THE APPLICATION OF DESIGN THINKING
METHODOLOGY ON RESEARCH PRACTICES:
A MIND-MAP OF TOOLS AND METHOD

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ABSTRACT
The difficult task of innovation is a key facet of Research & Development (R&D) institutions. Innovation is also closely related with processes oriented to achieve solutions in design. By addressing this topic, we propose to research new emerging design methods and provide an overview of design thinking tools that can be applied in an early stage of the R&D research process in order to produce meaningful results. This research presents a set of experimental guidelines and an analysis method for the application of these tools. In particular, it is taken into account that design, through design thinking, extends to the experience that customers/users have with products, services, spaces or even multidimensional experiences, which is a relevant input for R&D innovation development. It is well known that design has changed its scope beyond the conception of artifacts: Design thinking methodologies have resulted from the advancement of current design paradigms. However, design thinking is not a new design discipline. It is a fresh multi-disciplinary platform that utilizes conceptual tools in order to provide steps towards innovation. In fact, the establishment of coherent guidelines for the design thinking process is a very complex task, due to its interdisciplinary requirements, that convey many diverse mindsets. The main focus of this study is creating an analysis toolkit that enables non-specialist and specialist users to perform high-quality design production. This methodological tool is being applied in the framework of two research centers, namely, the Research center for Science and Technology of the Arts and the Telecommunication Institute of Oporto University. These trials provide valuable pilot studies in order to determine the efficiency of this ‘mind map’ in the R&D innovation process.

KEYWORDS
Design Thinking, Design Management, Innovation, R&D Organization, Creative Industries, Design Thinking Tools

INTRODUCTION
This paper follows the notion that design is increasingly an important tool that fosters economic growth as well as creative goals. The approach that is proposed within this paper focuses on the reflection of the enormous benefits that the concept of design thinking and its use in management, could offer to the R&D centers. Design methodologies can aid areas and organizations which focus on the field of science and engineering. The R&D organization must know about how to maximize the advantage of design integration. According to Achas (2010, p.5) “our understanding of the role and nature of design is still woefully lacking, in comparison to the substantial work completed on defining and characterizing R&D, science, technology and even innovation itself.”

Therefore, in order for these organizations to obtain a full return on their design investments, it is important to achieve a comprehensive understanding of the benefits of design and acknowledge its potential. It is in this context that design is used as a tool for development, innovation and productivity. The introduction of the design paradigms of thought associated with the R&D management processes are an opportunity to maximize the transfer of knowledge and technology to various industries, in particular the creative industries. If design is a sub-sector of the creative industries, relating design with other areas of knowledge-based industries can offer a new role in the management of innovation and knowledge processes. Based on this fact, the development of design might bring to this sub-sector exponential growth and inject the same into the creative industries.

The scale of the service economy has been increasing in Europe. To this point, design is now recognized as an important contributor to innovative organization’s performance and productivity. In this paper we
believe that combining design thinking and design management can be a very powerful approach to solving wicked problems or hard problems – complex challenges that research centers face every day. By addressing this topic, this paper proposes to explore new emerging designs methods and provide an overview of design thinking tools which can be applied in an early stage of the R&D research process to produce meaningful results. We present a set of experimental guidelines and an analytical methodology for the application of these tools. In particular, it is taken into account that design — through service design thinking — extends to the experience that clients/users have with products, services, spaces or even multidimensional experiences (which is a relevant input for R&D innovation development).

Therefore, our goal is to create an analysis toolkit that enables both non-specialist and specialist users in order to perform high-quality design production. The main challenge of this paper is to develop a methodological tool that increases productivity within the R&D framework and innovation processes.

**RELATED WORK**

**Design Thinking Approach**

Design is a creative activity, a facet of human knowledge that not only solves problems but searches for considering and criticizing the human need. The term design is used in a wide variety of contexts with many different meanings. In essence, all of the design disciplines are pertinent; however, what is important to this study is the perspective of design thinking.

“Design thinking — its human-centric methodology integrates expertise from design, social sciences, engineering, and business. It blends an end-user focus with multidisciplinary collaboration and iterative improvement to produce innovative.” Meinel & Leifer (2011, p.xiv)

Design thinking is difficult define, though it is a concept that is widely used. The establishment of a coherent definition for design thinking is a very complex process, due to its interdisciplinary requirements, that convey many diverse mindsets. However, instead of focusing on the definition, this paper is going to present an overview of the main principles of design thinking. For this reason, we build the next figure in order to reflect in which principles design thinking is based on.

![Figure 1. Principles of design thinking — own source.](image-url)
In order to develop our proposed method, we based our research on the principles and concepts of Buchanan’s\(^1\) (1992, 2001) matrix.

**Table 1 – Buchanan’s matrix (Buchanan 1998, p.13)**

<table>
<thead>
<tr>
<th>Communication Signs and words</th>
<th>Construction Things</th>
<th>Strategic Planning Action</th>
<th>Systemic Integration Thought</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventing</td>
<td>Signs, symbols and images</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Judging</td>
<td>Physical Objects</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Deciding</td>
<td>Activities, services and processes</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Evaluating</td>
<td></td>
<td>-</td>
<td>Systems, environments, ideas and values</td>
</tr>
</tbody>
</table>

Buchanan identified four areas entitled as “orders”, creating a hierarchy of design activity. Each order is a statement for rethinking and reconceiving the role of design. For Buchanan, the four orders should not be seen as areas of traditional disciplinary practice or specific outcomes (e.g. graphic versus product design), but as four broad areas of design thinking that are common to all design professions and applications. In addition, the matrix is not only described as the history of the design thinking disciplines, but also as the career development of designers. The author concludes (1992, p.10) that “the work of designers in each of these orders has created a framework for human experience in contemporary culture.”

To conclude, the intention in researching the structure of the Fourth Design Orders has the purpose of understanding how they could be applicable to design as a sub-sector in the Creative Industries. Therefore, by studying this matrix we consider that design thinking is a catalyst to the upstream and downstream flow of processes. Upstream, as it effects related organizations, companies, and projects which capture ideas and solutions — a direct incentive to creativity and productivity. Downstream, as design thinking provides a creation of dynamic environments (Fourth Design Order). As a result, the relationship that design has with other knowledge based fields of study business are very dynamic — this is the main advantage that design thinking can provide. Thus, design thinking fosters creativity by crossing experiences with multiple perspectives which can stimulate "conditioned" thought (inductive and deductive reasoning). From this perspective, design thinking can provide a new flow of productivity to all of the subsectors of the Creative Industries increasing economic value.

Still following the figure above, we agreed that Design thinking has six main characteristics:
- Human and user centered;
- Holistic;
- Co-creative;
- Problem solving;
- Multidisciplinary;
- Abductive reasoning.

*Human and user centered*

One of the main focuses of design thinking is the expression towards the user and end-user. Therefore, design thinking has a strong focus on human and user needs, in order to involve the user into the process as and placing them in the center of solving innovation problems (Lockwood, 2009).

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\(^{1}\) In the early 1990s, Dr. Richard Buchanan (1992, 2001), a professor at the Carnegie Mellon University School of Design, wrote the articles “Wicked problems in Design Thinking” and “Design Research and the New learning” that formulate the boundaries of design disciplines.
Based on Buchanan (1992) design research, the role of design has evolved in the last few decades. This development has led to a re-examination of the nature of design concepts, as well as development and framework. The designer accomplishes a new interaction with the customer and begins to focus on the end-user needs. This was the step that design needed in order to become Human-centered\(^2\), designing products and services that people find useful, usable and desirable — a crucial element for the design thinking approach.

For instance, as said by Thomas Lockwood (2009, pp.xi),

‘Design Thinking is essentially a human-centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis, which ultimately influences innovation and business strategy. The objective is to involve consumers, designers, and business people in an integrative process, which can be applied to product, service, or even business design’.

**Holistic & Co-creative**

Design thinking has also a strong foundation in a holistic perspective since it advocates a comprehensive analysis and a general understanding of the phenomena. Anderson (2007, p.1), “Design has long been recognized as a problem solving task, but there is a strong current within the design profession that recognizes design as an activity beyond that of simply fitting together pieces of a given puzzle.”

Following this, design thinking is co-creative as well. It acts as a bridge between the project and all the stakeholders involved in a project, focusing in optimizing the processes. Co-creation brings users to operate as a team and also to collaborate with stakeholders — they work together to a more customer centric processes (Stickdorn & Schneider 2012; Ambrose & Harris 2010).

**Problem Solving**

Problem solving is one of the crucial characteristics of design thinking because without this approach, then it would not be design thinking. Problems in innovation are normally addressed as *wicked problems*\(^3\). If we study the nature of design, easily we notice that there is no right solution in a design challenge — it is totally subjective (Martin 2009, Kolko 2011). Logically, there are certain solutions that are more accurate and appropriate than others.

How do we know which is the most logical or correct solution to a design problem? This is a main concern that both designers and non-designers struggle with. This is because design issues don’t necessarily have a right or wrong answer, which makes them extremely ambiguous. Following Martin’s (2009, p. 94) reasoning, we can confront problems as being hard or wicked. Hard problems can be solved within analytical tools that allow us to tackle and solve them. Design problems unlike hard problems; do not follow laws, theorems or formulas. This approach contrasts with science and engineering disciplines. This is where design thinking tools can take special relevance. For Buchanan (1992, p.17) design thinking allows designers to position and reposition the problems and its issues at hand. For him design thinking is based on the “tools by which a designer intuitively or deliberately shapes a design situation, identifying the views of all participants, the issues which concern them and the invention that will serve as a working hypothesis for exploration and development”.

Design thinking can be a good approach in order to solve this kind of issue (Buchanan1992; Martin 2009).

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\(^2\) Human-centered design, such as the process of design thinking, is a deeply human approach that relies on the ability of observed and developed ideas that are emotionally meaningful for the end-user, developing methods that emphasise user research.

\(^3\) According to Buchanan (1992, p.16) the phrase *wicked problems* was borrowed from philosopher Karl Popper. However, in the 1960s, a new idea emerged based in this train of thoughts, but formulated in a different direction. The *wicked problems* approach, as we know it today, was formulated by mathematician and planner Horst Rittel, in a period were design was achieving new notoriety. He defines them as messy, aggressive, and confusing.
Multidisciplinary & Abductive Reasoning

Design thinking has a strong element in multidisciplinary teams because it uses a vast range of methods and tools from various disciplines in order to explore and understand the behaviour and mindset of all people involved (Stickdorn & Schneider 2012). By the fact that designers use abductive reasoning, they are able to take incomplete data, manipulate it in various ways and invent things that are relevant, innovative or appropriate; for this reason this becomes one of the focal aspects of design thinking (Martin 2009; Kolko 2011; Golsby-Smith, 1996). Therefore, Design involves more than one approach to thinking; it encompasses a mix of mental processes in order to achieve different solutions, mainly in Abduction, which involves both Deduction and Induction. In short, deduction proves how something should be; induction shows how something can operate; abduction is on the contrary, the suggestion at how something can be. Thus, to grasp or understand the nature of phenomena, only abduction can work as an efficient method. In conclusion, performing this complex structure that operates parallel with Deduction and Induction (in order to revolve a *wicked problem*) is often seen as the core of design thinking.

THINKING AS A PROCESS

The design process is what puts design thinking into action. It is a structured approach to generating and evolving ideas. The design thinking process is a highly interactive and incremental process, driven by people with different backgrounds and experiences.

Some authors, such as Meinel & Leifer (2010, p.15) defend that the design process has five stages: discovery, interpretation, ideation, experimentation, and evolution. Even so, some other of defend that this process has seven stages, like Ambrose and Harris (2010, p.11) "The design process can be said to comprise seven stages: define, research, ideate, prototype, select, implement and learn. Each of these requires design thinking."

However, following Stickdorn and Schneider (2012, p.126), “Literature and practice refer to various other frameworks made up of three to seven or more steps, but fundamentally they all share the same mindset,” some authors such Stemple and badke_Schaub (2002) and Brown (2009) all defend that the design process has four stages. Due to this, in order to build our proposed method, we focus this research in the following four stages: (a) Exploration, (b) Creation, (c) Reflection and (d) Implementation.

![Figure 2. Stages of Design Thinking Tools — own source.](image)

(a) Exploration: the first stage of the model marked by the beginning of a project, which we will see, can begin with one of two typologies - Exploration or Exploitation. Normally, the beginning takes place as an idea or inspiration, often resulting from a discovery stage in which are in need of intervention in order to improve a product, service or experience. This stage could include activities such as:

- Market research;
- Research about user and end-user;
- Information and process management;
- Research groups focused on design.

(b) Creation: is the beginning of development and the execution of what must be projected. It is here that the first solution emerges and focuses on interactivity. The main activities in this stage are:

- Multi-disciplinary work and co-creation;
- Visual process management;
- Development of production methods;
- First testing.

(c) Reflection: this is the stage of definition, in which the interpretations of the first results are analyzed in order to support the project needs. In this stage, the proposed objectives of the project are designed to the future users/customers. The main activities of this phase are:

- Project management;
- Approvals for the project.

(d) Implementation: this is the stage that achieves the final goals of the project, whether it is to produce a good or service. It is here that the final product/service/system is finalized and released to its defined market. The principal activities of this stage are:

- Final testing, approval and launching;
- Evaluation of goals and feedback cycles.

In short, the design process consists in the alternation between stages, between the analysis and synthesis of alternative solutions, in cooperation with its stakeholders (Brown, 2009; Meinel & Leifer, 2011).

Exploration & Exploitation

Considering the sequence of design processes presented above, when we start a project from the (a) Exploration stage we can begin with two different typologies. According to Martin (2009, p.18) we can develop a project by starting from an exploration or exploitation principle. For March (1991), exploration and exploitation has been: “Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation. Exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution.” Martin (2009) and March (1991) share the same point of view. According to both authors, it is necessary to have an appropriate balance between exploration and exploitation — for the reason that both approaches are essential to an organization. According to March (1991), as a result, organizations make explicit and implicit choices between these two typologies.

PROPOSAL FOR A MIND-MAP OF TOOLS AND METHODS

Organizations are facing an increase in complex problems — wicked problems — and it is important to create and enforce processes and tools that can help sustain this reality. Design is prepared to deal with complex and inaccurate problems. The process and tools used by design thinking are flexible and allow an efficient balance between disorder and the need of control for the necessary innovation processes.

The presented methodology aims to identify the main criteria and tools that could be implemented into the actions of R&D organizations. To this end, we structured a flowchart (see figure 3) that allows navigating through an itinerary that permits identifying the driving objectives and purpose of each project. In order to build the flowchart, we unveiled a huge range of service design thinking tools and through an attempt of mapping them, we found a list of more than 250 service design tools, Exser (2009).

While analyzing and studying several tools, based on which tools could reduce the ambiguity of the project development and considering the requirements for the specific case studies analyzed in this study, which is based on the R&D context, the number of tools were reduced to 34. In order to organize the flowchart sequence, we followed the theoretical statement Stickdorn and Schneider (2012, p.126), namely we focus the flowchart in four stages: Exploration, Creation, Reflection and Implementation, as well in the Martin’s (2009, p.20) concept of Exploration and Exploitation described previously.
This allowed the projects to analyze the stage of their projects in both an internal and external context.

APPLICATION INTO R&D ONGOING PROJECTS

For this research, we performed the case study applied in the framework of these two research centers, namely, the Research center for Science and Technology of the Arts (CITAR) and the Telecommunication Institute of Oporto University (IT-Porto). Therefore, this work proposes a transversal approach to design thinking tools and R&D research processes. In the end, the relationship between these two realities can contribute to innovation success. This research work is based on tests performed in two different typologies of projects, in order to determine if design tools can influence innovation success in R&D. We conduct the following procedure structure:

Table 2 – Methodological procedure for the application of the proposed method.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Phases</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Field Work</td>
<td>1.1</td>
<td>Identifying two project to test the flowchart and serve as an example for the case studies</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>Define a list of participants</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Define a meeting date</td>
</tr>
<tr>
<td>Field Work</td>
<td>2.1</td>
<td>Conduct meeting one – diagnostic of applicable tools for each project</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>Preparation of customized flowchart using the tools identified in 2.1</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>Conducting meeting two – application of the flowchart prepared in 2.2 at the Exploration and Creation stages</td>
</tr>
</tbody>
</table>
It is important to be aware that these two projects have different scopes. The CITAR project -Assisted Real Time Technology for Singing (ARTTS), is focused on the final end-user and the IT-Porto project – Streambolico, is focused on market consumers.

In the first meeting, both projects were introduced for the purpose of this research. This was primarily in order to explain what design thinking is. We distributed to each participant, a box with 35 cards which explains each tool that is inserted into the flowchart. It also has one extra card that explains the process, with the purpose of clarifying the methodology and how it works. Additionally, a short introduction of the tool categories was given to be sure that each team understood where the tools were meant to be applied. After this, each team (through flowchart) selected a list of tools that was appropriate for the development of their project. In this order, the projects selected the following tools:

![Figure 4. Selected tools from each project according to the flowchart — own source.](image-url)

After the three meetings, we administered a questionnaire in order to evaluate a qualitative performance of the proposed model. By filling-out the questionnaire thoroughly, we obtained an overview of the methods strong and weak points, it was here that we could achieve the perspective that generally, the groups share the same conclusions.

In order to analyze the methodological procedures used during the meetings and to see if they were different from the procedures that the participants used normally. We asked each participant if they felt that the proposed method used during the meetings, were similar to the procedures they normally used during the working day. The results were positive and uniform in the Streambolico project but divergent in the ARTTS project. We can infer that the IT Porto, the organization that embraces the Streambolico project, had a more restricted view of the use of different methodologies and processes that diverge from standard science and engineering methodologies and processes. However, by the ARTTS results, the opinions are more open, and therefore, we can conclude that the CITAR organization is taking into account new forms of methodology and practices, which is not surprising as this research center is integrated in an Art school. An ARTTS project participant mentions that “Many of the procedures adopted are already taken into account when planning a technological project”. Proceeding with the
analysis method, we asked if the methodology is an appropriate procedure for R&D. The overall results were positive since every answer is classified above as average. One particular subject from the ARTTS project was very enthusiastic about this topic, claiming that “The idea is very innovative and allows us a glimpse into a new range of possibilities that without the procedures would not be possible”.

We also addressed questions in order to evaluate the performance of the design thinking methodology. One of the questions was if the role of design thinking can be relevant in developing innovative solutions. This is one of the most important questions in order to analyze the success or failure of the proposed method. The obtained results were very expressive and positive, which makes this entire research relevant. Streambolico project participants explains that this was achieved “The methods used allow addressing important issues that rarely arise from the application of other methodologies” and “The methodology issues puts us in a radically different perspective from the structured thinking and from the typical research algorithm, bringing disruptive perspectives on how to frame our team” and also “the several meetings were very productive, which allowed the initial objectives to be achieved. Design thinking allowed the characterization of the Streambolico’s context, as well as defining the different types of interaction with potential partners, Business Angels and customers.”

To finalize every single participant agreed that they would be receptive in using the proposed methods again. This is the best possible result. It is therefore reasonable to assume that even though these organizations consider themselves effective in terms of methodological innovation for research, when presented with a design thinking approach they become aware of their benefits of implementing this practice. This can be seen as an achievement that demonstrates the success of the proposed methodology in this pilot study.

CONCLUSIONS AND FUTURE WORK

The flowchart became a useful tool that is able to identify a set of design thinking tools in order to be applied in different situations. Hence, the evaluation of these two pilot case studies through the use of a questionnaire also showed that these organizations are open to the use of design thinking as a methodology and considered that the results were meaningful.

This conclusion could potentially be extrapolated to R&D organizations. However, in order to conclude definitively, it will be necessary to conduct further research and case studies. Additionally, it seems that the involvement of a designer in a team atmosphere is important when accomplishing design thinking processes — which is an important argument in favor of the role of the designer into R&D organizations in general, particularly for Portugal. The pilot studies in both cases demonstrate that the innovation processes associated with R&D centers produced meaningful results.

With its unique and integrative characteristics, design thinking has generated new opportunities for designers to engage with business management and other functions within various organizations.

REFERENCES


Stempele, J. and Badke_Schaub, P. (2002). Thinking in design teams, an analysis of team communication. Design studies, 23 (5), 473-496.

Stickdorn, M. and Schneider, J. (2012). This is Service Design Thinking. BIS Publishers B.V. Amsterdam.

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