created to describe design research are more open to interpretation and more fluid in their structures than those of the natural sciences.

This does not make design research classification redundant, quite the reverse. The freedom available within the realm of design research requires well-defined and agreed overall structures within which researchers and sponsors alike can get their bearings in relation to the overall effort. This is essential if the field is to be explored rigorously but efficiently. This view is being expressed in the literature and at conferences:

> . . . Design Methodology lacks:
>
> (1) a clear agreement about the goals to pursue
> (2) a shared research methodology
> (3) a broad theoretical framework to relate the findings of isolated pieces of research to one another.
>
> . . . This led to a discussion on the need to devise a system of classification, aiming to get a better overview of the field, and systematically to identify problem areas within the subject. [17]

If design is a science of the 'artificial', it follows that a classification structure for design research is also artificial and therefore can be conceived in numerous ways. Conse-

quently the definition of the classification system is, itself, a design process. Since we cannot merely observe, measure and classify, what are the main classifying criteria? How do we choose from all the possibilities? Who says so? Why?

It would seem logical at the start of this process to clarify the 'customer' needs, to ascertain the foundational value systems upon which the classification is to be based so that the information stored in the structure is most appropriate to the intended purpose of the ultimate user.

6. An Underlying Value System

Having recognized the requirement for classification and observed the 'artificial' nature of design, upon what basis should a classification be built? This is a fundamental question and deserves careful consideration. In short, what is the purpose of design research? If this question is not thought through in advance the resulting classifications will be limited in their usefulness.

Options might be general such as 'the advancement of knowledge'—in which case the classification would need to cater for values of uniqueness and originality—or 'the management of change and innovation'. Alternatively, a specific purpose could be defined for example 'the attainment of a particular project'—in which case the classification would need to cater for values of rate of progress towards the project goal, achievement of milestones, likelihood of successful completion, etc. (A classic example of this was the research in the 1960s in the US where the underlying value system was 'putting a man on the moon by the end of the decade'.)

It would seem logical first to search for a value system among the policy makers who fund design research. Being pragmatic, unless design research is fulfilling the expectations of policy-makers, funding is unlikely to continue to be forthcoming. The principal sources of most research are governments and industrial organizations.

We would suggest that in the UK the value system currently in force is that underlying the Government White Paper on competitiveness: *Realising Our Potential* [18]. This requires that design research should be focused on wealth creation and delivering industrially relevant and exploitable benefits to enhance the quality of life. This is stated explicitly as "... the generation of national prosperity and the improvement of the quality of life" (Page 2, Paragraph 1.7). This is to be achieved by awareness and relevance to industrial needs:

> The central thesis of this White Paper is that we could and should improve our performance by making the science and engineering base even more aware of and responsive to the needs of industry and other research users (Page 16, Paragraph 2.23).

This industrial orientation is unlikely to be disputed by industrialists and it is anticipated that other nations will have similar value systems whether explicitly stated or not.

The next question is how is design research linked with national prosperity and the improvement in the quality of life? The detailed study and effective implementation of mechanisms to achieve this could make an important contribution to the national goal. Such mechanisms may include:

- knowledge transfer;
- people transfer;
- people cycling;
- education channels;

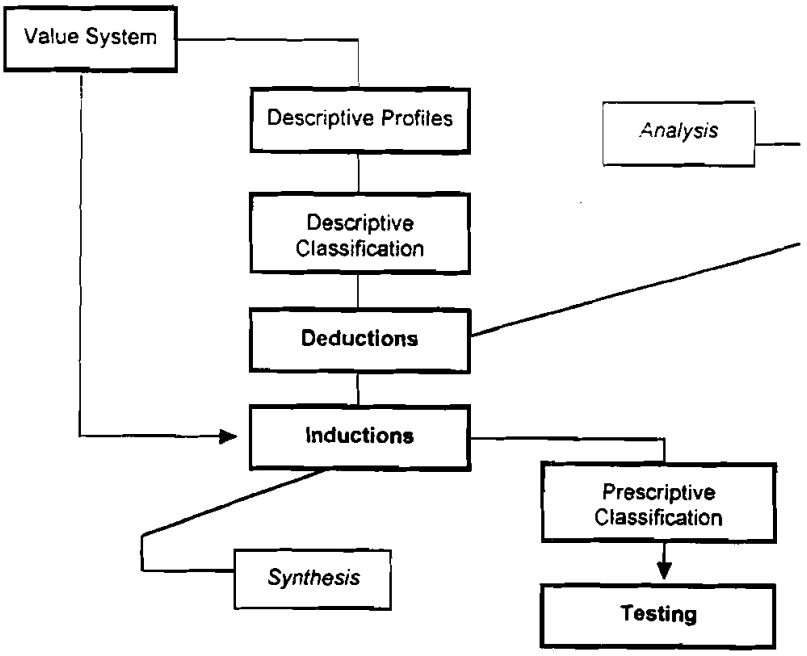

FIG. 1. Methodology for classification.

- re-education channels;
- exploitation intermediaries, etc.

Whatever the mechanisms are, classification, if it is to assist strategic decision making, must have dimensions pertaining to issues such as deliverables, benefits and exploitation as well as axes profiling the subject of the research itself.

7. A Proposed Methodology

Having suggested a value system, it is proposed that a suitable method for creating a classification system is by building a descriptive model of design research based on data from current and previous work in the field. This enables objectivity in an area which otherwise is governed by opinions and multiple viewpoints rather than deductive reasoning. However, the purpose of gathering and ordering information is not primarily to be descriptive, but rather to gather insight as to what design research could or should be like, i.e. to be prescriptive. The prescriptive classification can then be extended, if necessary, to include classifying criteria which will fulfill the value system. This is presented diagrammatically in Fig. 1. Consequently, a database is being designed to capture descriptive data in an orderly fashion with the intention of using the resulting information to deduce trends, relationships and patterns which will lead to fresh insights regarding the range and depth of current research and suggest what the main classifying criteria should be, as well as directions for future exploitation.

The raw data to be used for populating the database are, and will be, from a mixture of sources including:

- research project status reports;
- conference and other published papers;
- review papers;
- reference books and academic journals;
- visits to UK and international research centres for discussions with researchers on current projects;
- design thinkers from the industrial and academic world;
- industrial attitude surveys.

The data sources will also be recorded so that sorting and selection can be carried out as desired.

8. Data, Taxonomies and Representations

A full description of our approach to data modelling will not be given here; however, the following points are made:

- Data modelling is difficult because the research issues are complex, span several academic disciplines, can be descriptive or prescriptive, can be detailed or general, can be context specific or generic, etc.
- The process of building a data model is iterative.
- Multiple viewpoints need to be catered for.
- Multiple resolutions need to be catered for.
- Data are unstructured implying a need for systematic methods for eliciting data from their source.
- Data are largely qualitative, causing judgements to be necessary in the elicitation process in order to transform qualitative data to quantitative data (content analysis).
- Reliability and validity of results need to be scrutinized and tested where feasible.
- Reliability can be checked by tests for stability, reproducibility and accuracy.
- Value analysis is difficult to carry out objectively; frequency analysis is thought to be a better basis initially.
- A taxonomy is a structure in which a subject can be uniquely located and the axes of a taxonomy must be orthogonal.

The final point relating to a taxonomy means that a single taxonomy is unlikely to be a robust enough representation to adequately represent the breadth and depth of issues involved in design research. Consequently, alternative representations will need to be found.

9. Generic Content

Often, research focuses on increasingly specific issues in order to understand the problems and be able to propose solutions. This is valid, but requires abstraction of the results to the generic if the solution is to be meaningful in a wider context. It is not clear whether this is always done as rigorously as possible and whether the abstractions to the generic are supportable.

One of the major objectives of a classification system would be to determine and represent generic content of research work. This objective creates particular difficulties.

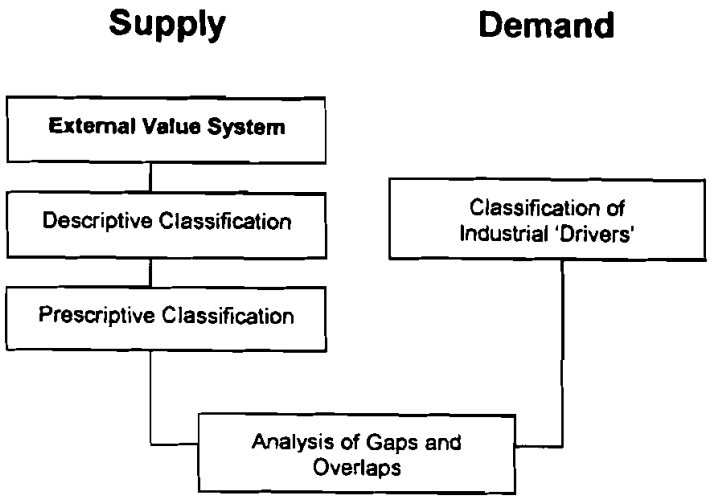

FIG. 2. Industrial relevance.

What does 'generic' mean and how can it be measured? A typical dictionary definition for generic is 'belonging to a group'. Therefore, to determine the generic content of a research project necessitates defining the group to which the project belongs. 'Generic to an industry type', 'generic to an organization type' or 'generic to a product type' are possibilities amongst many others yet to be researched. Therefore, for now, defining and quantifying generic content remains an open and difficult issue which needs further consideration and ideas if a useful measure is to be found.

10. Industrial Relevance

The foregoing work is, in essence, a unidirectional flow in which design research is first described in quantitative terms, then by deductions, and inductions will be extrapolated to a prescription based on a known value system.

It is intended to develop a parallel classification based on industrial demand. This enables the superposition of one classification on top of another and identification of design research topic 'hotspots' (topics which are strongly demanded) and 'coldspots' (topics for which there is little demand). It is contended that, given adequate, representative and widespread industrial input, this will enable measures of industrial relevance to be ascertained in an objective manner and permit a balancing of priorities by matching supply and demand. This is illustrated in Fig. 2.

11. Conclusions

This paper has described the state of design research at a macro level and commented on the need for more sharply defined field goals and agreed methods. Arguments have been made that this relatively new field will benefit as a whole from the creation of a broad classification system which will act as a useful tool for research sponsors, strategic planners and researchers alike, enabling more effective and efficient exploitation. Due to the 'artificial' nature of design (i.e. man-made as opposed to 'natural'), any

classification system must be based on a stable value system if it is not to be quickly outdated, or worse, irrelevant to the purposes of those who wish to make use of it. Such a value system has also been described. Finally, a method based on description, deduction, induction and prescription has been described by which it is intended to create a classification framework. This phase of the work is now in progress.

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