Comparative study of design: application to Engineering Design

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COMPARATIVE STUDY OF DESIGN WITH APPLICATION TO ENGINEERING DESIGN

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1 Introduction

A recent exploratory study examines design processes across domains and compares them. This is achieved through a series of interdisciplinary, participative workshops. A systematic framework is used to collect data from expert witnesses who are practising designers across domains from engineering through architecture to product design and fashion, including film production, pharmaceutical drugs, food, packaging, graphics and multimedia and software. Similarities and differences across domains are described which indicate the types of comparative analysis we have been able to do from our data. The paper goes further and speculates on possible lessons for selected areas of engineering design which can be drawn from comparison with processes in other domains. As such this comparative design study offers the potential for improving engineering design processes. More generally it is a first step in creating a discipline of comparative design which aims to provide a new rich picture of design processes.

2 Background

Design processes across domains vary considerably in many respects from duration and risk, to scale and complexity. The special nature of processes in each domain is reflected in professional groupings and institutions. However, historical or technical boundaries to domains are becoming less significant as design projects seek to integrate several domains of expertise and practice. Many scholars of design process have examined, in a general way, the structure of activities or sub-processes which constitute a design process - activities such as concept formation, embodiment and detail design (see[1] and [2] for a recent review). In some domains; engineering, architecture and product design for example, there is extensive research and reflection on how designs are conceived and developed (e.g. Schoen [3]). There seems to be considerable attention to the two ends of a spectrum. At one end are general characteristics of design processes in all domains (e.g Asimow [4] and Drake [5]), and at the other end, models for processes in particular domains. For example Pugh [6], Andraesen [7] and Suh [8] present models of engineering design process, Evans [9] a detailed model for ship design, and Hales [10] a rich model of engineering in context.

Comparisons can also be drawn between domains and domains grouped together according to common features. This middle of the spectrum, between the general and the particular, offers potential benefits to design practice. First, design project teams have members drawn from many areas; second domains have developed selected elements of their processes for specific competitive advantage in their domains which may be usefully applied elsewhere, and third significant issues and problems in one domain may be informed by the ways that other domains deal with similar issues. Potential advantages of comparative design go beyond immediate practice in that it also offers a new route to design process research. Patterns of designing, involving many features may be repeated across several domains [11].

This paper reports the results of an exploratory piece of research in comparative design which addresses these issues. Four sections deal with method and general findings across domains. Section 3 outlines a framework for collecting and analysing data Section 4 outlines the participatory workshop based methods which were used to record data. Sections 5 and 6 describe some similarities and differences that were found across the domains in the cases examined. Section 6 examines some of the key issues of engineering design processes and indicates how across domain understanding can inform good practice in engineering design. To conclude, observations are made about the potential for comparative design to contribute to design research and the scope for further work.

3 Framework

As the aim of the research into design across domains is to compare how design is conducted in distinct and disparate domains, it was essential to develop a common framework within which to record the characteristics and key features of each domain. The framework represents a collection of issues drawing on the literature and reflecting the extensive empirical experience of the authors. It provided a starting point both for the investigators, as a set of features against which to record observations, and, for the participants, as a prompt to aid reflection on their processes. Eight categories were set out, each containing several sub topics as shown in figure 1. These, in turn were presented as specific questions in the briefing documents participants received before each workshop.

The framework ought not be considered as rigid - indeed one of the objectives of the exploratory phase of the research reported here is to assess its adequacy for recording and eliciting data and information from participants and as a basis for analysis. The framework proved effective in collecting data systematically. However, we note that although some of the participating designers used the framework and its categories explicitly to structure their project presentations others hardly referred to them. The investigators used the framework to ensure coverage in workshop questions and discussions as well as in follow up interviews. We noted that the categories did not pose problems for our participants who seemed to regard them as relatively neutral with respect to particular views or models of the design process.

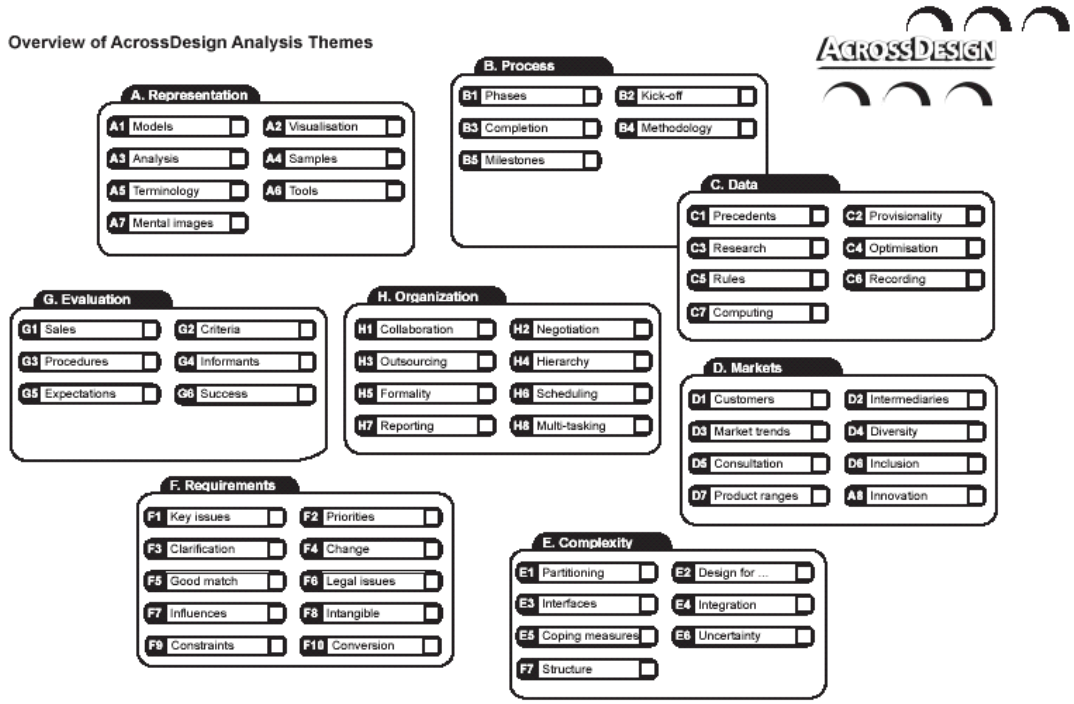

Figure 1. Categories of features of design used in the Across Design project

The research reported was conducted as part of a project called Across Design involving UK and US academic partners across several disciplines including engineering, architecture, computing, textiles and product design. A series of workshops, held over a period of two years, each with three or four participants from different domains started in 2002. The research in this project represented an initial exploratory stage of comparative design research and was not intended to be a comprehensive coverage of activities and processes in all domains. Rather it was an experiment with a framework and mode of investigation. It has led to some useful findings about design processes and has given pointers to the direction of future comparative design research and its potential benefits.

4 Participatory workshop method

Each workshop lasted a full day (with a second day for analysis) and consisted of (a) detailed presentations from each participant on a project from their practice and (b) clarifying, probing and discussion from other participants and investigators. We refer to below to participants as expert witnesses and this is how they were regarded in the workshops. Briefing notes presented the framework of issues within which the investigators collected their data (Figure1). The briefing asked participants to take the framework into account when presenting to the whole group which consisted of the other participants, and academic partners. As the workshops progressed participants at previous workshops returned as observers. Full audio visual recordings and transcripts of the proceedings were taken.

The briefing notes were used in different, but constructive ways by participants. Some fitted their presentations around categories if they felt that useful, whilst others ignored the details and structured their presentations and discussions in splendidly idiosyncratic and individual ways. The light touch on guidance proved especially valuable as it meant that the presentations were a mixture of descriptive detail, experienced reflection and designers 'selling' their expertise and capabilities. The latter provided insight into the vision designers brought to creative problems and how they presented themselves to colleagues and clients – a major component of the design process. There was considerable discussion among participants at each workshop. Feedback and strong engagement in discussions indicated that participants found workshops valuable as did the take-up of invitations to attend subsequent workshops as observers

The presentations and discussions were recorded audio-visually. Investigators also recorded their observations directly against the categories and elements in the framework. In some cases further interviews on an individual basis supplemented witness reports. This additional probing was necessary to clarify details of process – it proved surprisingly hard to get at the facts in some instances, especially with presenters who as experienced designers have encapsulated their projects as narratives for consumption by clients and colleagues. These 'engineered' presentations can slip over areas which are embedded as received wisdom and practice in a particular domain or which they prefer to ignore in telling their 'story'. We noted that the idea of ‘telling a story’ is not trivial. It seemed a key mechanism through which many designers communicated knowledge to others including ourselves as researchers, their clients and the third parties.

Table 1. Participant Domains

Oct 2002 (UK)	Automotive engineering (diesel engines), Software , Health, transport and consumer products , Architecture/Urban Planning
April 2003 (UK)	Civil engineering (structures), Web sites, Automotive styling and consumer products, Drugs/pharmaceuticals
July 2003 (UK)	Graphic media, Aerospace engineering and senior management (jet engines), Documentary film production
Nov 2003 (UK)	Artistic fashion , Medical devices, Food, Packaging, Architecture
Jan 2004 (USA)	Architecture, Technical fashion, Automotive engineering and senior management (cars)
July 2004 (UK)	Electronic products, furniture design, commercial and government software systems, course design

The participating designers at the six workshops to date came from a wide range of domains (Table 1) which can be grouped in subdomains. This is sometimes useful as a shorthand to refer to professional groupings like engineer or architect which cover a wide range of individual domains. The particular subdomains we have included are engineering (automotive, aerospace, electronic, civil), artistic (product design, furniture, fashion, packaging), architecture (structures, urban planning, small practice building) software (specialist, large government/company, embedded), science (drugs, food), multimedia (graphic media, film maker, web design, multimedia course design). These subdomains reflect professional boundaries rather than categories of process which emerge from the analysis.

The findings of this exploratory study indicated the characteristics and features in each domain and highlighted similarities and differences across domains

5 Similarities

With a wide range of design domains under investigation it was possible to observe common themes across the domains as well as more local similarities in subsets. The common themes did not always manifest themselves equally strongly but a selection of themes is now discussed which were prominent across all domains.

5.1 Improving processes

There was intensive interest among participants in continual search for better processes. They identified process improvement as a key to competitive advantage and directed considerable effort, including attendance at the workshops, to learning about processes across their own domains and wider. Examples from engineering – diesel engine design and electronic design – illustrate the strong emphasis on process improvement. Diesel engines as mature, but customised, products are subject to tiers of international emissions legislation and intense competition. Process improvements for meeting user requirements through product development tools and the effective use of computational modelling were vigorously implemented. The electronic designer described a 2-way pager designed for a market in transition under conditions of changing industry groupings. By a radical restructuring of team process, well documented and tracked, the throughput of successful products increased many times over. This witness regarded process improvement as a major achievement both in making it easier to customise the product for different markets as well as establishing new ways of working of benefit to future projects. The furniture design witness drove process improvement from craft design and production towards contracting out manufacturing process. The technical fashion witness displayed a mission to improve process through incorporating design for manufacture in apparel design. The food designer, creating a new ice cream, looked to improve processes by managing the communications between chemists and manufacturing engineers as well as more widely in a distributed team.

5.2 Quality

Quality is an important issue in every design domain. The precise concept of quality varies from functional reliability to pleasurable use (Jordan [12]) and depends on domain. For artistic designers and architects it is important to emphasise quality in the early stages of the design process. Artistic designers may design products over a year in advance of their launch and need to understand how taste and fashion will have changed by launch. A product design witness described a design for a hand held glucose tester for diabetics which had a strong emphasis on an ‘acceptable’ appearance. However, the schedule of release to market is determined by client and market. A delay in launch could render the product outdated at launch and so large effort is put into trend predication, market research and sources of inspiration.

Our architecture witnesses saw it as part of their role to broker between different groups of stakeholders to achieve quality. In particular, the architect/urban planning witness described a project designing a master plan for an urban redevelopment near London. At a critical point he presented a "*beautiful landscaped project. Now, there are five players involved … a financial adviser, a cost adviser, landscape architect, environmental designer and architect. Then there are highway engineers, transport advice …and then the developers come in with their own peculiar criteria which are opportunistic and market-based …And the real purpose of all this is so that the council can achieve high quality ... all this work is actually a quality control process.*" Software designers place great emphasis on the quality of the process for eliciting the product's requirements and translating them into software. For example our witness on large software systems emphasised the integrity of process as one of the guarantors of software quality through large scale requirements engineering and formal processes. Engineering designers place great importance on safe operation and reliable performance of their products and subject the products, prototypes and models to a series of well worked out tests and analyses. A graphic example was shown by our aerospace jet engine designer who shoed the industry standard bird tests on running engines. The food designer witness, reported a project where the opportunity for synthetic reproduction of a specialist regional ice cream arose because the natural ingredients for the product came from a protected species of orchid. Quality in this case was reproducing the texture, feel and taste of the original 'artisanal' or craft made ice cream, along with a stable product for mass manufacture and distribution.

5.3 Product architecture.

Product architecture represents the underlying structure of parts and subsystems and is an important issue for complex products especially when offered in several different versions. The diesel engine and automotive engineering witnesses emphasised the role of the common, often modular, structure of customised products which allowed reuse of components. Product architecture is also an issue for simpler products as described by our technical fashion and graphic designer witnesses. Their design processes illustrated a formal view of the product and the structure of its parts with integrity of a product range coming from recurring features. Related studies of knitwear design [13] show that considerable effort is devoted to developing interesting features that are used to tie collections together and get reused for several years as minor features in other designs.

Architects try to standardise parts of the buildings. One of our architect witnesses partially standardised service cores, in order to reduce design effort, even though there might be little economy of scale in construction over different sites. In software design one of our witnesses emphasised the inheritance of legacy systems – existing structures and functionality - into new designs. Food designers use different materials to achieve different features of their products, e.g. flavouring ingredients or gelling agents. Sometimes several features will co-exist as an 'architecture' for a range of foods. The food design witness pointed to the importance of patent protection of the 'stringiness' of the synthetic artisanal ice cream because of its potential in other products such as synthetic mozzarella cheese.

5.4 Identifying and managing risk

Risk, in many forms, is a constant concern. A companion paper [14] gives details. From technical to personal risk, managing and trading off the different risks is a key capability of designers. Identifying and managing the two components of risk - uncertainty and impact - proved difficult in many domains. Periodically reducing uncertainties identified by Suh [15] as a way of reducing uncertainties is demonstrated in freezing changes in the staged processes described by our automotive designers, for example.

Assessing and controlling impacts proved more difficult. For example a medical device designer described the product and market uncertainties of a needle free injection system. The response by *"trying to satisfy a small number of very big companies"* in manufacturing to tight specifications across several markets meant that product variety was high and costs ran out of control. In architecture and product design initial client uncertainties were managed through negotiation and extensive use of mediating representations such as models and visualisations. These domains also try to manage impacts by assessing design quality indices (architecture) or acting in a well defined contractual arrangement with a client who is manufacturing and supplying the product. Our expert witnesses noted a changing balance of risks as through-life performance and potential for future product development become more important at initial design stage. This covered not only the engineering domains in aerospace and automotive but also architecture, urban planning and software.

Domains which were exceptionally uncertain such as drug design and film making were interesting in their response. In drugs systematic search helps ensure opportunities are not missed *("this was on a pinpoint of balance. One tiny change to the chemistry and the properties are gone")* whilst in documentary film production based on 'found' materials *("I work with found materials. The things I filmed were only marginally under my control*") it seemed that the strength of underlying ideas served to direct search for materials and form them into final film.

5.5 Different views of multiple stakeholders

A common characteristic exposed by the comparative study was that design processes need to deal with different views on many factors such as requirements, performance, purpose, appearance, schedule and costs. The design process more or less harmonises the different views of multiple stakeholders, facilitating and clarifying expression of different views through mediating representations. This was particularly visible in the urban planning example where the role of the architect/planner at the early design stages was to generate and help articulate stakeholders' views from residents to developers: *"master plans emerge out of people's work as partners in process"*. This example also emphasised the importance of assessing the extent to which different views and requirements are balanced in a single design through quality indicators. Our civil engineer reported an interesting tension between engineers and project architects resulting from different perceptions of the route to a high quality building.

Designers provide the constructive resolution of competing views of different stakeholders through design proposals. In some domains, such as product design, this is manifest as the designer providing a missing ingredient or vision. As one product design witness remarked, *"Our skill is to create a personality for the product."* Further he noted that *"It is amazing how often the client's team don't talk to one another"*. Finally, the different views of stakeholders – clients, customers, manufacturers and suppliers, for example, - are resolved by concentrating on common questions to each party - such as the value of the product for example. The imperative for the designer is then: *"how do you reflect the value of a product?"* as the product designers remarked.

The example of the medical device designer is instructive because the design process tried to meet many different views – in this case different requirements of different market segments and strong market leaders – which contributed to cost and schedule difficulties. Domains such as software engineering exhibit complex relations with clients as requirements emerge, whilst food design presented a more constrained scientific exercise. Stakeholders can be mainly internal such as in drug design within pharmaceutical companies where different departments and divisions are stakeholders or mainly external as in the case of our medical device designer. Further, the stakeholders change from project to project although there may be a degree of commonality. Our witness in civil engineering and structural design noted *" the architect and engineer might work together on many projects, but only once with the same client"*.

5.6 Sensitivity to details

The line separating success and failure can be hard to pin down and depends upon the smallest details. Across our witnesses the attention to details by these experienced designers was clear. Success in artistic domains such as product design, fashion and film production was only realised by particular attention to detail. In drug design, searching systematically through detailed changes in chemistry (our witness showed very similar molecular structures with significant differences in pharmacological properties - *"This was on a pinpoint of balance. One tiny change to the chemistry and the properties are gone")*. A further complexity lies in the fact that designs are more or less optimised for performance and small changes can move the design a long way from optimum performance. This was especially clear in engineering domains such as aerospace jet engines but was also for artistic domains such as product design where detail drives success - "*The X factor - the factor that makes you want to buy that product*" as one product design witness said.

5.7 Expertise talent and experience

Experience and expertise were characteristics of all participants, indeed witnesses were chosen on these grounds. They presented views on the nature and importance of this expertise and how it contributed to process. We noted that each participant considered themselves as having a special or distinctive design expertise.

A key common characteristic, however, was the ability to understand both details and context. They were able to identify critical details and pursue them. Taking three of our participants as examples - the drug designer, the film producer and the jet designer - we observed that they were tenacious in developing details once they felt they could see a route to a solution. Details were considered in context of wider implications for costs, tradeoffs, markets and financial returns. It was remarkable to observe the seamless juxtaposing of details and context throughout the presentations by our expert witnesses.

It was perhaps surprising to observe that all domains used intuition in their search and decision making. In many cases, especially in highly uncertain domains we expect this since many possibilities and relatively few constraints give intractable searches. However, in more systematic domains such as engineering the workshops drew out the considerable uncertainties and the role of intuitive judgements which are validated through models and prototypes, although this is time consuming and expensive. As the structural engineer said *"even as computers get faster it takes a long time to prove that things are ok"*.

5.8 Importance of precedent in the design process

The expert witnesses at the workshops were asked to review at length a significant project. Their presentations made detailed reference to the significance of other related designs, both in discussions with clients and other stakeholders as well as in providing points of departure and sources of inspiration. Analysis of competitors' products is key across all domains from automotive and aerospace to fashion and graphics. One witness who stressed this particularly was the automotive diesel engine designer. Comparisons within the company about which features worked in previous products indicates targets for reuse and the diesel engine designer gave a strong account of such reuse. Timeliness is universally critical and designers spend considerable time and resources in keeping up to date. Our product design witness described a blood glucose self tester for diabetics and explicitly used sporting associations with watches in shape and configuration improve acceptability

Similarities across domains were certainly expected but the extent of common practice (and common problems) was surprising. The interest of the participants, and value of the workshops, was confirmed since several participants returned to subsequent sessions as observers. However, similarity did not indicate any uniformity and there were many differences.

6 Differences

In this section we consider some of the more significant differences we observed. One of the striking differences between the projects discussed were the different scale of the projects and the resulting diversification of roles within the design process.

6.1 Size of team and project

Some designers worked on their own carrying out the entire process from market analysis to prototype delivery by themselves. The graphic designer worked alone whilst others such as the web designer and one of the software designers worked freelance with a very small team. The architects, the fashion designer and the film designer worked in small well established team, while the engineers, the food and drug designer and one of the software designers worked in large teams with clearly defined roles. The boundary of the team was not always easy to establish from the witnesses. Automotive and aerospace engineering depend on large teams with requirements for coordination which determine the general characteristics of the process with established product architectures, staged development and clear definition of roles.

The size and complexity of projects varies considerably across domains. The descriptions of details of working in the large projects seem to have little relevance for small projects and vice versa. The processes of the drug designer, with extensive searching of possible compounds and testing, are quite different from the graphic designer working closely to client specification. The idea of size is relative since a 'big' project in one domain could look 'small' in another domain. Further, each domain has its own vocabulary to describe its processes which may exacerbate differences. In the third workshop where an aerospace designer presented with a film producer, the differences in scale and vocabulary were significant. The former is a long life product with technical support and maintenance a key objective whilst the latter is a 'for the moment' hit making its mark at transmission.

6.2 Boundaries of responsibility

Large complex projects have well defined task boundaries whilst smaller projects rely on an entrepreneurial and individual approach, making connections opportunistically. The former displays greater formality of process and language for mapping out roles precisely and providing clarity of communication across boundaries. The well structured processes of diesel engine design in a competitive regulated (for emissions) market have clearly defined structures of responsibilities and roles. The scope of a task within the product life cycle affects the boundaries of responsibility. Sustainability and commercial pressures for full product life cycle design mean that through life maintenance, service and disposal of complex products extends the scope of the design task and associated responsibility through the life cycle. The aerospace jet engine designer gave an account of this aspect with one of main drivers being moving the boundary of their product from a delivered and maintained product to a service for clients and customers – ‘on wing’ time becomes a priority.

6.3 Creativity

An apparent difference between domains is the way that creativity is expressed. It is not creativity itself which distinguishes domains. Stakeholders in artistic, fashion and media projects present themselves more strongly as offering new creative solutions than their engineering design counterparts who convince through more apparently rational and systematic approaches. The civil engineering (structures) witness reported this distinction in the way that architects won competitions with innovative schemes whilst engineers solved the associated structural problems in realising the design. It is interesting that the drug designer presented a key aim to make drug design as systematic as he perceived the engineering design of aircraft. Different professional cultures and differences in education and training contribute to creating professional identity but magnify differences. Indeed it was observed by several participants that education was often too specialist for their needs.

The aesthetic and qualitative drivers can be strong in some domains with intuition guiding product development and subjective decisions based on feeling and judgment. Decisions are made because they feel right and without apparent rational foundation. Our witnesses conveyed smaller differences than expected in aesthetic and qualitative drivers across domains. For example the drug design witness remarked on referring to a new compound which ultimately became new drug " *this is not a chunk of coal, this is a sort of elegant molecule, pretty small, pretty neat".*

The above differences are indicative. Many more were observed as differences in emphasis and importance afforded to elements of the design process. Next we examine how knowledge of other domains can inform and potentially improve processes in engineering design. To do this we concentrate on a few areas of engineering design processes for which we have observed good practice in other domains.

7 Learning across domains: lessons for engineering design

The aim of the project is to take a view across all design domains building a rich picture of design processes. However, the enterprise has more immediate benefits in that knowledge of processes in other domains may offer solutions to the problems and challenges of individual domains. For the purposes of this paper we indicate the benefits of comparative study for selected areas of engineering design where other domains have well worked out procedures.

7.1 User needs and interests

Some domains give greater emphasis to user needs and interests. Our study indicates that possible areas where good practice might be transferred to engineering design include:

Trend prediction: small engineering companies may find it difficult to identify functionality and styling for a new product, whilst large companies with experts to translate perceived market needs into a technical specification leave individual engineers short on where trends are going and where requirements come from. Our observations here and elsewhere [13] show that the fashion industry and other seasonal artistic design domains, systematically expose themselves to the trends; consulting specialist trend forecasting,, attending shows and visiting local and international shops. Market leaders put more effort into this research process.

Brokering the needs of stakeholders: a product rarely has a single user with a single use, but has many stakeholders who view it in different ways. We have seen how our architect/urban planning witness facilitated the negotiation process between different stakeholders. As the different stakeholders have different interests and prior knowledge designers may produce different representations for each group, for example sketches, hand rendering or computer simulation. Our product design witness described different representations and models which he used for different groups of stakeholders and the film producer emphasised that extensive discussions of ideas, intentions and ways to implementation were critical among stakeholders. The mode of representation for the film producer was primarily verbal rather than visual because the latter "*would be too constraining*".

Educating the users about their needs and interests: Customers may not know exactly what they need and can be pushed into providing inappropriate requirements. Our product designer witnesses educated clients in 'vision' for their products. Both our architect witnesses conducted lengthy, managed, discussions with clients as a process of education in expressing their needs.

Eliciting and maintaining requirements: products are rarely designed to meet a single requirement, but a complex web of requirements, which are likely to change over time – even during the process of design. In engineering the work of an engineer is seen as beginning once the requirements are elicited and new requirements lead to fairly formal change processes. Our corporate and government software expert emphasised that company processes, for which software is being developed, may need to be changed at the same time as developing the software.

7.2 Manufacture and delivery to customer

At the end of the design process when the product is nearly ready, engineering designers often see their tasks as being done. A finished prototype has been produced and the setup for manufacturing appears a formality. They are aware of the need to conduct multiple tests to check functionality, they are surprised by small, but costly changes to accommodate manufacturing. Our food design witness provided an interesting insight into how much of design is getting a product ready for production, storage and distribution. Working out the initial flavour and texture of the ice cream is a relatively short process compared with determining how mass manufacture of the ice cream can replace artisanal 'craft' manufacture and making sure the product will be safe under all use and abuse situations until its sell by date and beyond. Our medical device witness found the problems of scaling up manufacture for several markets different partners overwhelming.

7.3 Creativity and innovation

Artistic domains often strive for newness, whilst engineering design often tries to avoid it where possible. For example our expert witness from automotive diesel engine design formally assesses newness of a product and adjusts process, especially validation. Our expert in aerospace design who leads the design of state-of-the-art jet engines views the nurturing of a creative culture through exploration and sketching ("*I believe that sketching itself is not only able to capture concepts, but it is also a way of being creative")* as a vital part of new product development. To this end he had invited designers from other domains, such as consumer products, to discuss their work with his engineers.

We observed that potential cross-overs to engineering design also lay in sources of inspiration and environments which can assist creativity. Our civil structures witness remarked: "*Design [architecture] competitions can be an unrealistic basis for an engineering brief but engineering problems often produce dramatic buildings".* In film production, discussion and negotiation in small groups allowed free rein to ideas and associations. Drug design showed a well developed exploratory phase using dedicated computational tools, with rigorous assessment of results. Packaging design develops brand and product identity and our witness in this domain emphasised collaboration around shared 'space', sharing creativity tools and actively collaborating in the exploration of possibilities. *"We have something called an innovation process management which is where we start, taking ideas, going through a charter gate…. The charter is about getting enough resource to form the team".* There are lessons here on collaboration in creativity especially for engineering design projects where the decomposition of teams along technical capabilities emphasises collaboration by task imperatives rather than as creative opportunity.

7.4 Negotiation

In the example of packaging design referred to above, negotiation is associated with collaboration. Negotiation about which are the best ideas, negotiation about brand and customers, negotiation about responses, are all included. However, negotiation needs reference points and the packaging designer created "*shared understanding … around shared …Design Space, which you could think of as a table around which players or stakeholders sit".* Negotiation also takes place around mediating representations produced by the designer with clients and stakeholders. A strong example of this was the architecst/urban planners who, in the early exploratory phases of creating a development plan, regarded themselves as the generators or pictures, models and visualisations which became the objects of negotiation. The architects were effectively formulating a language in which stakeholders negotiate. Negotiation in engineering design is not as well developed as some other domains. Firm, explicit requirements are looked for early in the process where negotiation with users, clients and stakeholders might sometimes offer a more effective route. Our electronics design witness described the design of a 2-way pager and noted the importance to their process of negotiating change in specification with the customer because the market and user requirements were changing quickly in a declining market. Lessons for engineering design in general are not to leave this negotiation until late in the process. Although finished designs or prototypes are available for objective assessment they are costly to change.

7.5 Risk

Risk as a common theme across domains was introduced above. The case is made in a companion paper [14] that domains where particular types of risk dominate are instructive for domains where similar risks are less significant. The drug design witness described considerable financial and patient safety risks and noted shortcomings in his process - *"we need to understand the principles, the properties of molecules and therefore how we design drugs"*. However, engineering designers observing the search and data-capture methods and tools of the drug designers might reflect on their own management of risk which tends to restrict search and exploration.

Our architecture, software and artistic design witnesses considered that missing the real requirements of users was a significant risk. Feedback on the designs are especially personal for artistic designers, where the quality of the product is hard to assess objectively. Our artistic fashion witness described this in detail, particularly the emotional risk through failure in their products or processes. These risks may too easily be ignored in engineering design.

8 Conclusions

The paper reports research which compares design in different domains using a method of participatory workshops for expert witnesses. For collecting data a common framework is employed. Participants engage with this framework through being invited to use it to structure their presentations to the workshop. The workshops were assessed by participants as being of value to themselves, individually, as designers.The participatory form of the workshops, with each workshop having at least one engineering design participant, helped to draw out the areas we have described where good practice can be transferred to engineering design.

This paper has done two things. First it examined the rich picture of design and its processes through reviewing similarities and differences across the domains represented. Second it has looked across to other domains to observe good practice in tackling challenging issues for engineering design. The prospects for future work include mapping out persistent patterns of designing across several domains as the basis for a systematic study of 'comparative design'.

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