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UNITED WE STAND: A CRITIQUE OF THE DESIGN THINKING APPROACH IN INTERDISCIPLINARY INNOVATION

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Abstract There has been a recent upsurge in the promotion of 'creative thinking'. The input of several disciplines is necessary to innovate new products and services. However, there remain many challenges to collaboration amongst creative and science-based disciplines. This paper examines disparities between designers and technologists when innovating and tackling problems. It is suggested that dominance of one party is likely to result in inadequate results. This paper seeks to explore how collaboration can be mediated by design thinking. A case study of designers and technologists working on a software development project is presented. The case study highlights challenges resulting from differences between designers and technologists. Guiding principles aimed at facilitating collaboration are outlined. Finally, the paper reflects on the symbiosis between the disciplines, and how difference in fact cultivates innovation.

KEYWORDS: Interdisciplinary teams; design/technology collaboration; design thinking; design projects; project management

1. Introduction

While there are inherent differences in how the arts and sciences have evolved, rapidly changing present contexts are demanding greater intersection of disciplines. There has been a shift towards uniting creative- and science-based disciplines over the past decade. The value of 'creative thinking' gained popularity as a means to stimulate the industrial sector in the 2000s. Official reports (e.g. in the UK, The Cox Review (2004) and the DTI's (2005) Economics Paper 15; in Ireland, the Forfás (2009) report on skills in creativity, design and innovation; in Denmark, the Danish Design Council's (2003) report on the economic effects of design) herald a change in attitude towards the importance of creativity, and particularly design, as a means for stimulating economic growth through innovation. This shift is reflected in the inclusion of design within innovation and technology projects, for example in those run by Innovate UK and the European Institute of Innovation and Technology, whose programs recognise the importance of design and creativity as a critical component in interdisciplinary projects.

In terms of innovation, it seems that the division between disciplines is outmoded and is potentially restricting, as forecast by C.P. Snow almost 60 years ago (Snow, 2001). However, in modern education, the divide is still evidenced in the early specialisation between arts or sciences subjects in some national systems (Archer et al., 2013). The dichotomy of self-definition as *either* creative *or* scientific (i.e. having a disposition for analysis and logic, or intuition and holistic thought determined by dominance of the 'left brain' or 'right brain') is equally dated and false. Rather, recent research in the field of neuroscience emphasises equal connectivity and activity in both hemispheres of the brain when problem solving (Aziz-Zadeh, 2013; Nielsen et al., 2013). Table 1 summarises the qualities conventionally associated with the sciences and the arts, and delineates the groups of professionals categorised as 'technologists' and 'designers' in the course of this paper.

While the arts/science dichotomy is an overly simplistic categorisation, the notion of difference endures, making collaboration and interdisciplinary projects challenging. Inter- and intraorganisational projects are often blighted by problems (Lovelace et al., 2001). Research focusing on interdisciplinary design projects illustrates that several problems arise relating, for example, a lack of shared vision (Kristensen, 1998) and difference in language (Murray and O'Driscoll, 1996), leading to strained and misunderstood relationships (Dumas, 1994; Svengren Holm and Johansson, 2005). In terms of academic research, funding sources tends to divide disciplines, creating difficulties when establishing cross-disciplinary projects (Bruce et al., 2004).

Table 1: Qualities of the sciences and the arts

Sciences	***Arts***
Mathematics, physics, engineering	Creativity, language
Logic	Intuition, subjectivity
Left brain	Right brain
Linear, sequential	Holistic, chaotic, divergent
Reductionist enquiry	Naturalistic enquiry
Facts, figures, formulae	Interpretive forms, subjective expression
One correct answer	Many solutions
Technologists - computer scientists, software engineers, information science experts, coders…	***Designers*** - product designers, interface designers, design researchers, graphic designers…

The trend towards interdisciplinary collaboration highlights the need to revisit the dichotomy. How disciplines approach problems reflects their inherent differences. While disconnect can be problematic in projects spanning disciplinary divides, it is in fact difference upon which interdisciplinarity thrives (e.g. Kelley and Littman, 2006), and which can be considered to enhance innovation.

This paper explores the variation in approach, methodology and working methods of two divergent disciplines. Using a case study of an interdisciplinary software development project to investigate this issue, the authors look specifically at the case of designers and technologists. The article highlights divergences and convergences in the working processes of designers and technologists, including problem-solving approaches, terminologies, and methodologies. From this discussion, the benefits of resolving disciplinary divides emerge, particularly in relation to the adequacy of project outcomes. The paper offers guiding principles for addressing interdisciplinary differences. It is suggested that acknowledging and embracing difference is crucial for the success of interdisciplinary collaboration.

2. Innovating across cultural borders: The case of design and technology

The need for disciplines to work collaboratively enhances NPD (new product development) success (Felekoglu et al., 2013), particularly where products are highly complex. NPD stakeholder collaboration is assisted by 24/7 digital communication, the ability to instantaneously share updates to work-in-progress via the internet (Maciver et al., 2015), and the capability to work alongside partners in different time zones on production and manufacture (Kumar and Whitney, 2007). These shifts propagate the shift from traditional, bounded forms of working towards an expansive, holistic, interdisciplinary viewpoint. In this paradigm, collaboration with others stakeholders – from different countries and subject disciplines – is vital to contemporary practice.

Working practices are inextricably linked to the types of problems faced by disciplines. According to Rittel and Webber (1973), problems faced by technologists are 'tame' and can be solved rationally according to the principles of mathematics and physics, and with a correct or incorrect answer. By contrast, those of the design discipline are 'wicked', not conforming to any logical sequence, framework or methodology, and with many possible solutions. The starting point and style of problem solving strategies therefore varies for designers and technologists, and this can be stifling for innovation. In interdisciplinary projects, conflict and misunderstanding can occur as a direct result of the difference in backgrounds, approaches and expertise (Kim and Kang, 2008).

New product development theory offers insight into the variation in styles of innovating. The traditional modes are 'market pull' and 'technology push'. In the technology push approach, effort is focused on the acquisition of scientific knowledge, and in constructing new products around technology (de Assunção, 2008). This implies a passive role for users, the market being a receptacle for technological endeavours (Rothwell, 1986). By contrast, the market pull approach has its focus on demand and user research. By learning what the customer needs and desires, firms then respond by developing appropriate products. These contrasting approaches to innovation are compared in Figure 1.

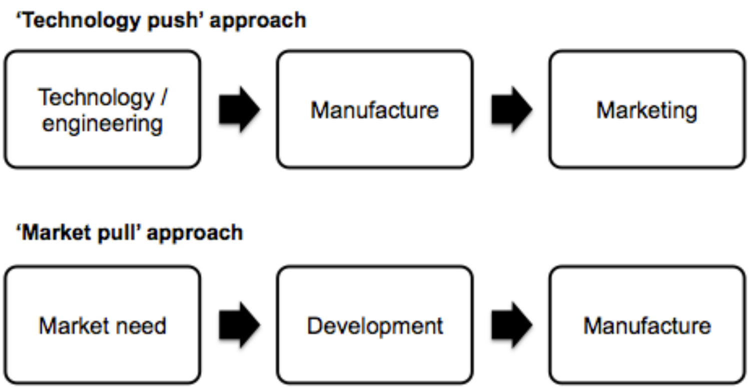

Figure 1: Two modes of the innovation process (adapted from Rothwell, 1986:110)

Factors such as product type, newness of the market, and age and expertise of the firm also affect the adopted strategy. For example, it has been suggested that smaller firms commercialising disruptive products are better suited to the push approach (Walsh et al., 2002). In general, where technologists instigate and lead NPD, the technology push approach is more common, while the market pull approach is more likely where design leads. However, one is not exclusive of the other: Lubik et al. (2012) posit that the strategic orientation can alter over time. Indeed, both modes have value and application in different situations, while Brem and Voigt (2009) suggest that the two styles can be combined. The following sections discuss and compare the paths of design and technology approaches in greater detail.

2.1 People at the centre: the 'market pull' design approach

In discussing the design approach to innovation, it is first necessary to reflect on the design discipline. Design by nature is concerned with the unknown, and with possibility. The role of the designer is considered to centre on improving existing situations (Roth, 1999; Simon, 1996). A fundamentally inquisitive disposition creates fluidity in structure, where the problem space is undefined and constantly evolving (Galle, 1996). New information is continually entering the process, meaning that the design problem and its solution evolve simultaneously (Cross, 1997; Lawson, 2005). Moreover, the requirements of the actors in the process (e.g. the society and people for whom the outcome is intended; the designer's personal subjectivity, taste and style) are balanced in the solution (Dorst, 2008; Forty, 2005). Significantly, the focus on people and problems permeates the design approach. Form, function and materials are only one part of a wider investigation where designers need to understand what makes a product 'useful, useable and desirable' for the people for whom it is intended Buchanan (2001:13).

The design process itself also offers insight on methodologies. The unpredictability of design means that there is no single methodology (Candy and Edmunds, 1996; Design Council, 2007), but broad principles underlie every design process. The Design Council's Double Diamond, a widely accepted framework, identifies four basic phases through which any design project progresses that allow teams to explore ideas, test solutions and innovate. The model also indicates that iteration can occur during phases, and that previous phases may be revisited during the process, a proposition which takes into account different modes of thinking (generative, externally-focused divergent loops, followed by evaluative, iterative, internal-facing convergent loops) occurring throughout the process.

The characteristics of design, such as lateral thinking and the ability to deal with ambiguous questions, can be deployed in a variety of contexts to bring new insights. The result is reflected in the designer's typically broad starting point in projects. Indeed, the Double Diamond encourages divergent thinking for generating multiple alternative ideas. Theory and practice suggest that an expansive approach to idea generation fosters innovation. For example, innovation consultancy IDEO retains all ideas gathered in the early phases of the design process for a later evaluation stage (Kelley and Littman, 2001). Common techniques used by designers focus on user research (e.g. Bruseberg and McDonagh, 2001; Fulton-Suri, 2005; Sanders, 2002) – integrating users in product creation (Redström, 2006) – as well as design-focused activities such as sketching (van der Lugt, 2005) and collaborative sketching (Malins et al., 2007; Tang et al., 2011); team-based brainstorm sessions (McAdam and McClelland, 2002); and mind mapping (Kokotovich, 2008).

Notably, the influence of human actors in design – designers and users – is at the forefront of the evaluation of ideas. In essence, how well the solution meets the needs of the intended user rests upon a range of distinctive criteria, including specific user needs (Papanek, 1984), rather than upon a standardised framework. In practice however, this unfixed, ambiguous stance can be misunderstood by other disciplines. We now contrast this with the technology push approach.

2.2 Science leads: the technology push approach

The development of new technology is driven by skills- and technological knowledge. In the technology push approach, customer groups and needs are investigated after the innovation is developed. This approach is typically adopted by SMEs and start-ups whose focus is on one particular innovation, or by university research teams where there is a premise for basic science and radical breakthroughs (Souder, 1989; Lucas, 1994).

While engineering literature highlights the importance of applying the principles of usability engineering (Nielsen, 1994), such as the technology acceptance model (e.g. Davis, 1989), and the user-driven design paradigm (e.g. Beyer and Holtzblatt, 1998; Greenbaum and Kyng, 1991; ISO, 2010; Koskinen, 2003) during the technological development of products and services, research on users is rarely deployed from the early phases of development. Market research is more likely to be undertaken in later phases, such as during evaluation of product performance, and to gauge perceived usefulness. How valuable such research is subsequent to costly development processes is questionable: Cooper (2011) emphasises the value of front-end homework in enhancing product success.

Indeed, a user-centric approach is considered to have significant drawbacks. For example, users are often unable to express latent needs or to imagine the possibilities of technology not yet in existence (Norman and Verganti, 2014). Furthermore, many innovations have been conceived without an initial clear purpose. For instance, the need for mobile phones and data connectivity arose post-invention (Pantzar, 1996).

2.3 Design thinking: Evolution of a unified, interdisciplinary method

Both the design and technology approaches have application in different situations. As previously described, the current context of innovation requires greater collaboration and the exchange of ideas across disciplines. However, in Brem and Voigt's view, reliance upon science based, technology push modes, at the expense of creative dominated market pull, is potentially damaging. There is symbiosis between the knowledge and insight brought by both sides. Therefore, flexibility and the ability to shift between different modes of innovation, as well as knowing when to do so in the course of a project, is key.

In doing so, balance, mutual understanding, and better integration are required to meet the evolving challenges of the current climate (de Wit and Meyer, 2005). This proposition has great currency in interdisciplinary innovation. While the modes of innovation deployed by design and technology disciplines have different starting points, there exists inter-reliance between the knowledge brought by both sides during collaboration. A tangible product cannot be conceived without the application of creative ideas and attention to users brought by design, nor can it be realised without technological skills and knowledge.

Recent interest in creative thinking suggests that multidisciplinary teams can harness the tools and approaches of design thinking (Nussbaum, 2013). The notion of integration is core in the design thinking methodology. Design thinking is considered to offer a methodology for the collaboration of arts and science poles of project teams. Brown (2008) emphasises crossover between creativity, technology and commerce, and suggests that this approach excels in strategically converting need into demand (Brown, 2009). Indeed, design has precedence in assuming an integrating role where art and technology disciplines are concerned. The word 'design', derived from the Latin meaning 'sign' (Flusser, 1999), has evolved to bridge the cultural gaps between art and technology since the Industrial Revolution (Coles, 2005). Likewise, design management literature emphasises its strategic placement in organisations, suggesting that it acts as a bridge between the technology and R&D and commercial management functions (e.g. Lorenz, 1990; Rassam, 1995). Similarly, Verganti (2006) suggests design straddles several disciplines, and is a lynchpin in interdisciplinary networks.

Such integrative approaches can be applied in a range of contexts and situations. In Simon's (1996) view, design skills are transferable to nondesign functions. At organisations such as Google, employees are referred to as 'designers' regardless of function: engineers, biologists, technologists, researchers. Furthermore, these inclusive approaches can be deployed in different situations to tackle a variety of problems. Design thinking methodologies have been used in multidisciplinary teams innovating and improving situations as diverse as crime prevention, social work and health care, and education (e.g. Brown, 2009; Kimbell, 2011; Press and Cooper, 2003).

However, how projects unfold, and the level of creativity enabled, depends in a large part upon the interactions occurring between team members (Vissers and Dankbar, 2002).

Surmounting division is therefore essential in innovation. The paper now explores the challenges of interdisciplinary collaboration by way of a contained case study detailing a research and development project with which the authors are involved.

3. A case study of interdisciplinary collaboration

The collaborative project used to examine the issues explored in this paper focuses on a research group developing new software. Funded by the European Commission under the Framework 7 programme, the project is entitled 'COnCEPT' (an acronym for 'Collaborative Creative Design Platform'). As the name would suggest, the software is targeted at the design profession. The development of such software is complex, calling for the expertise of a range of disciplines. The pan-Europe specialists in the assembled consortium work together collaboratively, sharing knowledge and skills. The team meets periodically for workshops, plenaries and review meetings, as well as speaking regularly on bi-weekly conference calls. Partners from academe and industry represent the disciplines of computer science and software development; information science; design; design research; and human-computer interaction (HCI). The project coordinator is a leading software company.

In the course of their participation in this team, the authors have observed and identified three key areas of challenge affecting how effectively the consortium works together. These are: a) incongruity in the project foundations; b) varying interpretations of terminology; and c) methodological disparity. Interestingly, formation of subdivisions along the lines of the design and technology division, have been noted. The case study illustrates the theoretical discussion on disciplinary divisions operating in practice. It also makes suggestion as to how constructs of design thinking have been strategically deployed to manage collaboration with varying degrees of success.

3.1 Where to start? Reconciling incongruity in project foundations

At the outset, the project was divided into seven work packages (WPs), which progress through the stages required to realise a new piece of software: 1) an initial scoping of the requirements of users, and gaps in existing market offerings; 2) enquiry into inner knowledge management structures of the solution; 3) conceptual modelling of the software application; 4) technical feasibility, integration and realisation; and 5) evaluation and piloting of beta versions in the field (Figure 2). Two further WPs deal with dissemination and exploitation of the results, and overall project management.

The project structure resembles the design thinking approach. Figure 2 compares the sequences of COnCEPT WPs with the design thinking methodology developed at Stanford

University's *d.school*[1]. The project structure acknowledges areas of overlap between disciplines, both in terms of timing of tasks, and in content. For example, smaller chunks of work undertaken as part of prototyping the software as part of WP3 overlap with the testing in WP5. This is reflective of the non-linear, unpredictable nature of the design process.

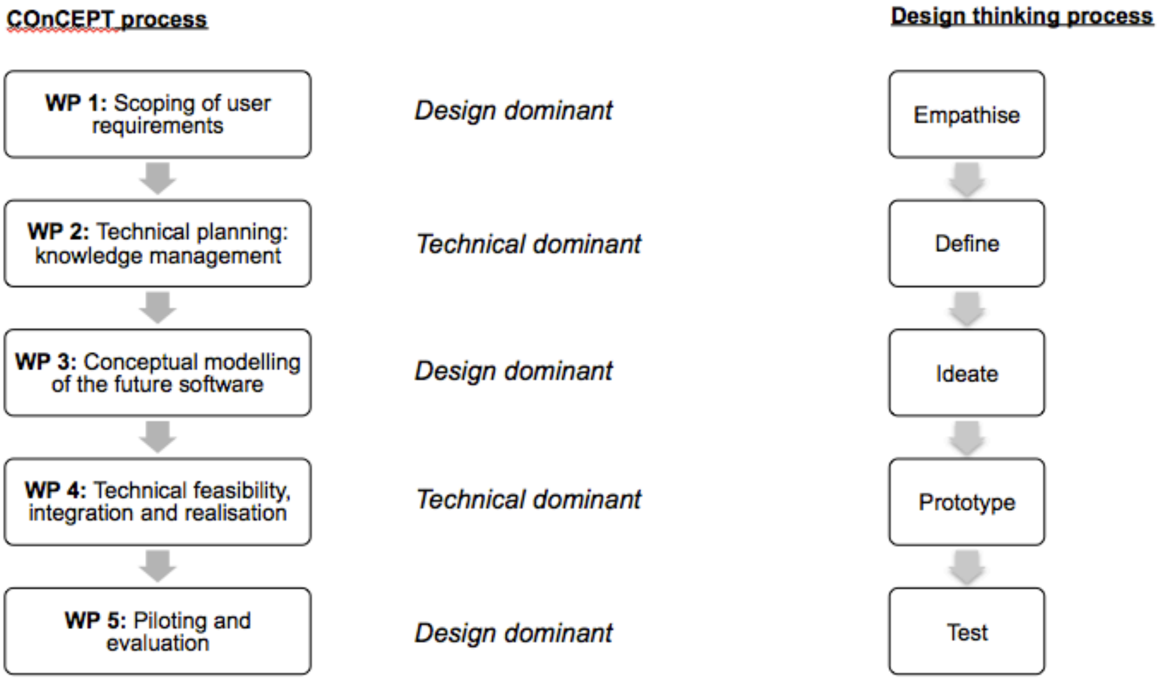

Figure 2: Organisation of tasks in the COnCEPT project

While in theory the design thinking approach emphasises the value of interdisciplinarity in each phase, in practice this has been problematic. The initial meeting, where the parameters and focus of the future COnCEPT platform were discussed, set the precedence for the project progression, and reflects the predilections of the technical and design partners. During this meeting, the technical experts concentrated discourse on technical and practical aspects of realising the software application, for example on deep coding, interoperability and search tools. In contrast, the design partners' priority was to discuss workflows in studios, and explore how these may be supported.

This illustrates a marked difference between the practical, logistical approach of the technologists, and the conceptual, holistic approach of the designers. In effect, the 'how' of the COnCEPT platform quickly became the realm of the tech team, and the 'what' became the designers' domain. There was no challenge to encourage disciplines to move beyond comfort zones or areas of expertise, and by consequence, the workload for each partner per WP was subsequently allotted along these boundaries. Although all partners have input in all WP, the weightings and partner interfaces adhere to disciplinary boundaries, and this has

[1] For further information, see: http://dschool.stanford.edu/dgift/

the repercussion of distinct cycles of activity which unfold according to the characteristics summarised in Table 2. For example, WP2 and WP4 are dominated by the technical partners' quest for practical advances in the software's development, while WP1 and WP3 focus on the design partners probing for deep understanding and to produce a range of potential solutions.

There were several opportunities to amalgamate the views of all partners, particularly concerning the choice of prototype alternatives. However at workshops to arrive at consensus, technical partners homed in on the feasibility of the solutions, while design partners discussed usability issues, reinforcing the disciplinary stereotypes set in the initial discussions.

Table 2: Comparing work processes in the COnCEPT project

	Technologists	**Designers**
Focus	The 'how'	The 'what'
Approach	Practical, logistical	Conceptual, holistic
Process	Linear, step-by-step	Iterative responsive to user feedback
Methodologies	Scientific discovery, testing	Idea generation, user research

Despite the disciplinary divides in COnCEPT participants, the division of tasks has reaped a functioning beta version of the software, currently in the iteration phases. The prototype connects the operational back-end of the software being completed by the technical partners, with the front-end work on interface and functionalities being completed by the design partners. Therefore, while there have been breakdowns in approach and priorities, it is surmised that each has had value at different stages of the development process. The strongest indication of the success, however, will be its pending evaluation with end users. Pilots will build the foundations for subsequent iterations.

3.2 Deciphering conflicting languages

Interpretations of certain terminology vary according to the background and discipline of the speaker and listener (Snow, 2001). This proposition has currency when working in interdisciplinary teams, especially those composed of creative- and science-dominant experts. In the COnCEPT consortium, there is evidence that terminology can lead to misunderstanding of the focus of areas of work, summarised in three examples in Table 3.

First, a key term in the development of the COnCEPT platform is 'ontology'. How ontology is understood and interpreted varies between partners. For the designers, it signifies a philosophical debate around the essence of design knowledge. By contrast, for the technologists, ontology refers to a form of taxonomy that allows for the sorting of data in the software according to a particular structure. Unsurprisingly, this has led to incongruity between partners regarding the focus of the tasks. Second, technologists use the term 'annotation' to refer to how the software adds and makes use of metadata assigned to files, which can be either manually or automatically added to the application. For the designers, annotation was interpreted as the adding of further layers of detail over an existing visual. Third, for the technologists, the term 'storyboard' is used to signify to the identification of a sequence of activities when a user is operating a piece of software; for designers it is the visual communication, usually by sketching, of a broad range of issues relating to the design problem or solution.

Table 3: 'Lost in translation' - Examples of disciplinary terminology

TERM	**Technologists' interpretation**	**Designers' interpretation**
'Ontology'	Taxonomy of the organisation of data	Philosophical understanding of the essence of the design discipline
'Annotation'	Tagging of information	Adding extra layer(s) of detail over an existing visual
'Story board'	Identification of a sequence of requirements between user and software	Visual communication of a range of issues associated with the design solution

While the difference in interpretation may be subtle, such terms have very precise connotations for different disciplines. Specific meanings can be misconstrued, often with the repercussion of inconsistency in tasks intended and work actually undertaken. In the COnCEPT project, this has had impact on the expectations of consortium members. Moreover, the challenge is especially pronounced in situations in which partners speak different languages. In navigating such misinterpretations, the authors have concluded that the best approach is to be explicit in acknowledging problematic terms. Immediate clarification helps to circumvent disagreement and time-wasting. Identification of disparity becomes more important than solely establishing a common definition in the first instance. This concept is developed in section 4.

3.3 Methodological disparity

A third key area of divergence centres on how the design and technical partners work to solve problems. In developing the COnCEPT project, the design partners have adopted a qualitative approach, spending time with end users, and accruing a rich knowledge of underlying issues and needs. Conversely, the technical partners have engaged in quantitative research to gain insight on competitor software. How the partners worked to envisage the software also highlights a profound disparity in approach. The design partners worked to produce a visual model (Figure 3), using icons and simple language, to illustrate how the software may be structured. This prototype is viewed using a web browser, and interactive buttons connect functionalities through interconnected screens. In contrast, the technical partners produced a diagrammatic interpretation (Figure 4) of the software architecture, featuring technical language to describe components and sequences of activities.

Figure 3: Visual interpretation of the COnCEPT architecture conceived by design partners

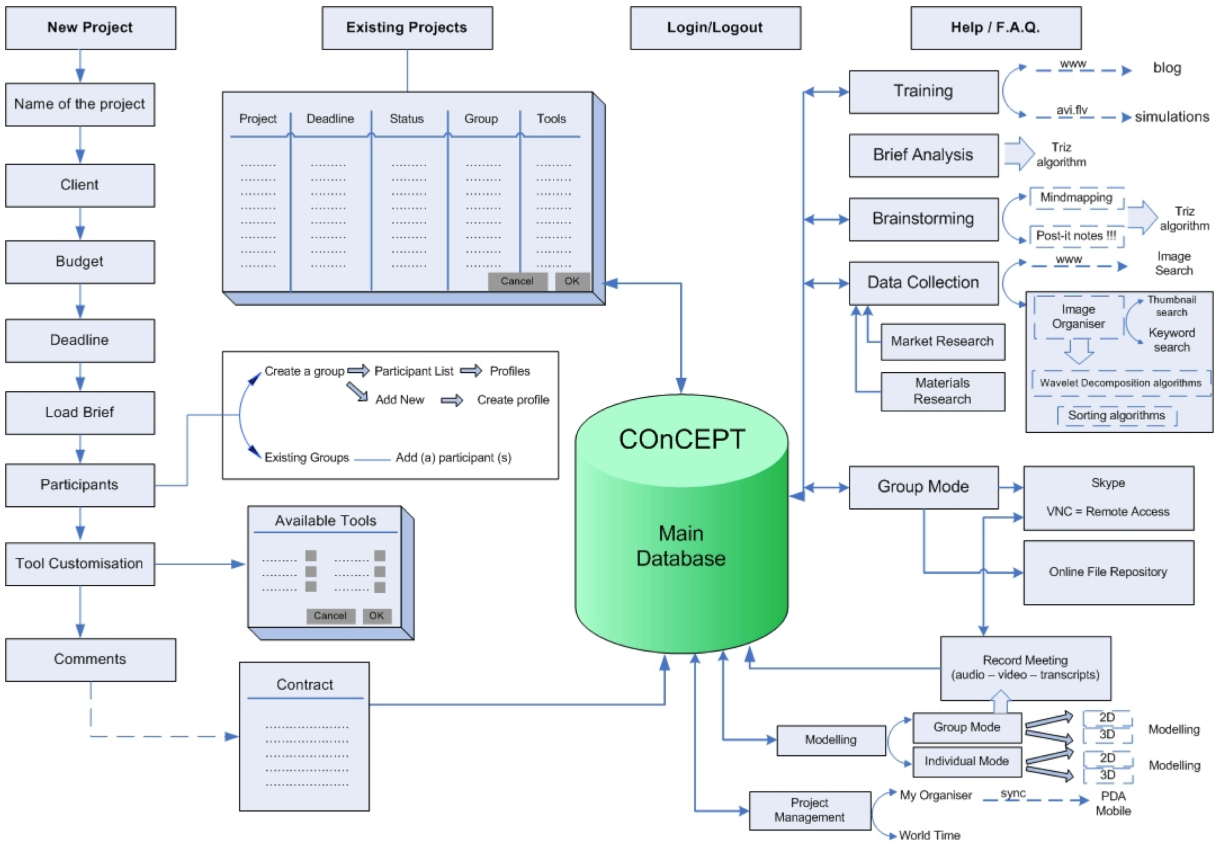

Figure 4: Diagrammatic interpretation of the COnCEPT architecture conceived by technical partners

Methodologies affect the outcome of the project perhaps more than any other area of divergence. Whether the focus is on 'what is' or 'what could be' – openness to creativity – influences whether the project outcome is more innovative or continuous in nature (Norman and Verganti, 2014; Vissers and Dankbar, 2002).

The attempt to manage the COnCEPT project using a design thinking approach has had successes, but has highlighted the difficulties in fostering an interdisciplinary approach. While the range of expertise brought by disciplinary groups is undoubtedly a strength, it is essential to actively manage collaboration, as well as to instil the design thinking ethic in all partners. The next section presents ideas that extrapolate design thinking principles to explicitly suggest how interdisciplinary effort can be enhanced.

4. PRINCIPLES FOR INTERDISCIPLINARY COLLABORATION

It has been acknowledged that all design projects are unique, hence that deploying a consistent methodological framework when boundaries are continually shifting is counterintuitive. However, from the lessons learned from the COnCEPT project, there are underlying principles that can enable more productive interdisciplinary projects that adequately balance technologists and designers' respective defaults. This section discusses these principles. These guidelines, that aim to facilitate interdisciplinarity in design thinking projects, can be applied in projects regardless of domain.

1. Fostering appreciation and unifying activities

Creating a balanced approach requires a mutual respect of others' roles within the interdisciplinary team. Establishing appreciation for one another's roles can be gained by understanding what others do and what they bring to the project. However, in unmanaged situations, the separation between technologists and designers is often highly pronounced.

A means to foster mutual understanding is active involvement in all tasks to prevent the separation of roles. In the COnCEPT project, this may have enabled a fuller understanding and ownership of the entire project. For instance, it would have been beneficial for each partner to visit and talk directly with end users in order to comprehend their issues. This is a concern for Japanese managers seeking to instil harmony (Song and Parry, 1997). This would have allowed a more equal knowledge base, circumventing lengthy debates. First-hand knowledge of the design situation is crucial. Time and effort could have been more focused, and there would have been a greater understanding of the work of all parties, had tasks not been labelled as either design- or technology-related.

2. Recognising, acknowledging and embracing difference in approach

A key benefit of interdisciplinary teams is harvesting the strengths and values of all participants. Active exploitation has major repercussions for the robustness and innovativeness of the project outcome, and is a means to stimulate new ideas and innovative solutions. However, having a clear roadmap in place from the earliest stages, as well as formal times to amalgamate work in progress (such as the workshops and calls organised on the COnCEPT project) is vital to keep all parties informed and on track, reinforcing the notion of periods of convergence and divergence in the Double Diamond model. This is especially important in interdisciplinary projects.

3. Challenging of assumptions

It is crucial that previous experiences, beliefs and assumptions do not become part of a new team culture. The acknowledgement of such differences in a verbalised and explicit way is recommended. An early questioning of assumptions – such as those concerning user needs, how others work, and project constraints – is essential. The first meeting of a new project team is a crucial step to establishing project culture. It is suggested that significant management effort is spent consolidating what partners understand their roles to be, and sharing expectations are of the project. Doing this helps to foster a climate for innovation and appreciation of others' roles.

4. Synthesising ideas via alternative forms of communication

As evidenced in the COnCEPT project, a lack of a common language hinders collaboration and the progression of ideas. The authors suggest that alternative forms of communication can assist with such challenges. The use of visual methods, such as mind mapping, rough sketching and prototyping can be deployed to develop common understanding. A key component of the design thinking process, in the COnCEPT project it had two clear benefits: 1) it allowed design partners to come to a consensus on the software interface, and 2) it provided a vehicle by which the dialogue could be built between design and technical stakeholders.

5. Conclusion

This paper has sought to examine the challenges of interdisciplinary innovation projects, and to delineate the differences between design and technology approaches. On the surface, the focus and processes of designers and technologists are seemingly opposed. However, it has emerged that this difference actually brings about more innovative outcomes. The COnCEPT project fortifies the necessity of symbiosis between design and technology prerogatives. For example, in the development of the software, undertaking qualitative research with the intended primary users resulted in deep understandings, which allowed the development of insights. Yet these insights could not have been translated into a functioning, tangible piece of software without the technologists' know how. Rather than an imposition of choice, the approaches are complementary: each adds value.

Reliance on the choice of either the design- or technological approach is inadequate to develop and realise new products and services. The case study illustrates that allowing one approach to dominate can result in products unfit for purpose. For instance, had time not been spent with designers in their studios, their lax attitudes towards tagging and organising of visual material would not have been detected, and the technologists may have developed a solution resting on tagging which would prove redundant. The contrary is also true: excess focus on *current* user needs is likely to limit the confines of innovation. Taking heed of both sides forges a more complete view of the problem, and requires conscious effort to appreciate the roles of the different partners participating in the project.

Indeed, design thinking implies integration and balance of a range of forces. This study has suggested achieving balance requires active management. To surmount the challenges of interdisciplinary collaboration, recognition and acknowledgement of difference is necessary. The COnCEPT case study contributes explicit guidelines for managing interdisciplinarity to design thinking theory. The principles are intended as a means to manage the meeting of sides, and can also be applied in other domains.

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