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MAPPING DESIGN PROCESS AND RADAR ANALYSIS OF DESIGN ACTIVITIES

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ABSTRACT
There is considerable interest in quantifying the impact of professional design activity: At a policy level governments and professional bodies require objective measures of value added to national economies. At firm level there are a range of benefits derived from understanding of value-added to individual businesses or product development activities. However, despite various initiatives, such as national surveys and competitions, there is limited effective communication and more detailed understanding of how design activity creates impact. Building on over 40 years of research into design process, the reported study proposes a rationalised design-space and process model for creating design process maps and radar charts as a basis for unified exploration of a range of factors which affect the outcomes, and therefore impact, of design activity. These methods: Design process maps and HEET radar charts, are applied in various longitudinal studies of design pedagogy. The results highlight differences between design theory and practice together with deficiencies in design process and project orientation within the sampled projects. The overall outcomes inform ongoing development of design evaluation techniques and the communication of design impact.

Keywords: Design process, design space, design impact, design process mapping

1 INTRODUCTION

Design is widely recognised as an important component of the creative industries, innovation and New Product Development (NPD)[1][2] and together, an important driver for national economies[3]. There is considerable interest in quantifying the impact of professional design activity: At a policy level the UK Design Council identify that 80% of UK business agrees that design will help them stay competitive in the current economic climate[4]. The UK DCMS identifies that design contributes £1.6bn of the £59.1bn GVA generated by UK Creative industries[5] and various government reports highlight the potential of design and the creative industries to contribute to the future economic wellbeing of the UK, eg Cox[6], Sainsbury[7] and Dyson[8]. Although it is noted that nearly 80% of businesses surveyed stated that designers are only; '*quite good'*, through to; '*not good at all',* at communicating the value of design activity[9]. At firm level the DBA's Design Effectiveness Awards or the European Design Management Award aim to highlight individual cases of the positive impact of design activity. But these initiatives do not necessarily lead to a finer grain understanding of the ingredients and recipe for design impact. Design is a component of innovation, and within this field there are numerous examples of models and methodologies with goals of identifying the constituent factors and added value of innovation[10]. However, in traditional business metrics terms the value of innovation and design have proved very resistant to quantification[11]. Within design there is more limited evidence of systematic explorations of how value is derived from design activity. Rather than simply considering outputs we can consider how outputs are derived from *inputs* and *process* in an *input-process-output* model. For example, within NESTA's work[12], input factors are identified as a basis for measurement of innovation as well as measurement of the more conventional output factors. Within the professional practice of design any instance of *input-process-output* is likely to be very complex. However, in order to develop better understanding of *potential* design impact there is a need for better understanding of the elements and inter relationships within an input-process-output model.
The relationships between theory and practice and the development of new design evaluation approaches can usefully be considered and developed in the context of design pedagogy with resulting benefits for design teaching as well as contributions to the overall issues of evaluating design activity.

2 MAPPING DESIGN PROCESS WITHIN THE DESIGN SPACE

Considering the design process core in an *input-process-output* model, Bruce Archer writing in Design Magazine in 1963 is credited with the first example of breaking down design process into a number of stages[13]. Subsequently, exploration of stages and sequences of design activity have been a significant focus within design research. Aims for this research are often focused on improving the performance of design outcomes. Models of design process have strong parallels with models of innovation and New Product Development (NPD) practice. For example based on NASA's work in the 1960's identifying four key sequential stages: Analysis, Definition, Design, and Operation[14].

Classifications of design process from the expanding body of literature reviews include: Rothwell's chronological categorisation of five generations of NPD models[15] and Blessing's four categories of design models (cited inWynn and Clarkson[16]). Wynn and Clarkson's own review of design process literature proposes three categories of design process models according to how relevant they are as a basis for exploring practical process improvement. The Design Council's 2007 study[13] recommended the Double Diamond model with four identified stages: Discover, Define, Develop and Deliver. The diamond shape relates to concepts of divergent and convergent *Behaviour*[17]. The Double Diamond model is reported as placing particular emphasis on the Discovery stage, with the stated benefits of maximising the impact of design interventions. The Design Council also asserts that there is a correlation between business success and presence of a formalised process for design. Four or Five 'D' design processes feature strongly in Dubberly's 'compendium' of 131 design process models[18]. Howard et al's study[19] on integrating creative process with engineering design process and output provides a more recent review of both design process and creativity literature. The core, staged, linear approach is confirmed as the dominant approach for design process models. 23 models are reviewed and rationalised within a six stage matrix. Significant points from this work include making the distinction between a 'routine path' and a 'creative path' based on the evidence from studies on innovation and the importance of creativity to economic success. They also promote the value of their work for targeting, developing and evaluating new design tools. For example, they identify the importance of, but limited understanding of *information* within various stages of the input-process/creativity-output matrix (p177).

Stuart Pugh[20] had introduced 'Total Design', a theoretical model of design process, also with a six stage linear core. A staged linear model is common to many representations of design process, however the distinction which is drawn out in his work is the importance attached to the idea of integration of a wide range of factors into an 'envelope' for the whole process. 34 categories of input factors are identified which should be considered during product engineering projects. Initial review and analysis of these factors, the first stage in the Total Design process, are defined in a Product Design Specification, which is another important element of Pugh's model (p44 op cit). The overall model also incorporates the idea of specific techniques, methods or tools which might be applied at each stage of the process (p220 op cit) The work goes on to explore how the model may also integrate with business in the form of a 'business design activity model' (p178 op cit). Pugh's envelope has strong parallels with the concept of a 'design space'. The advantages of enlarging a design space as a basis for more 'creative' design solutions is identified by Gero & Kumar[21]. Burgess et al[22] and Jones et al[23] explore methods for charting design variables within visualised design spaces as a basis for improving the performance of design and outcomes.

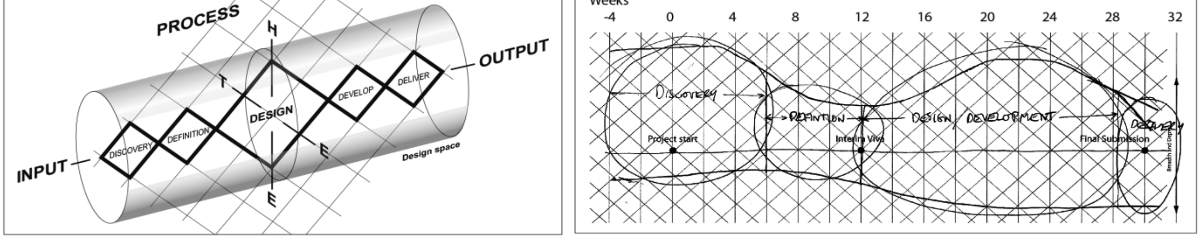

Figure 1. Design process within the design space (left), Tutor's view of 'ideal' Major Project design process (right)

An updated 'Total Design' Model (ref figure 1, left) accommodates, within an overall input-process-output model and design space, the following factors: Distinct STAGES or phases of work, DIVERGENT-CONVERGENT patterns of work and SCALEABILITY. In combination, recognition and exploration of these factors contribute to greater Knowledge and information[13][19]. Specific instances of a complete design process will also demonstrate the divergency of 'paths' adopted by different designers.

A longitudinal section of the model has been the basis for a series of exploratory exercises within the tertiary design teaching environment: Design tutors recording their reflections on actual and 'ideal' process within major projects and MSc students completing blank templates to explore their project planning and their actual design practice. The objectives for these initial applications of the mapping techniques include: refining teaching materials, highlighting issues and opportunities within the underlying design pedagogy and enhancing students' own understanding of design process as a basis for enhancing their design practice. Figure 1 (right) gives an example of a completed map template. In each exercise templates have been completed by the group taking part and results can be evaluated on the basis of these completed maps and also through discussion of points arising whilst sketching out information on the templates.

Analysis - Exploring design process principles with MSc students: Using the 5'D's model in the explanation of the map strongly indicates a favoured, and linear, structure. This can be a barrier to participants' developing a deeper appreciation of issues, with recognition that actual design practice does not necessarily conform to this representation of five sequential stages. This corresponds to the views of many critics of conventional linear design process models, eg Lawson[24]. The specific choice of terms for the stages may also be an example of criticism of inconsistent use of terminology within design methods[25]. However, in the opinion of the students, a graphic representation is a useful device within the context of design education, but the value of any application in commercial practice is untested. This underlines the gap between theory and practice, where initiatives such as this must effectively communicate potential for added value to the intended audience[26].

Analysis - MSc student maps: Reviewing 81 maps completed at various points by two separate cohorts, the distinction between theory and practice is marked. At early project stages, students understand the established principles of stage based activity and create maps which generally fit the theoretical models. However with maps reflecting actual practice; produced mid project, activities become more fluid with considerable overlaps and 'miss-matches' between designated milestones and activities. For example mapping projects which are not fully defined at a crucial deadline, but with creative work already generating ideas in response to an ill defined problem. Few participants' maps reflect *Design* activity taking place throughout a design process, and design is often 'squeezed' into short phases. Although inconclusive, this is an important finding from a pedagogical, professional and theoretical point of view. Whilst it might be argued that *Design* or creativity is a key characteristic of all design process activity and is a foundation to the Design Thinking concept, the findings from these cohorts highlight considerable potential to enhance these core attributes.

Analysis - tutor maps: The tutors' maps (completed for actual and ideal practice) strongly reinforce that students might pay more attention to *Design* or creativity throughout the design process. Figure 1 (right) shows an elegant variant of a map, where *Design* is shown as an activity enveloping all other activities. The tutors' maps also highlight their desire for students to spend more time on Development and Delivery stages. This underlines the pedagogical value of the mapping as an aid to project planning. An aspect of practice which students stereotypically struggle to manage effectively.

These longitudinal design process maps represent selective recording of the wide range of factors which ultimately determine design outcomes. However specific instances of design process can be explored in more detail using the same underlying model. This finer grain evaluation is carried through what is termed HEET radar evaluation.

3 RADAR EVALUATION

A radar chart or spider diagram is a widely accepted tool to visually compare multiple variables. The method demonstrates benefits derived from identifying data trends, communication within teams and evaluation of alternative data sets[22] . In this study a radar chart can be used in conjunction with the design process map to evaluate the contextual orientation of specific instances of design project, and the depth and breadth of the activities. The HEET acronym is derived from the significant macro contextual factors within PESTEL type analysis, re-defined as: *Human* factors (H), *Environmental* factors (E^1), *Enterprise* factors (E^2) and *Technology* factors (T). The underlying HEET radar concept can be applied very broadly to a wide range of situations where these contextual factors need consideration. A simple diagram can be used to communicate that a typical design project will encompass a wide range of contextual factors which can be grouped under the four headings. Further, the relative weighting of these contextual factors within any given project can be plotted onto the poles of the radar chart indicating the area covered by the project. Comparative evaluation of different plots or areas can be simply visually communicated.

This 360 degree overview of all of the factors, which may impact or be relevant to a design project, links to the principle of 'major primary specification elements' – the 34 categories of factors identified by Pugh[20] and the benefits of expanding the design space envelope[21]. In parallel with Pugh's Product Design Specification, the HEET radar provides a basis to consider the weightings of contextual factors for a project as whole, and at individual points during the chronology of a design process (ref figure 1, left). The HEET Radar chart was originally conceived with the twin objectives of analysing the enterprise orientation of Design Major Projects at tertiary level together with having applications in design pedagogy as part of communicating a wider range of factors which potentially affect design outcomes.

In order to apply the HEET radar chart as an evaluative tool, meaningful values need to be attached to each pole. In the early applications for the HEET radar a simple zero to three scale with defined generic criteria has been used. The underlying concept allows for significant variation in the nature of the values applied. For example an A* to F scale familiar within educational contexts could be developed with suitable grade point descriptors. Sub-headings within each of the HEET poles (eg Pugh's 34 categories) might be identified and quantitative measurement factors applied to each sub-heading.

A longitudinal evaluation of design Major Projects at two of the UK's leading design schools (Kingston and Brunel) formed the basis of the initial application of the HEET Radar concept. The research objective of this initial exercise was to provide a benchmark of enterprise orientation within student projects and to explore variations in results between the two institutions. In a first exercise, the outcomes of all final year design major projects from each of two previous years were evaluated at both institutions. Major Projects typically represent the culmination of the whole undergraduate experience and are intended to aggregate all the earlier knowledge, skills and experience. The data gathering and evaluation of individual projects was carried out by researchers based at each institution on the basis of reviewing images and descriptions of the projects, together with discussions with the project tutors. The researchers used a three point scale with defined criteria to grade projects against each of the HEET Radar poles.

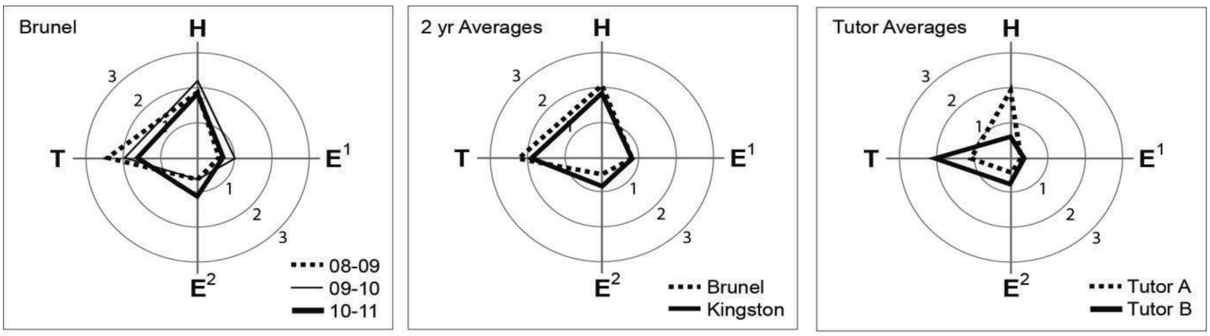

Figure 2. HEET Radar charts for Kingston and Brunel Major Projects

A total of 55 projects at Kingston, in two years, and 249 projects at Brunel over three academic years were completed in the Product/Industrial/3D design areas. It was acknowledged that the zero to three scale combined with evaluation based largely on review of project summaries is a relatively crude evaluation. But it met the requirements of establishing a general overview of the comparative levels of consideration between different contextual factors and a comparison between practice at Kingston and Brunel. The results are surprisingly similar between the two institutions (figure 2, middle). Average values for all the projects indicate strong focus on both *Human* (H) and *Technology* (T) factors. This is what might be expected for the professional activity of design where the historic focus, particularly in 3D design areas, ultimately leads to the production of artefacts. These artefacts typically include T in their production and/or use. They also typically aim to enhance user experience, H factors. However, as explored in the earlier sections of this paper, it is widely acknowledged within the profession that the scope of designers' activity is becoming broader and more complex[24]. The results do indicate consideration of a broader range of factors, but these other factors receive considerably less emphasis when considering the average results for the complete set of projects. The overall average for *Environment* (E^1) is 0.55, slightly lower than *Enterprise* (E^2) at 0.61. It is worth emphasising that these results are not intended to indicate a quality judgement on the work, rather to expose the comparison between the main HEET categories. The differences between E^1 values across the institutions are negligible, suggesting that neither could claim clear differentiation in these areas. H and T factors are surprisingly close. The averages for Brunel over the longer three year period do indicate a trend towards greater consideration of E^2 factors, albeit at the expense of T factors.

This initial quantitative exercise provides a simple overview as a basis for considering the relative contribution of the HEET factors within the pedagogy of the design courses at Kingston and Brunel. In relation to the economic and academic macro context summarised in earlier sections, the results provide clear evidence of the scope for, and need for enhancement of pedagogy in the E^1 and E^2 categories. The average values indicate that whilst all students' major projects demonstrate consideration of H and T factors, individual results show that a significant number of students have zero scores for E^1 and E^2 factors. Whilst the comparative importance of each main factor might be argued and could be a point of differentiation for individual students or institutions, it is suggested that in view of the importance of the complete 360° of factors, students should be able to demonstrate at least a baseline consideration of E^1 and E^2 factors within major projects.

A second research exercise based on 108 2010/11 Major Projects introduced the HEET radar methodology to the first and second project supervisors at Brunel. Each produced values for their project supervisions. The resulting charts therefore show the distribution of projects according to the influence of the professional backgrounds of the tutors. Figure 2 (right) shows two divergent examples from amongst the 13 staff involved. The averages from a member of staff with an engineering background (Tutor A) indicate a strong orientation towards T factors. Likewise, Tutor B, with a background in inclusive design results in averages with a marked orientation towards H factors.

Consideration of E^2 factors has increased overall for final year students at Brunel between 2009/10 and 2010/11, however some projects actively demanded consideration of enterprise factors, whilst others have a clear focus on technical or human factors. More detailed analysis would require consideration of an appropriate baseline followed by evaluation at the end of the project in order to review the impact of influences, such as the tutors' input, *within* the projects.

4 DEVELOPMENT CHALLENGES FOR DESIGN PROCESS MAPPING AND HEET RADAR EVALUATIONS

Factors not included within the design process model (figure 1) include: The culture/professional medium, eg Blackwell et al[27]& Strickfaden et al[28]), consideration of good/bad design (eg Blackwell et al[27]) & stakeholder relationships (eg Buchanan[29] & Blackwell et al[27]). Future work needs to explore how these factors might map onto the rationalised design-space design-process model in addition to any other currently omitted factors which might significantly affect design impact.

A relatively young and unstable history of design theory, combined with various critics of design process theories highlights significant credibility challenges associated with using literally any design evaluation methodology. For example entrants to the DBA design effectiveness awards adopt conventional business metrics to communicate the value of design impact yet these methods are acknowledged to be poor at capturing the essence of design or innovation[10]. Within this study the contribution of *Design* or creativity is perhaps inadequately identified.

This study also highlights another theme identified within design research; the gap between theory and practice. Most notably evidenced in before and after maps of instances of design process completed by student participants. However it is considered a strength of the model and methods explored in that they have considerable potential for simple direct visual comparisons of factors such as; the difference between instances of theory and practice, how creativity maps onto design process, the impact of different cultural and professional mediums and stakeholder relationships (input factors) and instances of good and bad design.

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