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Design thinking capability model: A management framework to support design thinking implementation for product development

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Declaration

I hereby declare that, except where duly acknowledged, the work presented in this thesis is my own, and I have not obtained a degree in this University, or elsewhere, on the basis of this work.

Danielly Ferreira Oliveira de Paula (14232759), October 2019

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Executive Summary

Design thinking is lauded to reduce cost and redesign work in the new product development process and shorten lead time to development. Because of that, researchers are investigating how to use using design thinking as an organisational resource to reinvent the entire new product development process. However, there is a lack of a management tool to guide companies in a strategic deployment of design thinking practice for product development. In order to address that gap, the goal of this research is to develop a Design Thinking Capability Model (DTCM) that can support companies in the selection of the most suitable design thinking practices to be implemented into the product development process according to the companies' strategic and objectives drivers.

In order to develop the model, a sequential exploratory mixed methods approach was employed. First, in order to capture insights into the design thinking domain, two rounds of in-depth exploratory interviews were performed with key opinion leaders (N=20 in total) with significant experience (n > 5 years) in DT in both academia and industry. From this initial exploration together with the findings from the literature review, success factors for design thinking implementation were identified and organised into an instrument (or scorecard) aimed at measuring a company's design thinking capability. The scorecard was applied in a large organisation as a case study in order to test whether the model could support the company in the design thinking implementation for software development. Through the case study, this study proved that DTCM (a) worked in a real world setting and (b) was valuable, consistent, complete, of sufficient depth, easy to use, clear, coherent and had the ability to forecast the next steps to be taken to improve the design thinking implementation in the company.

This study provides the first attempt to create a Design Thinking Capability Model that can support companies in the strategic deployment of design thinking for product development. The model establishes variables involved in design thinking implementation and management, and the relationship among them to allow effective implementation in business companies. From an applied perspective, companies can benefit from a capability model that diagnoses their current design thinking profile, identify areas for improvement and serve as roadmap to achieve a desired design thinking situation.

Key-words: Design thinking; capability model; organisational capability.

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1 Introduction

This chapter presents a summary of research undertaken to develop a model to measure design thinking capability in business organisations. First, it provides a background to the benefits and relevance of design thinking to both academia and the industry. It also discusses previous studies in the area. Then, the broad research problems and specific gaps to be investigated are presented. Next, the goals of the research are outlined. Then, the two-phase research process used to study the problem is presented followed by a summary of the study's findings and contributions. Finally, an outline for the thesis structure is provided.

1.1 Background

Design thinking (DT) has been heralded as a well-suited methodology for encouraging innovation and economic growth. In particular, prior research has demonstrated that design thinking offers a potent way to create breakthrough products because of its ability to find unarticulated needs and solve problems (BROWN, 2009b). Design thinking practices help organisations solve complex problems by reducing bias, encouraging innovation and inspiring people to become more creative (LIEDTKA, 2011). By making Design thinking a strategic component, many organisations throughout the world are leading through innovation with great success (CHANG; KIM; JOO, 2013). In this way, design thinking has been introduced in many different organisational settings, such as social innovation (CIPOLLA; MOURA, 2011), education (BURDICK; WILLIS, 2011) and management (CHANG; KIM; JOO, 2013).

Contemporary scholarship has suggested that design thinking is essential for the new product development (NPD) process (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016). Prior research has suggested that incorporating design thinking into the product development process can result in cost savings as DT is lauded to reduce redesign work (CARLGREN; ELMQUIST; RAUTH, 2014A) (CARLGREN; ELMQUIST; RAUTH, 2014B) and shorten lead time to development (D'IPPOLITO, 2014). From this perspective, it seems that scholars have perceived design thinking as a critical component for encouraging innovation and economic growth in business organisations.

The definition of design thinking has changed over the last decades. For instance, some authors have examined design thinking from a cognitive perspective and primarily explore the individual designer and how design experts make decisions (CROSS, 1982)

(ROWE, 1987). Others adopt a more general theory of design and say that the concept of design thinking shifted from aesthetic modelling to wicked problem solving and propose the notion that all professionals should be able to design (BUCHANAN, 1992) (SIMON, 1996). Since the early 21st century, the third discourse on design thinking, which considers it in terms of an organisational resource for product development has gained significant traction in the field of design and management. By recognising this strategic role for product development, researchers point out the importance of diffusing design thinking practices and principles throughout organisations (VERYZER; MOZOTA, 2005) (VERVAEKE, 2009). In order to enhance design thinking implementation for product development, design thinking needs to move "upstream," where strategic decisions are made (BROWN, 2009a). That happens because the implementation of DT usually requires a change in the organisational culture (RAUTH; CARLGREN; ELMQUIST, 2014), and also an understanding of how and where efforts should be concentrated in order to properly introduce design thinking practices into the company. In other words, it is fundamental to understand the critical success factors (CSFs) for a successful implementation of design thinking (MICHELI et al., 2012)(CARLGREN; ELMQUIST; RAUTH, 2016B). In this way, design thinking is becoming more recognised as a management capability than as a specialised expertise. As a result, the integration of design as a business capability for an organisation is now increasingly being investigated (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016). (LIEDTKA, 2015) (MICHELI et al., 2012).

In recent years, it has been discussed that having design thinking as a managerial capability is essential to companies that have recognised the need to invest in an environment that promotes continuous innovation. Scholars argue that design thinking can enable the expansion of an organisation's innovation capabilities because of its ability to include non-designers in the design process (ROSENSWEIG, 2011). Thereby, it has been suggested that organisations can derive value from a design thinking capability, but design thinking must be strategically integrated. For this study, design thinking capability is defined as a company's ability to deploy design practice to support its innovation efforts on strategic and functional levels. Organisations can benefit from having a design thinking capability irrespective of their size (ACKLIN, 2013) (CHANG; KIM; JOO, 2013), geographic location (RAUTH; CARLGREN; ELMQUIST, 2014)(WONG, 2009), or sector (CIPOLLA; MOURA, 2011)(LINDBERG; MEINEL; WAGNER, 2011).

Recently, there has been widespread agreement that design thinking can add value to the capability discourse. Rosensweig (2011) proposes a theoretical model that identifies how DT can help turn design into a dynamic capability for any organisation. Hobday, Boddington and Grantham (2012) state the need to recognise and develop the notion of design capability as an important dimension of design and design thinking. Storvang,

Jensen and Christensen (2014) provide an analysis of how to map out a design capacity in organisations. Carlgren, Elmquist and Rauth (2014A) argue that implementing DT may enable the development of sustained innovativeness by addressing the three dimensions of innovation capability: organisational resources, processes and mindset. Liedtka (2017) explores how design thinking affects innovation outcomes by the creation of local capabilities. These studies have one characteristic in common, namely that they initiate the debate on the relevance of design thinking to building innovation capability.

1.2 Problems and gaps

It seems that design thinking is becoming a valued part of companies' new product development process and also has been identified as a core competence, intrinsic to a company's success. Despite the potential benefits of design thinking, its application has not reached companies worldwide, mainly due to difficulties in design thinking implementation (CARLGREN; ELMQUIST; RAUTH, 2016B).

One of the barriers in the adoption of design thinking is that different understandings of the concept seems to exist (HASSI; LAAKSO, 2011b). In terms of concept, researchers argue over the existence of different discourses of design thinking in the design field and also in the management field (KIMBELL, 2011). In the design domain, design thinking is seen as the way designers think and work (CROSS, 1982), whereas in the management field, researchers and practitioners consider design thinking to be a powerful and effective tool for problem-solving that can be used by designers and also non-designers (LIEDTKA, 2015) (BROWN, 2009a).

Due to the different understandings of what design thinking is, the concept of design thinking is broad (COOPER; JUNGINGER; LOCKWOOD, 2009) and the term is considered confusing (KIMBELL; STREET, 2009). As a result, both discourses are normally intertwined, which leads to a misconception of how to implement design thinking (CHANG; KIM; JOO, 2013). The confusion and disagreement surrounding the concept calls for investigations that provide clarity and common understanding, paving the way for a more fruitful discussion on the issue (HASSI; LAAKSO, 2011b). For instance, a common understanding is needed in order to distinguish a design thinking approach from a non design thinking approach to enable the evaluation of the outcomes of these different processes. Without this understanding, the question arises over, how can one determine whether or not design thinking is actually being applied? (HASSI; LAAKSO, 2011a).

In this way, the different ideas of design thinking knowledge reveals one important aspect. When adopting design thinking, a common language and understanding of design

thinking concepts among the people involved needs to be developed. Having a shared understanding of the concept can lead to the further development of the understanding on design thinking, its use, application, benefits and limitations (HASSI; LAAKSO, 2011b). Therefore, the creation of a common language is crucial for design thinking practice (CARLGREN; ELMQUIST; RAUTH, 2012). In other words, there is a need to understand the concepts and theories related to design thinking and how they are related to product development (MOULTRIE; CLARKSON; PROBERT, 2007) (MICHELI et al., 2012) (LIEDTKA, 2015).

In addition, the ability to properly implement design thinking is unclear (CARLGREN; ELMQUIST; RAUTH, 2016B). In particular, authors suggest that there is a lack of guidance concerning how to manage design thinking implementation for product development process to maximise design thinking's benefits (MICHELI et al., 2012). Considering that companies are being encouraged to adopt design thinking in areas where people may not have prior experience with such methods, it is fundamental to provide them with appropriate support to implement design thinking (SEIDEL; FIXSON, 2013). If implemented poorly, companies might abandon design thinking practice without realising its potential benefits (SEIDEL; FIXSON, 2013). Therefore, learning how to successfully use design thinking as an organisational resource it is still in a state of emergence. In other words, there is a need to provide companies with an appropriate framework that can guide them for a strategic deployment of design thinking practice for product development (MICHELI et al., 2012) (D'IPPOLITO, 2014). In order to do that, it is necessary to understand the variables involved in design thinking implementation and management, and the relationship among them to allow an effective design thinking implementation. In particular, it is fundamental to investigate the success factors for effective implementation of design thinking for product development.

In order to enhance design thinking implementation for product development, Mahmoud-Jouini, Midler and Silberzahn (2016) suggest that the creation of a design capability on an organisational level is key. Vetterli (2015) pointed out that tools and processes are not enough to sustain the long-term embodiment of design thinking. If organisations could reach a certain level of maturity, and the people involved are confident in using design thinking, maybe they would be able to apply and adapt design thinking according to a specific problem (BAILEY, 2012), which has the potential to enhance the likelihood of product success. However, there is a lack of a management tool to guide companies to implement design thinking beyond its traditional role (i.e. as a process or toolbox). In particular, it is still unclear how to support companies in the effective selection of design thinking practices in order to help them to develop a design thinking capability across the organisation. A managerial approach for design thinking would enable

companies to investigate their design thinking capability in order to uncover problems, and also to guide companies as to where they wish to be in the future regarding design practice.

In summary, the three most prominent challenges in the design thinking research are in terms of design thinking implementation and management. In particular, that happens because of the following specific gaps (i) lack of a common understanding of design thinking knowledge, (ii) lack of an understanding about the variables involved in design thinking implementation and management to allow an effective design thinking implementation for product development, and (iii) lack of a management tool to guide companies in a strategic deployment of design thinking practice for product development.

1.3 Research goal and objectives

Upon analysis of the problems discussed in the previous section, the goal of this research is to develop a Design Thinking Capability Model (DTCM) that can support companies in the selection of the most suitable design thinking practices to be implemented into the product development process according to the companies' strategic and objectives drivers. The following specific objectives can be formulated in relation to the main objective.

- To examine and synthesise the literature in relation to design thinking as a concept through a review of existing scholarship on theories and models. The purpose of this analysis is to understand definitions, perspective, and evolution of design thinking research.
- To analyse the state of art in the area of design thinking and new product development in order to build a framework that provides an integrated perspective of both research domains. The purpose of the model is to summarise the evolution, challenges and benefits of the discourse of design thinking literature in relation to the new product development domain.
- To identify the value of design thinking for product development by conducting interviews with key opinion leaders (N=10). The purpose of the interviews is to investigate dimensions for design thinking implementation for product development.
- To identify the success factors involved in design thinking implementation for product development based on findings from the literature review and also insights from in-depth interviews (N=10) with academics and practitioners in the area. The purpose of this second round of interviews is to compare theory and practice in order to improve the design thinking dimensions and also identify and categorise the success factors into the dimensions.

- To derive practices from the success factors and classify them into capability levels aimed at measuring how well a company applies design thinking in practice. The capability levels can be understood as a scale that indicates the path a company should follow for design thinking implementation considering its current situation.
- To develop the Design Thinking Capability Model through the identification of fundamental components for capability models based on a thorough investigation of how researchers structured well-established capability maturity models. The purpose of the model is to enable the assessment of a company's current design thinking capability profile, the understanding of improvement opportunities, the selection and prioritisation of design thinking practices and the deployment of roadmaps for implementation.
- To develop a scorecard aimed at operationalising the Design Thinking Capability Model. The scorecard illustrates a conceptual understanding of how to measure a company's performance in each design thinking dimension.
- To develop two information management tools - DTCM Capability Radar and DTCM Dashboard - that can analyse and display a company's current capability profile in design thinking in order to show strengths and weaknesses and identify gaps for improvement in design thinking implementation.
- To develop an application method aimed at guiding the application of the model and establishing a continuous improvement framework for the implementation and management of design thinking practices.
- To evaluate the application of the model with teams that implemented design thinking to develop new software. Relevant criteria were used (e.g. utility, consistency, completeness, precision, depth) to assess the application of the model.

1.4 The research process

In order to develop the model, a sequential exploratory mixed methods approach was employed. The purpose of this approach was to employ qualitative and quantitative techniques to explore design thinking in theory and practice in order to identify relevant variables to build the capability model and then apply the model as a case study in a large organisation that use design thinking to develop new software. The overall methodology and methods used for this research are summarised in two phases: (i) Developing the design thinking capability model and (ii) Applying the design thinking capability model.

Developing the Design Thinking Capability Model (DTCM). Initially, a literature review was carried out with the aim to analyse cognate literature, and synthesise

the state of the art in the design thinking and product development domain. Then, two rounds of interviews with key opinion leaders in the area of design thinking were conducted in order to understand the value of design thinking for product development.

The interviews with key opinion leaders together with the literature review led to the identification of relevant dimensions of how design thinking adds value to business organisations. In addition, 20 critical success factors for a successful implementation of design thinking were also identified and organised within the dimensions. The qualitative findings then guided the development of items and scales for a quantitative survey instrument - the DTCM scorecard. The DTCM scorecard aims to be used as a mechanism to operationalise the model and a vehicle to test it.

Applying the Design Thinking Capability Model (DTCM). The theoretical version of DTCM was then further developed by means of a case study at a large company that implemented design thinking to develop software. Analysis of context and purpose was the first step of the case study, which enabled the definition of the application scope (i.e. where in the company and how the model would be applied) and also to identify key employees to answer the survey. Then, the DTCM scorecard was applied to selected employees in order to diagnose their current capability profile. Finally, based on the survey results, the design thinking practices were evaluated and an actionable plan with a roadmap for improvement was created. The actionable plan was presented to relevant employees. Then they were asked to answer an evaluation questionnaire aimed at assessing the application of the model in the company.

The evaluation questionnaire was developed following the criteria proposed by Vernadat (1996) and adapted by Pigosso, Rozenfeld and McAloone (2013). In total, nine criteria were used to evaluate the application of the model at Company D: utility, consistency, completeness, precision, depth, simplicity, clarity, coherence and forecast. Company D scored DTCM well across all nine criteria. The only criterion classified in need of more attention was precision. Precision aims to identify whether DTCM could provide a correct description of the capability profile for each team.

1.5 Findings and contributions

Findings. As a result, this study proposes a model aimed at supporting companies in the design thinking implementation for product development. The main findings of this study are:

- A framework that integrates research based on design thinking and new product

development.

- Four dimensions - strategy, culture, implementation and skill development - considered relevant to manage design thinking implementation.
- A list of 20 critical success factors for a successful design thinking implementation for product development and the establishment of the relationship among them in order to categorise them into design thinking dimensions.
- A list of 52 practices aimed at implementing the 20 critical success factors. The list describes what activities should be performed in order to address each critical success factor. In general, the design thinking practices are those related to the management of design thinking implementation.
- A list of components - dimensions, capability levels, goals, practices and evolution levels - that are relevant to create a design thinking capability model. Each component was deeply investigated and proven to help companies in the selection of relevant design thinking practices for product development
- A scorecard based on scale development research, which aims to operationalise the model. The purpose of the scorecard is to use the components of the Design Thinking Capability to measure a company's design thinking capability.
- Two information management tools that provide a clear and graphic representation of their current capability profile in design thinking showing strengths and weaknesses and identifying gaps for improvement in design thinking implementation and management.
- A Design Thinking Capability Model, which aims to support companies in the selection of the most suitable design thinking practices to be implemented into the product development process according to the companies' strategic and objectives drivers.
- Finally, an application method that serves as a guideline to explain how to use the scorecard to operationalise the Design Thinking Capability Model.

The results obtained from this study provide more evidence to sustain the argument of design thinking as a factor that has potential to lead to organisational growth. Besides enabling a broad understanding of the current situation of the company on design thinking implementation, the results provide the first evidence to show that design thinking capability is a measurable variable.

Contributions. Given the emergence of developing a design thinking capability, this study discusses the development of the concept of the Design Thinking Capability Model and its elements. The research was developed based on solid scientific foundation, following a methodology that comprised theoretical development, by means of a literature review, and evaluation by design thinking experts for further improvement and then a case study. The academic contributions of the research are many.

First, it proposes a synthesis of the evolution of the theories and concept of design thinking and how they influence other fields. Then, it proposes an integrated perspective of research based on design thinking and new product development. Third, it proposes a consolidated list of the design thinking critical success factors. Twenty critical success factors for a successful design thinking implementation for product development from a management perspective were identified based on an extensive literature review and recommendations from experts. Next, it proposes an instrument that contains a list of practices aimed to implement the critical success factors. Then, it provides two information management tools to communicate a company's current design thinking profile. Finally, it provides the first attempt to create a Design Thinking Capability Model that can support companies in the strategic deployment of design thinking for product development. The model establishes variables involved in design thinking implementation and management, and the relationship among them to allow effective implementation into business companies. From an applied perspective, companies can benefit from a capability model that diagnoses their current design thinking profile, identify areas for improvement and serve as roadmap to achieve a desired design thinking situation.

1.6 Thesis structure

This section provides an overview of the subsequent chapters in this thesis, which is structured into seven chapters and five appendixes according to the scheme presented in Figure 1.

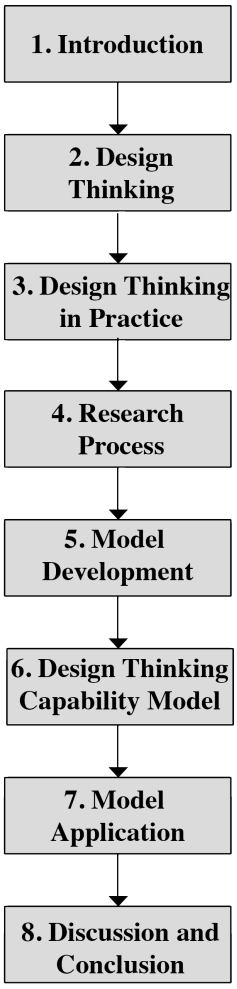

Figure 1: Thesis structure

Chapter Two: Design Thinking presents a review of the literature on how the concept of design thinking has evolved over the years. It begins by highlighting the general theories and gaps related to design thinking and then the chapter analyses how design thinking research is influencing research in other fields.

Chapter Three: Design Thinking in Practice reviews research on design thinking; more specifically, the benefits and challenges associated with its implementation for product development. It also provides a framework that synthesises existing research on DT in NPD and a map that illustrates how research trends in design thinking have changed over the years, thus indicating directions for future research. Finally, research gaps and the challenges researchers face when addressing these gaps are discussed.

Chapter Four: The Research Process, presents the research methodology used to develop the design thinking Capability Model. First, it uses qualitative approaches in

order to identify variables involved in the design thinking implementation and management for product development. The qualitative findings then guided the development of items and scales for a quantitative survey instrument - the DTCM scorecard. The DTCM scorecard was used as a mechanism to operationalise the model and as a vehicle to test it.

Chapter Five: Model Development, presents the steps undertaken for the development of the model. First, two systematic mapping analysis on the historical evolution of design thinking are presented. Then, the chapter explains the development and application of a survey aimed at identifying the critical success factors for design thinking implementation. Next, the critical success factors for a design thinking implementation are described and analysed. Finally, the chapter concludes with the consolidation of the critical success factors into a scorecard (DTCM scorecard).

Chapter Six: Design Thinking Capability Model, offers an overview of the main components of the Design Thinking Capability Model. Then, it explains how the DTCM Scorecard can be used to operationalise the model.

Chapter Seven: Model Application, presents the results of the application of Design Thinking Capability Model in a large company. First, the chapter explains the scope of the case study (i.e. where in the company and how the model would be applied). Then, it shows how the model was used to diagnose the current capability profile of the selected unit of analysis. Next, the data from the case study is interpreted, summarised and presented. Finally, the chapter concludes with an analysis of the company's feelings and perceptions about the Design Thinking Capability Model.

Chapter Eight: Discussion and Conclusion, provides a conclusion to this exploratory research on how to develop a design thinking capability. First, the chapter states the study's key findings. Then, it relates the findings to previous research on design thinking. Next, the chapter summarises the study's contributions. Finally, the acknowledges the study's limitations. Finally, the chapter concludes with some suggestions for further research.

2 Design thinking

The purpose of this chapter is to review and synthesise relevant literature on design thinking, so as to guide the development of the Design Thinking Capability Model. This chapter discusses the findings presented in the paper "Understanding design thinking in design studies (2006-2015): a systematic mapping study" listed as number 5 in Appendix D.

The chapter begins by examining the existing design thinking theoretical lenses and positioning this study according to the theoretical perspective of design thinking as an organisational resource. Then, it is explains how scholars who follow this perspective have defined the term “design thinking” over the years. This review points towards four divergent manifestations of design thinking implementation (i.e. mindset, process, toolbox and management capability) that seem to enable teams to learn and identify what is the best strategy for specific organisational challenges. Finally, the chapter introduces the review process followed to perform a systematic mapping analysis to understand how design thinking research is influencing research in other fields. Finally, the findings from the systematic mapping process are analysed and discussed.

2.1 Perspectives on design thinking

Different perspectives of design thinking have been proffered over the years. In tracing the roots of design thinking, Kimbell (2011) proposes a typology and characterises design thinking in terms of three different theoretical lenses: cognitive style, general theory of design and organisational resource.

By the early 1980s, cognitive research was introduced by Schön (2017) and his collaborators who emphasised the role of the designer and the importance of the study of design thinking. These studies primarily explore the individual designer and how design experts make decisions. Similarly, Cross (1982) introduces the term “designerly ways of knowing”, which is particularly significant, since it also introduces the notion of knowledge in design and what this might imply. Overall, researchers who follow this perspective and consider design thinking in terms of a cognitive style primarily explore the individual designer and how design experts make decisions. For example, Rowe (1987) provides one of the earliest discussions of the concept of design thinking. He describes design thinking as the *“interior situational logic and the decision-making processes of designers in action, as well as the theoretical dimensions that both account for and inform this kind*

of understanding". Authors who adopt this theoretical lens attempt to understand the cognitive processes and methods by which successful designers solve problems. These studies examine the neurological basis of DT to understand those who exhibit DT traits in order to increase their "problem-finding" behaviour.

The second theory on design thinking is referred to as a general theory of design. Researchers adopting this perspective claim that the concept of design thinking shifted from aesthetic modelling to wicked problem solving and proposed the notion that all professionals should be able to design (BUCHANAN, 1992)(SIMON, 1996). Based on that, it has been suggested that designers should work closer with other functions. Hart, Tzokas and Saren (1999) claim that the nature of information flows between functions influenced success or failure of the new product. In addition to the abundant research challenges, by the mid-to-late 1990s companies were grappling to integrate separated functions in the NPD process in order to facilitate cross-functional information exchange (GRIFFIN; HAUSER, 1996) (KAHN, 1996). Due to the new challenges, scholars begin to highlight the need for the recruitment of design managers to manage the interaction between departments (BRUCE; VAZQUEZ, 1999). In this way, by using design thinking as an interlink between departments, researchers aim to offer a common language that cross-functional teams could use to enhance collaboration.

Since the early 21st century, design thinking is considered in terms of an organisational resource. This discourse has gained significant traction in the field of design and management. It has been proven that the intensity of customer interaction can have a positive impact on new product success (GRUNER; HOMBURG, 2000). Others argue that design thinking can enable the expansion of an organisation's innovation capabilities because of its ability to include non-designers in the design process (ROSENSWEIG, 2011). Recently, in order to encourage innovation and economic growth, researchers are investigating how to use using design thinking as an organisational resource to reinvent the entire new product development process. According to Liedtka (2015), the benefits of using design thinking for product development are many. For instance, benefits include positive effect on idea generation, more robust prototyping techniques and a reduction in cognitive bias. Additionally, within the industry, applying design thinking to new product development has become fundamental to companies' strategy and product success. However, design thinking is a relatively new addition to the management literature (BLOCH, 2011), and integrating design practices into new product development is still a challenge (MICHELI et al., 2012).

Together, these studies indicate that the understanding of the concept of design thinking has changed over the years. For this study, the theoretical lens of design thinking

as an organisational resource is explored. The next section provides a detailed analysis of the definition of design thinking as an organisational resource.

2.2 Defining design thinking

The concept of design thinking as an organisational resource has been the subject of definition attempts for a long time. Although a generally accepted definition of DT has yet to emerge (LIEDTKA, 2015), many authors tend to define design thinking according to their perspective. Table 1 illustrates some of these definitions.

Table 1: Design thinking definitions

Definition	Reference
"A human-centred innovation process that emphasises observation, collaboration, fast learning, visualisation of ideas, rapid concept prototyping, and concurrent business analysis".	Lockwood (2010, p. xi)
"Bringing designers' principles, approaches, methods, and tools to problem-solving"	Brown (2008, p.86)
"A way of finding human needs and creating new solutions using the tools and mindsets of design practitioners."	Kelly and Kelly (2013, p.24)
"[Design thinking] integrates expertise from design, social sciences, engineering, and business. It blends an end-user focus with multidisciplinary collaboration and iterative improvement to produce innovative products, systems, and services. Design thinking creates a vibrant interactive environment that promotes learning through rapid conceptual prototyping."	Meinel and Leifer (2011, p. xiv)

Lockwood (2010) provides a more descriptive definition of design thinking that is strongly related to design thinking implementation as a process. In his definition, the author draws out salient activities that support a balance of users' needs with technical and business feasibility, generating customer value and market opportunity.

Kelley and Kelley (2013) bring a definition more connected to the theoretical lens of design thinking as a cognitive style. In his perspective, design thinking is about using the tools and mindset of designers as a way to find out human needs.

Plattner, Meinel and Leifer (2010) give a more detailed definition of design thinking with more focus on diversity, collaboration and learning. In the authors' view, design think-

ing integrates knowledge from different fields and should be practised by multidisciplinary teams.

Similarly to Kelley and Kelley (2013), Brown (2009b) offers a definition more connected to the theoretical lens of design thinking as a cognitive style. However, in his perspective, design thinking can be applied to problem-solving in general. In other words, the author leaves it open for the audience to discuss how and where it can add value. For this study, the definition of Brown (2009a) is followed. In this view, design thinking is a set of practices that helps organisations to solve complex problems by reducing bias, encouraging innovation and inspiring people to become more creative, which is line with other authors (DUNNE; MARTIN, 2006) (LIEDTKA, 2011) (MARTIN, 2009).

However, some authors such as Hassi and Laakso (2011a), Kimbell (2011) and JOHANSSON and WOODILLA (2012) strongly reject the idea of a single definition of DT. Johansson-Sköldberg, Woodilla and Çetinkaya (2013) claim that

"As social constructionists we regard an approach that begins with the question, 'What is design thinking?' as an essentialist trap. We do not believe that there is a unique meaning of 'design thinking', and accordingly we should not look for such a one. Instead, we look for where and how the concept is used in different situations, both theoretical and practical, and what meaning is given into the concept."

In this way, descriptions of design thinking can have several different meanings. Summarising the various practitioner-based descriptions of design thinking, Holloway (2009) states that DT is often understood as a generic approach to problem solving that can be applied to any situation. Due to the different situations that design thinking can be applied, authors (BRENNER; UEBERNICKEL; ABRELL, 2016) suggest that design thinking as an organisational resource can be described at three different levels: as a toolbox (STICKDORN et al., 2011), as a process (BROWN, 2009a) and as a mindset (CARLGREN; ELMQVIST; RAUTH, 2016A). Recently, there is a new stream line that investigates design thinking as a management capability (CARLGREN; ELMQUIST; RAUTH, 2014B) (PAULA; DOBRIGKEIT; CORMICAN, 2018). These four different manifestations of design thinking are explained in detail in the next section.

2.3 Manifestation of design thinking

Authors suggest that design thinking can be considered in terms of as mindset, a process, toolbox, or management capability (WÖLBLING et al., 2012) (BRENNER; UEBERNICKEL; ABRELL, 2016). As a mindset, DT is characterised by several key

principles, such as a strong orientation to both obvious and hidden needs of customers and users, and prototyping (BRENNER; UEBERNICKEL; ABRELL, 2016). By following this line, authors also suggest that applying the principles alone - without structure - is too demanding for novices (BRENNER; UEBERNICKEL; ABRELL, 2016). In this way, in some cases it is necessary to follow a structured process in order for novices to understand what DT is and how it can contribute to the product development process. Additionally, there are different design collections of tools, both aimed at practitioners (STICKDORN et al., 2011) and academics (HASSI; LAAKSO, 2011a). Deployment of appropriate methods is one of the core success factors of DT projects (BRENNER; UEBERNICKEL; ABRELL, 2016). A new research line is emerging that investigates design thinking as a strategic capability. In the next sections, studies related to each representation of design thinking are summarised and discussed.

2.3.1 As a mindset

The emergence of a design thinking mindset is an idea central to DT and DT research. Authors suggest that some mindsets are helpful when learning or applying DT. For instance, an empathetic mindset is useful to develop an understanding of the user and to facilitate working in diverse teams (CARLGREN; ELMQUIST; RAUTH, 2016B). Several authors describe how DT has brought a more user-centred and more collaborative thinking to team members in business organisations (PEDERSEN, 2016) (D'IPPOLITO, 2014) (WÖLBLING et al., 2012). The DT mindset is often characterised as a collection of principles. Table 2 gives an overview of three different sets of such principles.

Table 2: Collection of design thinking principles

Lindberg et al., 2011	**Wölbling et al., 2012**	**Brenner et al., 2016**
- Openness to diversity - Problem exploration - Iterative alignment of the problem and solution space	- Collaboration - Mindfulness of the team and process - User-centered / empathy - Fail early and often - Creative confidence	- Convergent thinking - Prototype - Human-centred - Fail early and often - Creative spaces

The idea of a mindset as a way of individual embodiment of principles is central to design thinking. In order to develop a design thinking mindset, authors suggest that it is necessary to understand its core principles first. For instance, Wölbling et al. (2012) discuss the following principles (i) collaboration, (ii) mindfulness, (iii) user-centred, (iv) fail early and often, and (v) creative confidence. Similarly, Brenner, Uebernickel and Abrell

(2016) suggest the following principles are the most relevant in terms of fostering the method's success: (i) combine divergent and convergent thinking, (ii) fail often and early, (iii) build prototypes, (iv) test early with costumers and (v) make use of creative spaces. In a more software-related scenario, Lindberg et al. (2012) discuss the following DT principles for software development: (i) team diversity, (ii) problem and solution space exploration and (iii) iterative alignment of the problem and solution space. Overall, it seems that the design thinking' principles are a combination of divergent and convergent thinking, empathy, experimentation, collaboration and creativity.

Many of the principles identified are linked to one another. For instance, an empathetic mindset is useful to develop an understanding of the user and to facilitate working in diverse teams (CARLGREN; ELMQVIST; RAUTH, 2016A). Similarly, the focus on building team diversity is seen as enhancing collective creative problem solving by bringing to conversations diverse points of view (ROSENSWEIG, 2011). Additionally, there are also some techniques (e.g., brainstorming) that contribute to exploring the solution and problem space, and which facilitates the changing of the mindset to frame and re-frame the problem through a diverge and converge way of thinking (CARLGREN; ELMQVIST; RAUTH, 2016A). However, one of the main obstacles of developing a design thinking mindset is the limited amount of research on the different ways design thinking manifests itself. In particular, there is little published data on the principles/mindsets, practices and techniques addressing how to build design thinking traits.

2.3.2 As a process

A review of the existing models reveals a widely shared view of the design-thinking process, despite each using different terminology. Descriptions of DT vary but mostly focus on extensive user research to gain a thorough contextual understanding of user needs, iterative working, prototyping and learning from failure. These processes are usually presented as a linear or cyclic sequence of steps with recommended methods for each step. Additionally they are described as being highly iterative and flexible. Table 3 illustrates some of the existing models in the literature.

Table 3: Design thinking models

Model	Format	Differences	Focus	Target Public
Brown (2008)	Cyclic	3 phases methodology	To build the solution	Different contexts
Plattner, Meinel, and Leifer (2010)	Linear	6 phases Curves	To teach students and professionals how to become design thinkers	Inexperienced teams
Rosensweig (2011)	Pyramid	DT for supporting design as a dynamic capability	To identify how design becomes a dynamic capability	President/CEO in large companies
Chang, et al. (2013)	Matrix	Psychology innovation Matrix	To identify the right Design Thinking path	Managers in large organisations
Storvang, Jensen, and Christensen (2014)	Spider diagram	Clarification of key drivers for innovation	To measure the design capacity of a company	Managers in micro, small and medium-sized companies

The most well-known DT model was proposed by Brown (2009b), and it can be used in different contexts (e.g. social innovation, products, and services). Brown (2009b) claims design thinking is a way of thinking rather than a sequence of orderly steps. Based on that, he proposes a cyclic model with three phases that focus on discovering new opportunities and solving problems.

2.3.3 As a toolbox

Design thinking is often equated to a process with an associated toolkit. The purpose for this is to *"make the practices of designers accessible and meaningful to managers"* (JOHANSSON-SKÖLDBERG; WOODILLA; ÇETINKAYA, 2013).

There are different design collections of tools, both aimed at practitioners (e.g. (STICKDORN et al., 2011) and academics (HASSI; LAAKSO, 2011a). As a deployment of appropriate methods is one of the core success factors of design thinking projects (BRENNER; UEBERNICKEL; ABRELL, 2016), it is imperative that teams fully understand how to apply them.

DT is an established way to bring value to some parts of business, yet it remains

a well-kept secret from many who could use it most (CLARK; SMITH, 2008). One possible explanation for that is that the concept of design thinking is broad (COOPER; JUNGINGER; LOCKWOOD, 2009), and the term is considered as confusing; there are debates over what exactly is meant by it, for instance Kimbell and Street (2009). To further understand these issues, it is necessary to understand how DT manifests itself in organisations and what are the critical factors that can help companies to successfully implement DT.

2.3.4 As a management capability

Many authors suggest that design thinking can provide significant value to innovation and management (ROSENSWEIG, 2011)(MICHELI et al., 2012) (CARLGREN; ELMQUIST; RAUTH, 2014B) (LIEDTKA, 2015). According to Brown (2009b), design thinking uses the *"designer's sensibility and methods to match people's needs with what is technically feasible and what business strategy can convert into customer value and market opportunities"*.

Recently, studies have begun to emerge that seek to explore the use of design thinking as a capability in business organisations. For instance, Cooper, Junginger and Lockwood (2009) showed that design thinking has contributed significantly to the innovation of new processes, products and services. Liedtka, King and Bennett (2013) showed that design thinking is being embedded to foster organic growth through continuous innovation. Thus, scholars argue that having design thinking as a managerial capability is essential to companies that have recognised the need to invest in an environment that promotes continuous innovation

According to Mahmoud-Jouini, Midler and Silberzahn (2016), as a strategic capability design thinking can provide significant contributions to product development, as it lauded to facilitate a deep understanding of user needs and increase team collaboration. In addition, Mahmoud-Jouini, Midler and Silberzahn (2016) claim that design thinking emphasises the need to involve the various stakeholders in the innovation process and proposes methodologies, tools, and processes for easing their interactions. The focus on collaboration through cross-functional teams associated with DT is seen as enhancing collective creative problem solving by bringing to product development diverse points of view (CARLGREN; ELMQUIST; RAUTH, 2016B).

Due to its ability to promote collaboration, design thinking is considered a powerful contribution to product success. For instance, D'Ippolito (2014) suggests that having professionals who are equipped with design thinking skills during the design process can increase collaboration, lead to product differentiation and consequently, contribute

to companies' competitiveness. Seidel and Fixson (2013) claim that the increasingly widespread use of design thinking leads to the existence of multidisciplinary teams during the concept generation phase of the design process which brings positive effects - such as increased team reflexivity. From a more general perspective, Carlgren, Elmquist and Rauth (2014B) found that incorporating DT into the product development process can result in significant cost savings as DT is lauded to reduce redesign work and shorten lead time to development. In light of recent events, researchers have been discussing how to facilitate the integration of DT to the product development process in order to integrate more diverse knowledge to the design process and also to address pressing challenges during the product development process (MICHELI et al., 2012).

Moreover, the need to interact closely with customers and learn about their needs is predominant in the literature. Liedtka, King and Bennett (2013) state that design thinking is seeing as a way to promote a user-oriented learning culture in business organisations. In particular, design thinking is based on an learning cycle (BECKMAN; BARRY, 2007) of quick iterations and testing with users. In addition to that, design thinking embraces innovation and gives companies the freedom to explore multiple ways to solve problems and discover the option that best delivers competitive advantage (CLARK; SMITH, 2008).

Carlgren, Elmquist and Rauth (2014B) demonstrated that many companies are implementing design thinking throughout their complete innovation process due to DT's contribution to enhancing collaboration and developing more user-centred solutions. As a consequence, authors state that organisations need to redefine their way of creating knowledge in order to redesign their business (throughout the organisation) to include design thinking (MARTIN, 2009). In this way, in order to encourage innovation and economic growth, researchers are investigating how to use using design thinking as an organisational resource to reinvent the entire new product development process.

Considering this evidence, it seems that the most common reasons for embedding design thinking in the organisations are linked to how it can contribute to the complex situation and open-ended challenges that organisations face nowadays by offering a more cross-functional user-centric perspective (DORST, 2011)(BECKMAN; BARRY, 2007). In summary, proficiency in design thinking can contribute to the success of many companies. However, companies face many challenges when implementing design thinking because the implementation of DT usually requires a change in the organisation culture (e.g. the creation of new job positions and new physical spaces), which might mean cost for organisations. In the next section, some of these challenges are analysed.

2.4 Design thinking state-of-art review: inside the Design Studies Journal

This section aims to provide evidence of how the understanding of design thinking as a concept has evolved in a range of disciplines, suggest important implications for practice and identify research areas for improvement. In order to do that, as an initial starting point, papers published in Design Studies Journal from 2006 to July 2019 were analysed. These findings led to the identification of the need to further analyse design thinking research in the new product development research. For that, a more broad systematic mapping analysis was conducted in the following scientific databases: ACM Digital, IEEEXplore, ScienceDirect, Scopus, and Wiley. Chapter 3 discusses the findings derived from the analysis.

For the initial starting point, the Design Studies Journal was chosen because as indicated by its publisher, Elsevier, Design Studies is one of the most important journals to approach the understanding of design from comparisons across all domains of application, including engineering and product design, architectural design and planning, computer artefacts and systems design. A total of 172 papers were found in manual searches, and 74 relevant papers were selected from 2006 to July 2019.

The next section explains the procedures undertaken to perform the analysis of the Desigin Studies Journal

2.4.1 Review process

The research strategy followed the practices for conducting systematic literature reviews (PETTICREW; ROBERTS, 2006) as well as the systematic map process (PETERSEN et al., 2008)(KITCHENHAM, 2010). It is worthwhile to highlight that the importance and use of systematic map process is increasing (CONDORI-FERNANDEZ et al., 2009) due to its relevance and potential. As defined by Kitchenham (2010), the main reason to perform a systematic map process is to identify clusters in a set of primary studies, in order to identify topics and areas to perform more complete systematic reviews.

The following central research question guided the search: How has the understanding of design thinking evolved from 2006 to July 2019 in the Design Studies Journal? The selection of relevant papers was performed in two steps: pre-selection and selection. In the pre-selection step, all the papers in which either the string “design thinking” or “design-thinking” appeared were selected. In the selection step, inclusion and exclusion criteria were applied to the set of papers resulting from the pre-selection step. As an inclusion criterion, papers were selected in which at least one of the keys was quoted twice. The inclusion criterion was chosen due to the fact that papers that quote the strings only

once do not address the theme further. Consequently, they were not useful to answer the research questions. Keynote speeches, workshop reports and editorials were excluded. Only empirical and theoretical papers were considered because they can provide evidence to answer the research questions of this study. In total, 172 papers were found in the manual conduct search and 74 relevant papers were selected based on the inclusion and exclusion criteria.

First, all the abstracts were read in order to identify the problem, goal and solution. In cases where abstracts lack relevant information, the introduction was also studied. Second, the set of keywords were clustered and used to form the following categories table.

Table 4: Research type facet

Year of publication	Temporal view of publications
Country	Countries of the authors' affiliations
Themes	The research topics related to DT
Disciplines	The disciplines influenced by DT

In order to identify research trends as viewed by researchers, an author keyword analysis (GARFIELD, 1990) was performed. Author keywords describe the article's contents and provide information about research topics. Keywords were identified and listed. Similar keywords were grouped together into themes which resulted in the following research topics: design practice, design theory, software design, design education, and design cognition, as shown in Table 6. This search strategy was used to ensure we comprehend how the perception of DT has evolved in the design literature.

2.4.2 Findings

Temporal view of publications. From 2006 to 2011, the number of publications related to DT increased reaching its maximum with six publications in the last three years (2009 - 2011) with six publications per year. However, in 2012 this total fell by 50%. The number of publications in 2013 and 2014 remained a constant of two papers per year, whereas the total reached its maximum again with six publications in 2015. The peaks reached from 2009 to 2011 may be explained by the Design Thinking Research Symposia (DTRS) that was held in London in 2007. Based on that, two workshops were held in the next two years about DT, which may have inspired the researchers to contribute to the discussion with their perspective. In 2015, there was a peak of publication, which proves that DT has become increasingly important to academia.

Countries of the authors' affiliations. A total of 174 authors and 18 different countries were identified and are presented in Table 5. The countries of authors' affiliations were grouped into three periods. A large proportion of articles in Design Studies come from North America and Europe. The number of articles from North America and UK increased significantly from period II to period III. Even though the number of authors from Oceania and Asia decreased, authors from these two continents are still devoting attention to design thinking research. This result proves that design thinking has been attracting more attention over the world.

Table 5: Country of authors' affiliations

Period	North America	UK	Oceania	Asia	Europe (Continental)
I (2006 - 2010)	11	18	05	09	04
II (2011 - 2015)	17	02	08	05	11
III (2016 - 2019)	27	16	03	03	35

The most correlated themes with DT. The most-related themes with DT in Design Studies from 2006 to July 2019 were identified based on an author keyword analysis (GARFIELD, 1990). In order to perform the keyword analysis, a manual search was conducted in each of the 74 papers to identify the keywords listed by the authors in the paper. Then, the abstract and introduction were studied to identify one keyword that better reflects the content of the paper. Finally, the set of identified keywords from all selected papers were clustered and used to form the categories illustrated in Table 6. The purpose of this analysis is to determine the themes that are influenced by DT and understand how they are related. Although one research theme does not necessarily exclude the others, the authors' keywords were very clear regarding which one provided a reasonable picture of the article's subject.

Table 6: Research themes

Period	Design Practice	Design Theory	Software Design	Design Education	Design Cognition
I (2006 - 2010)	05	05	01	03	09
II (2011 - 2015)	05	03	04	02	05
III (2016 - 2019)	12	03	03	08	06

It seems that in the first period, the design cognition theme was leading research projects with nine publications, whereas software design was the least recurring theme with just one publication. In Period II, all themes had a decrease by 50%, whereas the number of publication relating to design and software doubled. In Period III, research on design thinking practice doubled, whereas all the other topics remained around the same. Moreover, the table suggests that research on design thinking moved from a focus on design cognition to a focus on design practice. How DT influences the research themes is analysed as follows.

- Design Practice: from 2006 to 2019 the papers focused on understanding how DT would look like in practice and what benefits it could bring to organisations. In recent years, many studies sought to understand whether managers and engineers should also participate in the design thinking activities in order to improve the creation process.
- Design Theory: Design thinking has been understood as a new way of "design making". The papers investigate how DT affects the construction of problems and how they are solved using digital technology. In this way, the term "digital design thinking" was formulated and it has been considered as a new design medium.
- Software Design: the first paper was published in 2010 and aimed to understand how software designers make decisions during the design activities. In recent years, many studies started to investigate how computer-mediated communication could add value to collaborative design.
- Design Education: Design thinking is considered one of the most valuable modes of thought. Therefore, researchers are seeking to understand what the nature of DT is and how one can become a design thinker. Initially, the researchers were more preoccupied with discussing how DT could be taught to interior design students.

Nowadays, a larger variety of disciplines is being included such as architecture and computer science.

- Design Cognition: Many studies attempt to understand the cognitive processes underlying the creative behaviour of human designers. These studies examine the neurological basis of DT and those who exhibit DT traits in order to increase their "problem-finding" behaviour.

The most correlated disciplines with DT. The purpose of this analysis is to identify which disciplines have been influenced by DT research. Table 7 presents a list of disciplines and their respective period. Considering that the aim of the Design Studies Journal is to promote interdisciplinary research, it is not surprising that 15 different disciplines were found. However, it is remarkable to notice that design thinking has influenced disciplines such as Physical Therapy, English and Geography. In order to identify the disciplines of the authors, the affiliation they described in the paper was considered. According to Table 7, the engineering field has been the discipline that publishes more papers about design thinking with 26, followed by design with 25 papers. From period I to period III, the engineering, design, and education disciplines had an increase in the number of papers published, which means that DT has demonstrated great potential to solve the challenges in those fields. In addition, the education field is having a steady increase, which might explain why many studies seek to comprehend how one can become a design thinker. In period II, different disciplines rose such as business, English and physics. In fact, this indicates that DT has gained popularity over the years by making contributions to a variety of disciplines.

Table 7: Disciplines influenced by design thinking research

ID	Discipline	I (2006 - 2010)	II (2011 - 2015)	III (2016 - 2019)
ENG	Engineering	8	15	26
DES	Design	12	11	25
ACH	Architecture	10	5	10
PHI	Philosophy	1	1	0
PSY	Psychology	3	0	0
COM	Computer Science	8	3	4
EDU	Education	2	4	7
HES	Human Environmental Studies	2	0	1
PhT	Physical Therapy	1	0	0
MAN	Management	0	2	7
EnG	English	0	1	0
PHY	Physics	0	1	0
ART	Arts	0	0	2
GEO	Geography	0	0	1
IND	Industry (non-academic)	0	0	1

2.5 Summary

The purpose of this chapter was to analyse how the perception of the design thinking concept has evolved and how it affected other fields from 2006 to July 2019 in the Design Studies Journal. From 272 papers found in manual searches, 74 relevant papers were selected.

First, the research themes related to design thinking were investigated. The following research topics were found: design cognition, design practice, design theory, design education and software design. The findings show that design practice is the most addressed research topic; however, research on design education had a considerable growth in the total of papers published and it is more likely to continue on the increase.

Then, what disciplines are influenced by design thinking research were analysed. From the 14 disciplines found, the design area was identified as the one that publishes more papers related to design thinking, followed by engineering. From period II to period III, Architecture, Education, and Management had the greatest increase, with Arts and Geography also demonstrating an interest in design thinking. Based on the analysis, it is evident that DT has gained popularity and is become more influential over the years

by making contributions to a variety of disciplines. In general, the findings suggest that current research on engineering, design, and education has focused on the design cognition and on the challenge that is to understand how to become a design thinker.

Overall, this chapter provided a deep understanding of how design thinking as a concept influenced other fields, the most researched themes associated to DT, and also uncovered many challenges that might be addressed in the future. The next chapter narrows down the discussion by focusing on how design thinking is applied in practice for product development, along with the implications for management research.

3 Design thinking in practice

Researchers argue that the role of design thinking is shifting from a tactic function to a more elevated strategic position in organisations due to its ability to reduce costs in the new product development process. It is evident that design thinking's involvement in NPD has changed and consequently it is imperative to articulate the scope of this transition.

In this chapter, more insights into the relationship between DT and NPD are provided. The chapter begins by highlighting the pressing need for developing an integrated perspective of design thinking research into the new product development research. To address that gap, a systematic mapping process was used to select and review relevant papers that discuss DT in NPD. In this way, this chapter analyses, discusses, and aligns those two rich bodies of empirical research in order to develop a framework. The framework provides a common language for discussing, analysing, and reflecting upon this growing state of art on the topic. In addition, it also provides a combined perspective of research topics addressed by research of DT and NPD. Then, a map is provided as a way to illustrate how these research topics have evolved over the years, thus indicating research trends and directions for future research.

3.1 Design thinking in the product development process

A company's capability to innovate its products is an essential capability to ensure success in the marketplace and also to boost economic growth into the future (CARRILLO; DRUEHL; HSUAN, 2015). Contemporary scholarship has suggested that integrating design thinking into the new product development is essential for its successful application (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016). Best (2006) notes that integrating the design thinking process into product development strategy can improve a company's competitive position, as design thinking is lauded to present an alternative to typical approaches to problem-solving. Due to its importance to problem-solving, design thinking has been implemented in many different organisational settings. From the perspective of social innovation, many authors have seen the potential of DT as a way to improve the quality of health care and public transportation (CIPOLLA; MOURA, 2011). At the same time, the 'new media educators' have been advocating for DT to be taught in universities to help the students become innovative professionals (BURDICK; WILLIS, 2011). Moreover, it has also been applied to industrial contexts such as small and medium-sized enterprises (SMEs) (ACKLIN, 2010) and large organisations (CHANG; KIM; JOO, 2013). In contrast

to traditional management approaches, design thinking practices are based on learning through experimentation by working closely with the users. Contexts, in which there are high uncertainties and ambiguity can benefit from an experimental approach that explores multiple solutions (LIEDTKA, 2011).

In recent years, design thinking has gained ground in the industry, especially in the United States (WONG, 2009) and Europe (RAUTH; CARLGREN; ELMQUIST, 2014). Companies are seeking competitive advantage by leading through innovation. This is because the design of products and services is a major component of business competitiveness, to the extent that many known companies have committed themselves to becoming design leaders (DUNNE; MARTIN, 2006). Dorst (2011) states that DT is intimately linked to organisations by promoting a deeper transformation of the organisation's practices. In light of this, Chang, Kim and Joo (2013) analyse how large organisations' decision in adopting design thinking team has strongly contributed to the success of their products. In a more recent work, Storvang, Jensen and Christensen (2014) indicate that having a design thinking team is tightly related to the success of Danish companies, by creating design awareness among management and staff members. Rosensweig (2011) identified that by using DT as a strategic component, an organisation can exceed the expectation of its stakeholders and advances its assets - the idea is to promote a strong relationship between DT and business. In this way, the literature has highlighted DT practices as a powerful tool to create breakthrough products and promote the success of organisations.

Considering this evidence, it is evident that design thinking can play a big role in the product development process and therefore, it is important to articulate the scope of DT's involvement in the NPD research. Liedtka (2015) emphasises the need for more systematic studies in order to understand how design thinking can contribute to product success. In addition, D'Ippolito (2014) suggests that a combined perspective is needed to enable the next generation of research on product development. Micheli et al. (2012) point out that it is only through such comprehensive understanding that we can recognise design thinking's specific contribution to product development. Thereby, there is a clear need for developing an integrated perspective of deign thinking research into the new product development research. In order to address that, a comprehensive and exhaustive systematic mapping review was performed. The next section discusses the procedures considered when conducting the search, selection and analysis of the papers.

3.1.1 Review process

To articulate the scope of research based on DT and NPD in order to combine the concepts and central propositions from both approaches into a new single set of integrated concepts and propositions, two complementary methods namely systematic mapping and

thematic analysis were adopted. By combining systematic mapping (SM) (PETERSEN et al., 2008) with thematic analysis (BRAUN; CLARKE, 2006) it was possible to not only synthesise and understand the extant literature but also recognise research topics from the selected papers and categorise them into specific themes to build a framework. Figure 2 illustrates the essential process steps to generate the key deliverable. Each process step has a final outcome that serves as the conceptual framework and systematic map.

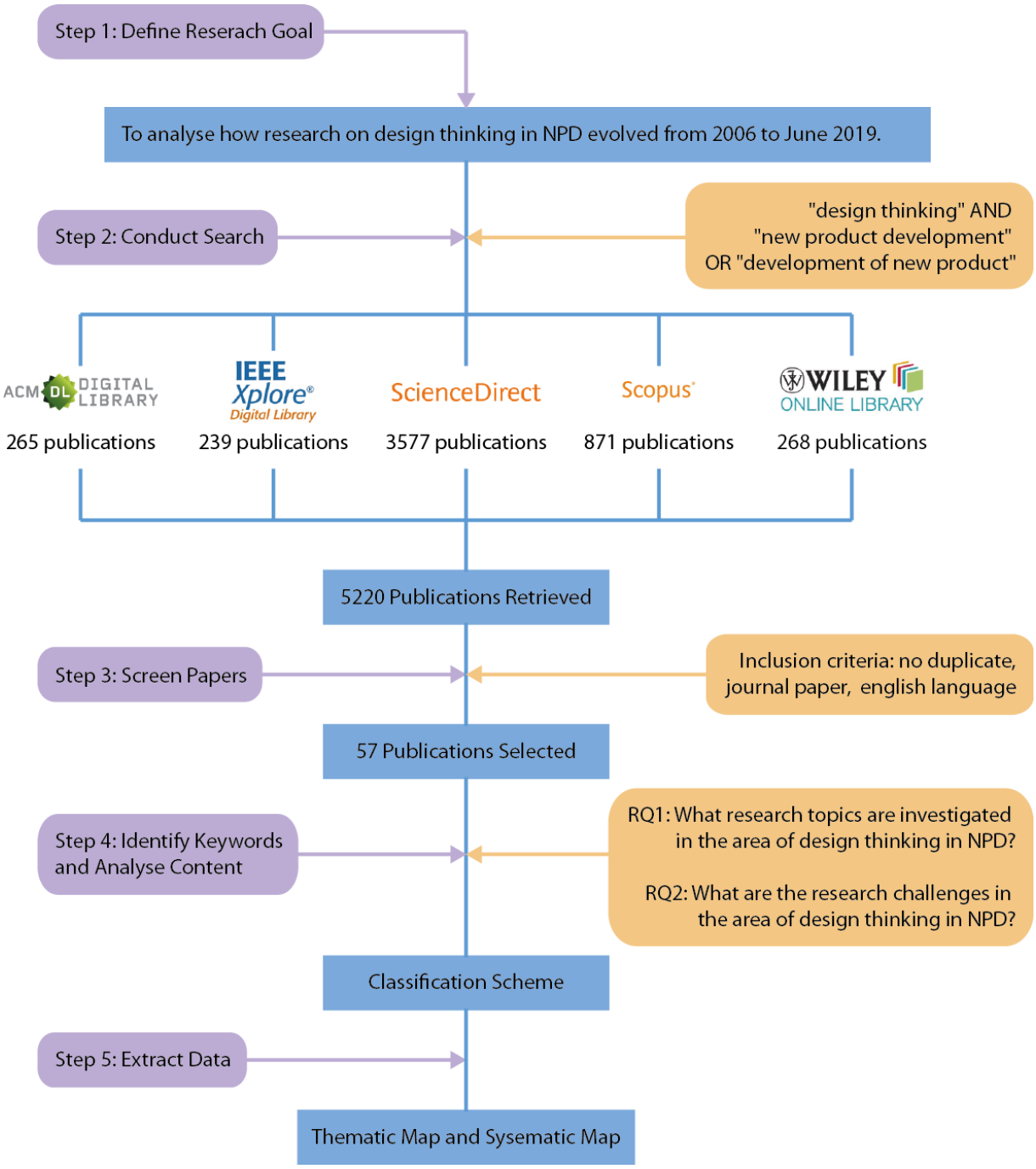

Figure 2: Review process

A comprehensive and exhaustive search for relevant papers published from 2006 to July 2019 was performed using the following scientific databases: ACM Digital, IEEEXplore, ScienceDirect, Scopus, and Wiley. The main search strings used were design thinking and new product development. To increase the sensitivity of the search and to ensure higher coverage, variations of the terms were considered. To build the string, the variations were joined with “OR” and the set of each term was joined with “AND”. Finally, the search strings used were "design thinking” AND “new product development” OR “development of new product”. In total, 5220 papers were identified.

Then, a manual search was conducted in each of the 5220 papers to identify how many times each search string was quoted. All papers in which either the keys “design thinking” AND “new product development” OR “development of new product” appeared twice were selected. As inclusion criterion, all papers in which at least one of the search strings was quoted twice or more were selected. Studies were excluded if they were (1) keynote speeches, workshops reports, editorials and conference papers; (2) duplicated studies; or (3) written in a language other than English. As such, only empirical and theoretical high quality peer reviewed papers were considered. Based on the chosen criteria, from the 5220 papers found in the initial conduct search, 57 were selected for further detailed analysis.

Similar to the previous systematic mapping, keyword analysis (GARFIELD, 1990) was used to describe each article’s contents and provide information about research themes and specific topics. In order to perform the keyword analysis, a manual search was conducted in each of the 57 papers to identify the keywords listed by the authors in the paper. Then, the abstract and introduction were studied to identify one keyword that better reflects the content of the paper. Content analysis was performed in cases where there were no keywords. Furthermore, abstracts were read to identify the research topics and gaps. In the cases where the abstracts lacked sufficient information, the introduction was also studied. By drawing on principles of thematic classification (THORPE et al., 2005), the list of 57 papers was broken down descriptively and thematically to derive themes and research topics. In the thematic analysis, the abstracts were coded and further analysed to derive themes. By following a rigorous synthesis approach to review selected studies and reveal themes, a framework was developed, and future research areas were identified. Table 8 illustrates the name of the journal where the 57 selected papers were published. Moreover, the total number of papers from each journal is presented. In this way, this study covered a comprehensive range of journals from different disciplines to understand design thinking research in NPD research.

Table 8: List of selected journals.

Journal	**Total**
Design Management Journal	07
Creativity and Innovation Management Journal	06
Journal of Product Innovation Management	06
Design Issues	05
Journal of Cleaner Production	03
International Journal of Design Creativity and Innovation	02
The Design Journal	02
European Journal of Engineering Education	01
International Journal of Engineering Education	01
Business Horizons Journal	01
Journal of Marketing Education	01
Economic Research Journal	01
Journal of Systems and Software	01
International Journal of Operations	01
Innovation: Organization & Management Journal	01
International Journal of Innovation and Learning	01
Journal of Promotion Management	01
International Journal of Project Management	01
Industry and Innovation Journal	01
Sustainability Journal	01
International Journal of Entrepreneurship and Innovation Management	01
R & D Management	01
Foresight	01
Artificial intelligence for engineering design analysis and manufacturing	01
Journal of Marketing Management	01
Technovation	01
Journal of Engineering and Technology Management	01
Social and Behavioral Sciences	01
Journal of Business Research	01
Design Studies	01
International Journal of Information Management	01
Journal of Innovative Education	01
Decision Sciences Journal of Innovative Education	01

3.1.2 Framework

Figure 3 illustrates a framework aimed at identifying and synthesising existing research that has expanded the definition of DT to address the challenges of product development. The purpose of the synthesis is to provide a common language for discussing, analysing and reflecting upon this growing state of art on the topic. By integrating relevant studies from DT and NPD, the conceptual framework analyses three themes and seven research topics.

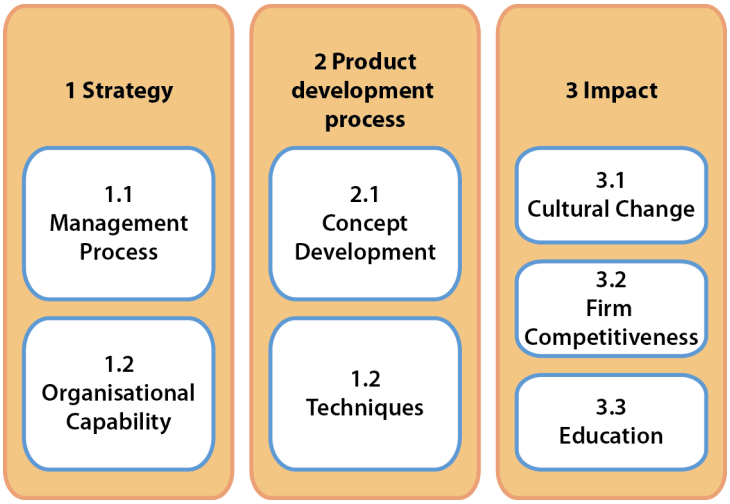

Figure 3: Conceptual framework: Synthesis of research on DT in NPD

Strategy. The purpose of this theme is to provide a better understanding of the reasons behind DT adoption and to facilitate an understanding of how researchers are responding to emerging needs. Papers within this theme were classified into two topics namely: management processes and organisational capability. "Management processes" refers to theories related to design management and product development in the literature. From the analysis of the literature, an evolution of concepts and theories related to design management, design leadership, and product development was observed. It has been suggested that DT has been linked to the design of business models (ERICHSEN; CHRISTENSEN, 2013). In light of this, emphasis has shifted, from a narrow focus on how to manage the design process, to a wider perspective, which focuses on the value provided by DT to product development (LIEDTKA, 2015). According to Micheli, Perks and Beverland (2018), methods associated with design thinking can address tricky issues in organisational strategy and therefore, design thinking should be elevated to a more strategic level. Similarly, Ford and Terris (2017) state that there is a proven need for companies to embrace and use design and design thinking in their business strategies, which might lead to long-term company success.The literature review suggests that management is discovering the potential of DT to improve the chances of success in NPD and innovation

management processes.

"Organisational capability" synthesises studies relating to companies' reaction to the implementation of DT to enhance an organisation's capability. Dominant topics in this category include the role of DT in the organisation's strategy (AWAN; SROUFE; KRASLAWSKI, 2019) and the use of DT as an organisational capability (BELTAGUI, 2018). Identifying the variety of roles that designers can fulfil in companies is pivotal to support the strategic utilisation of design, and to strengthen their product development processes (VALENCIA; PERSON; SNELDERS, 2013). However, it has been suggested that many small and medium-sized enterprises (SMEs) reject the idea of integrating design into their NPD projects. According to Moultrie, Clarkson and Probert (2007), SMEs feel that they are not equipped with adequate support to use DT as a strategic function. Authors are also calling for more research to understand how design thinking is associated with creativity and how it can be integrated within the organisational structure and product development (AWAN; SROUFE; KRASLAWSKI, 2019). Overall, these studies highlight the need to provide companies with the necessary support to apply specific design related knowledge to product development.

Product Development Process. It explains the challenges faced when adopting DT and synthesises research related to tools and methods in product development. One of the most researched concepts in product design relates to understanding the role of design in creating products that promote meaningful experiences. Consequently, providing the optimum conditions for product development has been a significant concern for researchers (MICHELI et al., 2012). The greatest opportunity to move this area forward may be in identifying conditions in which design activity, coupled with product development strategies maximises team performance.

In this category, the first theme to emerge was "Concept development", which explains how research attention is shifting from whether organisations should use DT to how to actually use it to deliver better user experience. In this category, researchers are concerned about how to deliver targeted experiences to users with particular lifestyles (experience). For instance, to develop products to shape the user's experiences, it has been postulated that the perceptions of designers and NPD managers and the language they use play an important role in the product development process (MICHELI et al., 2012). Wenngren, Ericson and Parida (2016) investigate the impact of introducing design thinking to the product development process with a focus on how engineering teams understand open-ended problems and develop radical solutions during the concept development stage. Jerrard, Martin and Wright (2017) provide an analysis of how designers and new product developers discuss and select ideas during the early stages of the design development

process. Overall, different paradigms to describe and understand how to improve the NPD process to meet people's concept of "value" have been proposed.

Finally, the second theme to emerge is related to "Techniques", which synthesises studies related to the different ways of supporting design activities in the NPD setting. Studies on this topic state that the value of design is not confined to the end result of the design process. Rather they assert that design has a contribution to all components in the design process. For instance, Bagno, Salerno and Silva (2017) suggest that design thinking acts mainly in the idea generation phase of the innovation process, by structuring idea generation to be more successful. García, Deserti and Teixeira (2017) postulate the use of a set of design tools as creative capabilities for empowering aspiring entrepreneurs in the front-end of the entrepreneurial process to frame, create, develop and assess business ideas. In an effort to understand more about brainstorming practices in the NPD setting, Callaghan (2009) reviews the connections between Myers-Briggs Type Indicator (MBTI) type and performance. In particular, it has been hypothesised that the creative problem solving (CPS) method has much in common with DT by analysing personality types with brainstorming performance factors.

Impact. This category focuses on consequences, or outcomes, of integrating DT to the NPD process, such as organisational cultural change, product and firm performance, as well as adaptations in educational programmes. The impact of integrating DT to the NPD process in terms of cultural change and firm performance has drawn attention from several researchers. Therefore, the theme "Impact" focuses on the consequences emerging as a result of the integration of DT to NPD. This category consists of the following research topics: (1) cultural change, (2) firm competitiveness, and (3) education.

First, "Cultural Change" analyses the consequences of applying DT to the NPD process. Specifically, it explores how DT can change organisational culture and influence product's performance. Research on this topic sets out to explore how design practice relates to or even stimulates organisational change (CARLGREN; ELMQUIST; RAUTH, 2016B). It has been suggested that integrating DT with NPD can be used as an effective strategy for generating and implementing organisational change. However, product development has largely been ignored for its role in changing the organisation (JUNGINGER, 2008). In particular, there are still substantial hurdles to enable design to extend its reach beyond its traditional role to influence the entire organisation's culture (LEE; EVANS, 2012).

Then, "Firm Competitiveness" introduces the first debate of how to measure design thinking's impact on product performance. Researchers working on this topic suggest that creativity and innovation might be a way to secure a successful differentiating factor for

organisations. D'Ippolito (2014) provides a review of the literature that focuses on how design influences organisations to consider consumers' needs, approaches to NPD and strategy making, and the overall impact on the mechanisms of value creation at a firm level. The review has also drawn attention to the debate as to what type of indicators could help assess the impact of design on firm performance. Similarly, Kim and Baek (2011) believe that it is through careful insight into customers' minds that a business can improve its product and revenue. In particular, the authors claim that the use of DT can be understood as a mature tool for business. Overall, the authors on this topic argue that DT has now become a valued part of companies' new product development and has been identified as a core competence, intrinsic to its success.

Finally, "Education" gathers evidence regarding how educational organisations were required to adapt its programme to meet new industry's needs. The purpose of this category is to increase insight into the consequences of integrating those two approaches to provide companies with a basis for their decision about how to improve the development process. This category emphasises the importance of understanding NPD in design education. Bont and Liu (2017) discuss how breakthrough innovation can be stimulated in China through design education. Chen et al. (2018) discuss how educators can help students appreciate and understand the processes and the consequences of developing new products using different design thinking approaches - user-centred design and design-driven innovation. Fernandes et al. (2009) assert that creativity and the use of structured methods such as DT foster improvements in the product development process. However, it seems that the use of structured methodologies for product development is not as widespread as it needs to be if companies are to remain competitive in the future (FERNANDES et al., 2009). It has been argued that design students should be educated on the management of all NPD processes and on the importance of strategic innovation and DT to survive in the business world (GUNES, 2012). An important challenge to institutions adopting interdisciplinary and experiential approaches in their design teaching is how to better measure the impact of these courses on the learning and development of its students. Overall, the authors suggest that teaching product design in education programmes promotes significant improvement in NPD activities and positively affects product design activities and performance.

3.1.3 Evolution of the literature of DT in NPD

In an effort to gain additional insight into the relationship between DT and NPD research, a map was developed based on the papers used to construct the conceptual framework. The map illustrates the distribution of the papers according to their themes and years. By doing that, it was possible to recognise trends in past research and then identify current opportunities to provide guidance for future research. The purpose of this section is to provide a better perspective on the evolution of the literature and enhance

theoretical understanding.

As can be seen from figure 4, 'Management Processes' and 'Concept Development' are the two most steady research topics since 2011. Challenges in this area include how to provide guidance on how to embed design thinking within the company. The theme addresses the potential of DT to improve the chances of success in NPD and innovation management processes. These findings concur with other studies (MOZOTA, 2008) (HOBDAY; BODDINGTON; GRANTHAM, 2011), indicating that there is a need to discover the potential of DT to improve the chances of success in NPD processes. In particular, it seems that DT is becoming a valued part of companies' new product development process and also has been identified as a core competence, intrinsic to a company's success.

Figure 4: Map of research topics and years

"Organisational Capability" was the only theme to appear in 2019. In this theme, the most prominent challenges include the lack of guidance for applying design thinking principles and practices in a very wide range of scenarios and how can this be developed as a core element of establishing on organization-wide innovation capability?. In particular, researchers suggest that many small and medium-sized enterprises (SMEs) reject the idea of integrating design into their NPD projects. SMEs feel that they are not equipped with adequate support to use DT as an organisational capability (MOULTRIE; CLARKSON; PROBERT, 2007).

"Techniques" is the most addressed research topic since 2016. The theme addresses

the potential of tools and technique related to design thinking (e.g. prototype, brainstorm) to improve the chances of success in NPD. Researchers are also calling for investigation on what design thinking-related practices can reduce development time (evolution, status) and also what training methods should be adopted to improve how the implementation of these practices (prototyping in theory and practice).

Even though there are not many papers published in the topic "Cultural change", researchers claim that, there are still substantial hurdles to enable design to extend its reach beyond its traditional role to influence the entire organisation's culture (LEE; EVANS, 2012). thus there is a clear need for the entire organisation to resonate with designerly ways of thinking if they are to maximise benefits (LEE; EVANS, 2012).

Interestingly, only one paper related to "Firm Competitiveness"' was retried from this analysis. The mentioned paper is a review of the literature that raises the question of: what are the consequences for strategy when design thinking is involved? (D'IPPOLITO, 2014). It seems that understanding how design thinking influence firm competitiveness' is still in its infancy. Researchers should recognise this opportunity and explore more the role of design thinking to enhance competitive advantage in business organisations.

It is interesting to note that there were no papers related to the "Education" field published for three years (2013 – 2015). Initially, researchers were trying to understand whether teaching product design in education programmes has the potential to promote improvements in NPD activities and positively affect product design activities and performance. However, it seems that the use of structured methodologies for product development is not as widespread as it needs to be if companies are to remain competitive in the future (FERNANDES et al., 2009). In addition, an important challenge to institutions adopting interdisciplinary and experiential approaches in their design teaching is how to better measure the impact of these courses on the learning and development of its students.

3.2 Summary

This chapter sought to provide an integrated perspective of research based on design thinking in the NPD domain. The conceptual framework was developed based on the collective wisdom of researchers who have contributed to our knowledge of DT in NPD from 2006 to July 2019. The findings discussed here provide a first step in aligning research from both approaches as well as enabling the next generation of research on DT in NPD.

To develop the framework, research papers published in the area of DT, specifically

related to NPD, were examined. From this analysis, seven salient topics were found: management processes, organisational capability, concept development, techniques, cultural change, firm competitiveness, and education. Each topic was analysed in detail and the framework was developed. In the following paragraphs, the insights derived from this systematic literature review will be discussed.

First, one of the most researched concepts in the area is the design's role in the NPD process in creating products that promote meaningful experiences; in particular, how to facilitate the integration of DT into the NPD process. This requires considerable investments in appropriate training policies for designers on product development and non-designers on design. However, findings suggest that since 2008 research has shifted to how those two approaches can actually change an organisation's culture. Authors argue that DT has now become a valued part of companies' strategy effort and it has been identified as a core competence, intrinsic to its success. In light of this, it seems that the role of DT has shifted from a tactical level function to a more elevated strategic position in organisations. Surprisingly, the review indicates that organisational culture often remains resistant to such change (LEE; EVANS, 2012). A possible explanation for this might be that there is little guidance for organisations in how to adopt and operate a more designerly approach.

The framework presented here sheds new light regarding product development strategies, roles and contributions of DT to the NPD process and the evolution of the literature of these two bodies of research. From the perspective of advancing the knowledge of DT and product development, it also provides a common language for discussing, analysing, and reflecting upon the growing state of the art of DT and NPD. By offering a common language, this systematic literature review can help researchers investigate product development in ways that support a better integration of design thinking into the NPD process. The understanding of the relationship of both approaches can help researchers develop specific measures to accurately assess its outcomes and contributions, which could lead to better product performance.

4 The Research Process

The goal of this study is to develop a design thinking capability model that can support companies in the effective implementation of design thinking. This chapter presents the research methodology and scientific approach used to develop the Design Thinking Capability model (DTCM). The phases of the research, data collection methods, and best practice protocols used in this research are presented here. In order to develop the model, a sequential exploratory mixed methods approach was employed. First, in order to capture insights into the design thinking domain, in-depth exploratory interviews were performed with key opinion leaders with significant experience (n > 5 years) in DT in both academia and industry. From this initial exploration together with the findings from the extant literature, an instrument (or scorecard) aimed at measuring a company's design thinking capability was developed. Best practices for scale development were followed to create the instrument. The scorecard was applied in a large organisation in order to test whether the model could support the company in the design thinking implementation.

Chapter four focuses on the methodological choices made when addressing the research question. In this chapter, the philosophical and interpretative assumptions of this study are presented. First, the chapter introduces the rationale for using a mixed methods approach. Then, the research structure is presented. The following section explains the qualitative phase of the research. Finally, in order to test the model, the quantitative phase is presented.

4.1 Research design (mixed methods approach)

This research follows a mixed methods design because it draws on the strengths of both qualitative and quantitative research (TASHAKKORI; TEDDLIE; TEDDLIE, 1998). Tashakkori and Creswell (2007) define mixed methods as *"research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches, or methods, in a single study or a program of inquiry"*. By using this approach it was possible to address the research aims and objectives of this study by combining best practices and protocols from both qualitative and quantitative methods.

An effective strategy of inquiry in mixed methods research is exploratory sequential design (CRESWELL; CLARK, 2017). This approach begins with a collection of qualitative methods in order to explore the design thinking phenomenon, followed by the collection of

quantitative methods data in order to empirically measure the data collected during the qualitative phase. The intent of the two-phase exploratory design is that the results of the first method (qualitative) can help develop or inform the second method (quantitative) (GREENE; CARACELLI; GRAHAM, 1989).

This design is based on the premise that an exploration is needed for one of several reasons: For example, it is most suited to studies where measures or instruments are not available, the variables are unknown, or there is no guiding framework or theory such as in this current study. Because this design begins qualitatively, it is best suited for exploring a phenomenon (CRESWELL et al., 2003). Since the goal of this study is to develop a model through the validation of an instrument, this design was particularly useful as noted by other researchers (CRESWELL; FETTERS; IVANKOVA, 2004). The exploratory sequential design was also appropriate for this research because of its ability to generalise results to different groups (MORSE, 1991) to test aspects of an emergent theory or classification (MORGAN, 1998), or to explore a phenomenon in depth and then measure its prevalence. Figure 5 illustrates the phases carried out in this research.

For the first phase, a literature review, which comprised two systematic literature reviews, was carried out, with the aim to analyse cognate literature, and synthesise the state of the art in the design thinking domain. Then, interviews to understand design thinking in practice with key opinion leaders in the area of design thinking were conducted; more specifically, to generate key insights relating to challenges and success factors and to explore how DT adds value to organisations. To do this, an interview guide was developed. In this way, it was possible to contrast real world insights with what researchers are doing in the area. By comparing the literature review with the interview findings, the first version of the Design Thinking Capability Model was developed.

The qualitative findings then guided the development of items and scales for a quantitative survey instrument - the DTCM scorecard. The DTCM scorecard was used as a mechanism to operationalise the model and a vehicle to test it. In this way, the qualitative and quantitative methods are connected through the development of an instrument with 52 items. The second phase of this study followed a quantitative approach aimed at applying the Design Thinking Capability Model in a large organisation in order to investigate whether the model could support companies when implementing design thinking. As a result of this, a final version of the model was developed.

According to Bell, Bryman and Harley (2018), quantitative and qualitative research complement each other, where one approach compensates for the weaknesses of the other. However, the use of both qualitative and quantitative data collection methods in a single

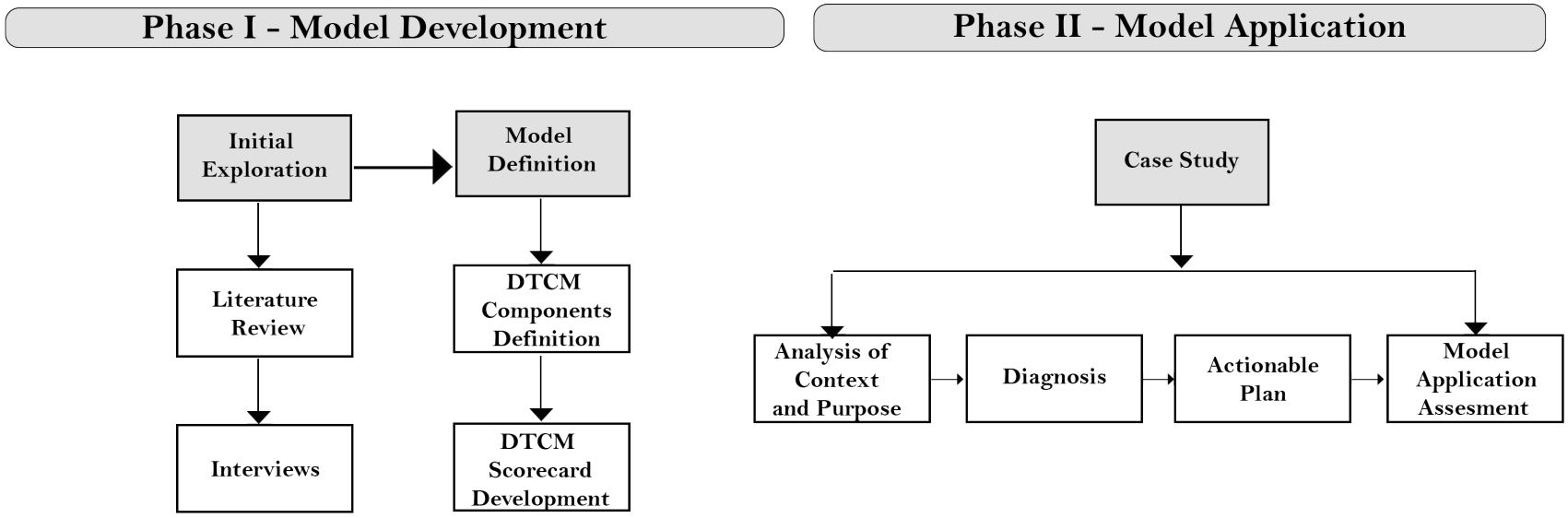

Figure 5: Exploratory sequential mixed methods research design

study is not sufficient enough to categorise a study as 'mixed methods.' It is in the integration or linking of the two strands of data that defines mixed methods research and highlights its value. Integration can happen at multiple levels of a study – design-level, methods-level, or interpretation-level – and can happen in a variety of dierent ways – connecting, building, merging, or embedding (FETTERS; CURRY; CRESWELL, 2013) (CRESWELL et al., 2011). In this study, the data is linked at the design-level with the use of a sequential design. Here the results from the first phase of the research were used to build the second stage of the research design. Overall, the notion of this study can be written as QUAL – QUAN = validate exploratory dimensions by designing and testing an instrument where both phases are equally important. In the next subsection, the details of each phase are discussed.

4.2 Phase I - model development (qualitative phase)

The first phase of this research aims to provide a theoretical basis for the study. It focuses on the scientific approach used to develop the Design Thinking Capability Model. The following research questions guided this phase:

RQ1: How has the understanding of the concept of design thinking evolved over the last years?

RQ2: How has research on design thinking in new product development evolved over the last years?

RQ3: What are the fundamental dimensions for design thinking implementation?

RQ4: What are the success factors for a successful design thinking implementation for product development?

RQ5: What are the components necessary to build a Design Thinking Capability Model?

In order to answer these questions, a literature review was conducted to understand the theories and gaps related to design thinking. Then, an interview guide was developed to explore key themes and insights related to the design thinking implementation from the perspective of both academics and practitioners.

4.2.1 Initial exploration

This section explains the exploratory study conducted aimed at understanding design thinking as a concept and also design thinking's contribution to product development from a practical perspective. In order to do that, qualitative interviews were performed with key opinion leaders from the industry. The next sections explain the procedures for conducting the qualitative interviews. In addition, it also explains how the combination of both research methods resulted in a list of components for the Design Thinking Capability Model.

4.2.1.1 Interviews

Semi-structured interviews with design thinking experts were conducted in order to formulate propositions and identify key insights on the design thinking value. There were two rounds of interviews followed by theoretical comparison after each round. Similarly to the literature review, the first round of interviews (N=10) aimed at capturing the interviewees' understanding of the value of design thinking to business organisations also to find hidden needs, more specifically, the outcomes produced by design thinking implementation and also how design thinking helps companies to identify user needs. In this way, it was possible to compare and contrast the practitioners' perspectives of the value of the design thinking with the concepts and theories proposed by the literature. This first round of interviews and theoretical comparison resulted in the definition of a set of dimensions related to the management of design thinking implementation for product development.

Then, these findings guided the questions for the next round of interviews. The second round of interviews aimed at going deeper into the topic of how to manage design thinking implementation by focusing on the dimensions previously identified. In particular, the purpose of the second round of interviews was to identify success factors for a successful design thinking implementation and categorise them into the identified dimensions. After the interviews, once again the findings were analysed against the literature and a final set of four dimensions and 20 success factors for design thinking implementation were created.

Understanding the value of design thinking (1st round). In total, ten design thinking professionals were selected from organisations conducting pioneering work in the area of design thinking. The criterion to select the interviewees was based on their level of experience with design thinking. Participants were selected based on a proven track record of conducting research in the area together with experience in applying design thinking in companies. By following a non-probability sampling technique, respondents were recruited for the study via email. In this way, the respondents were purposefully chosen to meet the

selection criteria rather than on a random basis. The interview questions were adapted from Bohlmann et al. (2013) and were split into three sections:

1. *Questions about the participant's background*
   Can you tell me about your experience with design thinking?
2. *Questions about the value of design thinking*
   How do you define a successful design thinking process in terms of the outcome?
3. *Questions about the user needs*
   How does design thinking help you to find out about user needs?

The first section covered the interviewees' general experience with design thinking. The answer from the previous section served as a guide for the next sections. The second section aimed to collect data about the value of design thinking in terms of the outcomes produced in the product development process. Considering that discovering hidden user needs is one of the biggest promises of design thinking, the final section aimed to understand how design thinking could help companies identify and assess user needs. Interviews typically lasted 30 minutes and were recorded for subsequent analysis. Through these questions, it was possible to obtain a general idea of what design thinking is. The purpose was to identify salient topics to guide the development of specific questions for the next round of interviews. The interviews were analysed using an iterative process of coding and refinement to identify core themes (CHARMAZ, 2014).

Theoretical Comparison. The next step in the process was to compare the data collected from the interviews to the literature. A constant comparative method of data analysis was used, which consists of comparing the similarities and differences between the categories that emerged from the data collected and analysing iterative sessions of the recorded interview, each time going deeper into the material to note connections, patterns, and juxtapositions. The constant comparative analysis is the process. The constant comparative analysis was the process used (HARDING, 2013), which continued until a strong theoretical understanding of an event, object, setting or phenomenon emerged. This technique is recommended by researchers (GLASER; STRAUSS; STRUTZEL, 1968) when it is necessary to make decisions to foster the development of emergent categories regarding initial collection of data based on an initial understanding of the phenomenon. This phase resulted in defining a set of dimensions related to design thinking implementation and management as shown in Table 9. These include: Strategy, collaboration, users' involvement, concept development (front-end phase) and implementation.

Table 9: DTCM Dimensions I

Dimension	Justification
1. Strategy	How to facilitate DT adoption
2. Collaboration	To investigate who is involved in the DT-related
3. Users' involvement	How users are involved in the NPD process
4. Concept phase	How DT can help teams develop the product concept
5. Implementation	How to implement DT

Implementation focuses on how design thinking is implemented in the organisation, whereas collaboration aims to investigate how widespread design thinking is in the company in terms of teams collaborating when doing DT-related activities. User's involvement aims to identify to what extent users are involved in a company's product development process, whereas concept development aims to investigate how design thinking can help teams develop the product concept at early states of the development process. Finally, strategy aims to investigate what strategy is being implemented to facilitate design thinking adoption. Following this new analysis, a guide of questions for the second round of interviews was developed.

Understanding design thinking success factors for product development (2nd round). A second set of semi-structured interviews was developed that followed good practices proposed by Moody (2005). The interview questions (see Appendix A) contained five categories resulted from the first round of interviews and theoretical comparison: implementation, collaboration, users involvement, concept development (front-end phase) and strategy. Criterion-based purposive sampling approach was used to select participants as it is lauded to help select individuals that are especially knowledgeable about or experienced with a phenomenon of interest (CRESWELL et al., 2011). The criterion used in this study was: to target high quality participants with a minimum of 5 years experience with design thinking in academia and industry. Therefore, Stanford University was targeted as they are recognised leaders in the design thinking area. In addition, employees from a large company that is a well established organisation in the area of design thinking were also interviewed.

The interviewees comprised academics and practitioners who also have significant experience in implementing DT in companies. From this, deep insight was gained into the respondents' perspectives on the success factors for design thinking implementation for product development considering the five dimensions previously identified. In particular,

the interview guide was developed based on the set of DTCM Dimensions I

Moreover, this process allowed for a deep discussion on the relationship between the literature and industrial practices. The process continued until saturation was reached. In total 10 interviews were conducted (CHARMAZ, 2014). The interviews lasted 60-120 minutes and were recorded and transcribed for analysis. The method, scope, and a number of interviews for this exploratory study are similar to other studies relying upon in-depth interviews (BOHLMANN et al., 2013). In order to identify key concepts and dimensions related to design thinking from the interviews, interviews were transcribed and the transcripts anonymised with a code stating the body and role of the interviewee and a number for later reference. For this study, open coding was used with the help of qualitative analysis software NVivo.

Theoretical Comparison. Similarly to the previous theoretical comparison, constant comparative method of data analysis was adopted again in order to compare the new findings from the interview to the literature. As a result of this process, Table 10 illustrates the final set of dimensions for the Design Thinking Capability Model.

Table 10: DTCM Dimensions II

Dimension	Justification
1. Strategy	How to facilitate DT adoption
2. Culture	How to create a culture that fosters DT
3. Implementation	How to implement DT
4. Skill Development	How to develop the necessary skills to apply DT

The findings from the second round of interviews were used to confirm the findings from the first round and also to identify new dimensions. Finally, emerging patterns were structured into more general categories that helped to refine the dimensions and define key concepts. As a result, the dimension "Strategy" was kept. The dimension "concept phase" was integrated into the dimension "implementation", whereas "collaboration" and "users' involvement" were merged into a new dimension "Culture".

In addition to the list of DTCM Dimensions, a list of critical success factors for design thinking implementation were identified. In total, 20 CSFs for a successful design thinking implementation for product development from a management perspective were identified. These CSFs were organised within the four DTCM dimensions. Based on these new findings, the final components of the DTCM model were defined and are explained in

the next section.

4.2.2 Model definition

In this section, the procedures to define the components of the Design Thinking Capability Model are described. In order to develop a comprehensive model that measures the design thinking capability of business organisations, this study borrows from best practices and guidelines for constructing capability models (CHRISSIS; KONRAD; SHRUM, 2011)(LEONARD-BARTON, 1992) (PIGOSSO; ROZENFELD; MCALOONE, 2013) and also best practices from scale development (HINKIN, 1998) (DEVELLIS, 2016).

4.2.2.1 DTCM components definition

In order to identify the fundamental constructs and variables when building capability models, capability models from other knowledge areas were analysed and synthesised. In particular, an analysis was conducted into how these models build up the capability levels, how they are applied by companies and how the process improvement is carried out. For this study, the Design Thinking Capability Model was built based on two existing models, EcoDesign Maturity Model (EcoM2) (PIGOSSO; ROZENFELD; MCALOONE, 2013) and The Capability Maturity Model Integration-Dev 1.3 CMMI-Dev 1.3 (TEAM et al., 2010). Both models were selected based on their relevance to academia; their international recognition and application in worldwide companies; and their level of consolidation and completeness. Essential elements from each model were identified and used to construct the Design Thinking Capability Model (DTCM). The main components of the Design Thinking Capability Model are (1) Dimensions, (2) Capability Levels, (3) Goals, (4) Practices, and (5) Evolution Levels. Figure 6 presents an overview of these components and their interactions.

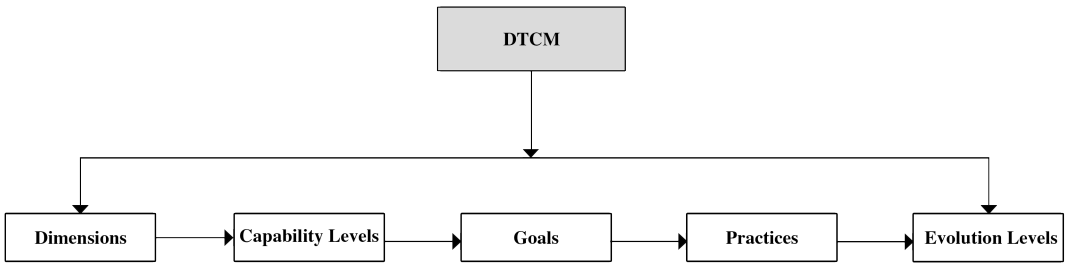

Figure 6: DTCM Components

1. **Design Thinking Dimensions:** These are the four DTCM dimensions identified from the Initial Exploration: strategy, culture, implementation, and skill development. Each dimension is a comprehensive collection of practices related to design thinking.

In total, 52 practices are proposed as a way to implement the 20 success factors also identified in the Initial Exploration.

2. **Capability Levels:** a prescriptive set of successive levels for the incorporation of design thinking practices into the product development processes. DTCM follows four capability levels: not performed, performed, managed, and defined. Each capability level is composed of goals, practices, and evolution levels in design thinking.

3. **Goals:** describes specific goals that should be addressed for each specific capability level. The goals evolve so that each goal provides a foundation for the next.

4. **Design Thinking Management Practices:** These practices describe what (not how) activities should be performed in order to address each goal. The practices aim to address each of the 20 CSFs.

5. **Evolution Levels in Design Thinking:** it aims to capture the company's own perception of how well the teams perform each practice on a 1-5 scale.

The Design Thinking Capability Model enables the assessment of a company's current design thinking capability profile, the understanding of improvement opportunities, the selection and prioritisation of design thinking practices and the deployment of roadmaps for implementation considering companies' strategic objectives and drivers. In order to test the model in companies, an instrument was developed. The DTCM Scorecard was developed as a way to operationalise the model and measure the design thinking capability in business organisations. The next section explains how best practices from scale development research guided the development of the scorecard.

4.2.2.2 DTCM Scorecard development

Scale development offers a systematic way to develop valid instrument aimed at measuring a construct or assess an attribute of interest. It is an iterative process that emerges through a series of interrelated steps (ANASTASI, 1954)(CLARK; WATSON, 1995)(DEVELLIS, 2016)(GERBING; ANDERSON, 1988)(SLAVEC; DRNOVŠEK, 2012)(WORTHINGTON; WHITTAKER, 2006). In order to develop the DTCM Scorecard, a rigorous five step process of scale development was used to construct the scale: (a) establish the construct's boundaries, (b) generate a pool of efficacy items, (c) determine the item response format and (d) have experts review the items. Each of these is now discussed. Table 21 illustrates the final version of the DTCM Scorecard.

Establish the constructs' boundaries. As it is inherently difficult to measure that which is ill-defined (WORTHINGTON; WHITTAKER, 2006), it was essential to

clearly specify and frame what is to be measured. This comprised the dimensions for a successful design thinking implementation discovered during the Initial Exploration stage of this study; strategy, implementation, culture, and skill development.

Generate a pool of items. This step of the scale development process involved generating a pool of items to capture companies' design thinking capability level. Item-writing is of crucial importance (CLARK; WATSON, 1995), since each item may be viewed as a test of the strength of the theoretical construct (DEVELLIS, 2016), and poorly worded items may introduce possible sources of error variance (WORTHINGTON; WHITTAKER, 2006). Some characteristics of item quality include clarity, conciseness, readability and distinctiveness (ANASTASI, 1954)(DEVELLIS, 2016)(HINKIN, 1998)(DAWIS, 1987). For this study, 52 items were generated to measure the four constructs (or dimensions) previously mentioned.

Determine the item response format. This step of the scale development process involved determining and justifying the measurement format for the 52 items. As a result, the scorecard was divided into two parts. The first part contained a glossary in order to facilitate the understanding of the items. The second part of the scorecard asked about how well the respondents perform each item using 1-5 scale, where 1 represents "not preformed" and 5 represents "excellently performed".

Have experts review the items. This step of the scale development process involved having design thinking experts to review the item poll (DEVELLIS, 2016). In order to ascertain that the items in the instrument were measuring all aspects of the constructs, translational validity was performed. More specifically, content and face validity. For content validity, eight experts in the area of design thinking were asked to review the items and content validity index (LYNN, 1986) was used to estimate the validity of the items. For face validity, items were reviewed in terms of relevance and clarity by eight reviewers until all items scored at least 3 in relevance. As a result, statements deemed ambiguous and unclear were made more precise and in some cases, alternative wordings were suggested by the experts. In this way, improvements were made to the items until all items were deemed fit for purpose and intended use. Both methods were necessary to determine the validity of the instrument and the details are explained in the next section.

In the next section, the procedures that were taken to ascertain validity and reliability of the study conducted under Phase I Model Development are explained.

4.2.3 Validity and reliability of the study

It is imperative that all qualitative researchers incorporate strategies to enhance the credibility of a study during research design and implementation. For qualitative research, there are many comprehensive protocols that researchers can follow to ensure validity and reliability.

To ascertain validity of Phase I of this study, it was necessary to investigate (i) whether the research questions are valid for the desired outcome, (ii) the choice of methodology is appropriate for answering the research question, (iii) the design is valid for the methodology, (iv) the sampling and data analysis are appropriate, and (v) the results and conclusions are valid for the sample and context (LEUNG, 2015). Several methods were adopted to enhance validity, including discussing the findings with experts in the area (first tier of triangulation), checking data collection resource and theories from the literature (second tier of triangulation) (CHARMAZ, 2014) (CORBIN; STRAUSS et al., 2008), well-documented trail of materials and processes (LIEDTKA, 2011)(RAUTH; CARLGREN; ELMQUIST, 2014)(CARLGREN; ELMQUIST; RAUTH, 2016B) and respondent verification (LEUNG, 2015).

In order to develop a valid instrument, best practices from content validity and face validity were adopted to develop the DTCM Scorecard. *Content validity* was undertaken to ascertain whether the content of the questionnaire is appropriate and relevant to the study purpose. Once the conceptual model was defined, experts (N=8) in the area of design thinking were asked to review the items of the questionnaire to ensure they are consistent with the model. Each reviewer rated the relevance of each item using a 4-point Likert scale (1=not relevant, 2=somewhat relevant, 3=relevant, 4=very relevant). The Content Validity Index (CVI) was used to estimate the validity of the items (LYNN, 1986). According to the CVI index, a rating of three or four indicates the content is valid and consistent with the conceptual framework (LYNN, 1986). For example, if five of eight content experts rate an item as relevant (3 or 4) the CVI would be 5/8=0.62, which does not meet the 0.87 (7/8) level required, thus indicating the item should be dropped (DEVON et al., 2007). Therefore, items that yielded CVIs of 5/8=0.62 to 6/8=0.75 were removed from the survey. The process was iterative and some items were dropped or refined during the process. As a result, all items with valid CVIs ranging from 0.87 (7/8) to 1.00 (8/8) were retained.

Face validity tests to see if the questionnaire is appropriate to the purpose of the study and content area. It evaluates the appearance of the questionnaire in terms of feasibility, readability, consistency of style and formatting, and the clarity of the language used (HALADYNA; RODRIGUEZ, 2013). To determine face validity, an evaluation form

was developed to help respondents assess each item in terms of the clarity of the wording. Each reviewer (N=8) rated the relevance of each item using a 4-point Likert scale (1= strongly disagree, 2=disagree, 3=agree, 4=strongly agree).The evaluation form was applied in person and participants were also asked to explain the reasons for each rating choice. Furthermore, the likelihood that the target audience would be able to answer the questions and the layout and style of the items was discussed. This step was iterated many times until all items scored 3 in relevance and were also clear enough.

In order to enhance the reliability of this study, strategies for consistency (CRESWELL; MILLER, 2000) and applicability (CHARMAZ, 2014) were followed. Consistency was achieved by a meticulous record keeping, demonstrating a clear decision trail and ensuring interpretations of data are consistent and transparent. Additionally, peer review was also employed as it is recommended by other researchers (CORBIN; STRAUSS et al., 2008) to provide a critical reflection of methods to ensure sufficient depth and relevance of data collection and analysis. To establish that the findings can be applicable to other contexts, this study provides a rich detail of the research process, demonstrates clarity in terms of theories and its different interpretations, and finally offers an application guide on how to apply the design thinking capability model.

4.3 Phase II - Model application (quantitative phase)

In order to perform the test of the final version of the Design Thinking Capability Model, this study followed good practices and guidelines proposed by Pigosso, Rozenfeld and McAloone (2013) to develop an application method. The DTCM application method is a guideline that explains how to use the DTCM Scorecard to operationalise DTCM. Figure 7 illustrates the steps of the application method.

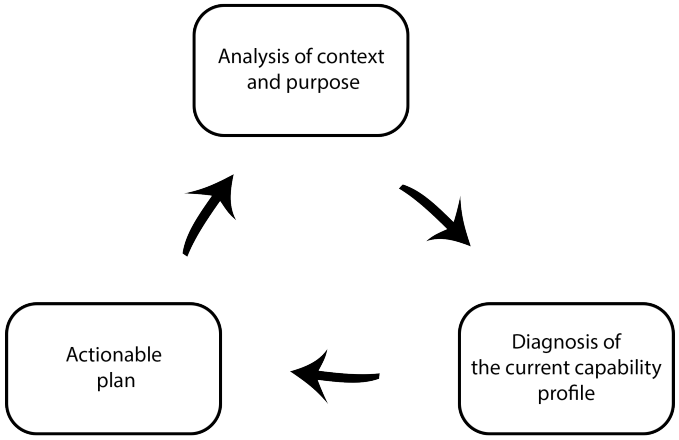

Figure 7: DTCM - Application Method

The DTCM application method was applied in a large organisation as a case study. The case study methodology conducted at the large organisation allowed a detailed investigation of the model application whereby the design thinking implementation in the company was investigated and the context in which it takes place could be understood.

The goal of the case study was to identify whether the model could provide a comprehensive evaluation of the teams' design thinking capability profile. The case study followed the guidelines proposed by Pigosso, Rozenfeld and McAloone (2013) for applying a capability model in a large organisation. After the case study, the respondents were asked to answer an evaluation questionnaire aimed at evaluating the application of DTCM at the company.

In order to use the Design Thinking Capability Model to measure Company's D design thinking capability profile, the following steps were carried out (1) Analysis of Context and Purpose, (2) Diagnosis of the current capability profile and (3) Actionable plan for improving design thinking capabilities.

4.3.1 Analysis of the context and purpose

Before implementing the model, it was necessary to understand the context and background of the company and also the goals and purpose of the company. The case study was performed at a large company founded in 1831. The company is one of the biggest companies in the sector it operates in, employing 70 000 employees around the world. Driven by innovation, business opportunities and customer satisfaction, the company

realised the great importance of effectively integrate design thinking into their product development process and also to grow their design thinking capability. The organisation was chosen due to its experience in implementing design thinking - more than ten years of experience leading design thinking projects. Moreover, since it is a large organisation with many different levels of design thinking application, the company was also chosen due to the possibility of comparing the design thinking capability of different departments. The selected company is called "Company D" throughout this thesis. In order to perform an analysis of how design thinking is implemented in the company, the following points were discussed with the person responsible for DT implementation:

1. Introduction: design thinking definition, brief explanation about the context of the model application at the company, clarification of the structure of the survey, time commitment from the company and discussion about the capability levels.
2. Definition of the application scope (i.e. where in the company and how the model would be applied).
3. Definition of key employees to answer the survey prioritising people from different functions in order to ensure a broad overview of how design thinking is applied in the company.
4. Actionable Plan: an explanation of what results the model would provide to the company, including (i) assessment of strengths and weaknesses in DT implementation, (ii) evaluation of the DT teams compared to recommendations and best practices from years of research, and (iii) development of a roadmap for DT improvement.

As a result, it was agreed that three teams would be the unit of analysis to be measured as part of the case study (see chapter 7 for a detailed analysis of the teams). During the case study, the company had access to a diagnosis of its current design thinking capability profile, a roadmap of improvement, a list of the most suitable design thinking practices to be applied, and the description of the proposed practices to be developed. The company ensured support and commitment for the application of the Design Thinking Capability Model, and willingly provided the needed information and access to relevant employees.

4.3.2 Diagnosis of the company's current capability profile

The goal of this step was to identify which design thinking practices are applied by the company and at which capability level.

First, the DTCM scorecard was distributed to relevant employees at the company. The employees who answered the scorecard were identified jointly with the company. The company was also responsible for distributing the scorecard and ensuring that their employees would answer it.

In total, seven employees from three selected teams answered the survey. Although the sample is small, only relevant employees were selected. By doing that, it enabled to capture in-depth insights into the design thinking implementation in the projects. This is line with Pigosso, Rozenfeld and McAloone (2013) who claim that in order to capture relevant information on the application of a capability model, it is necessary to ensure that the most relevant employees from the company are included in this phase.

Based on the results, the design thinking practices were evaluated according to their capability level of application in order to determine the current capability profile of the company.

4.3.3 Actionable plan

The results of the DTCM Scorecard application in the previous step were summarised and analysed. In order to represent the results of the company's current capability profile, the Design Thinking Capability Radar was developed (Figure 8). The Design Thinking Capability Radar is a combination of the design thinking evolution levels and capability levels. The design thinking practices are represented by their codes and organised in the radar according to their dimensions following a clockwise direction from Strategy to Skill Development. The capability levels are represented by the different shades of colour. The lightest colour (or lightest green) is capability level 01, medium colour (or medium green) is capability level 02 and the darkest colour (or darkest green) is capability level 03.

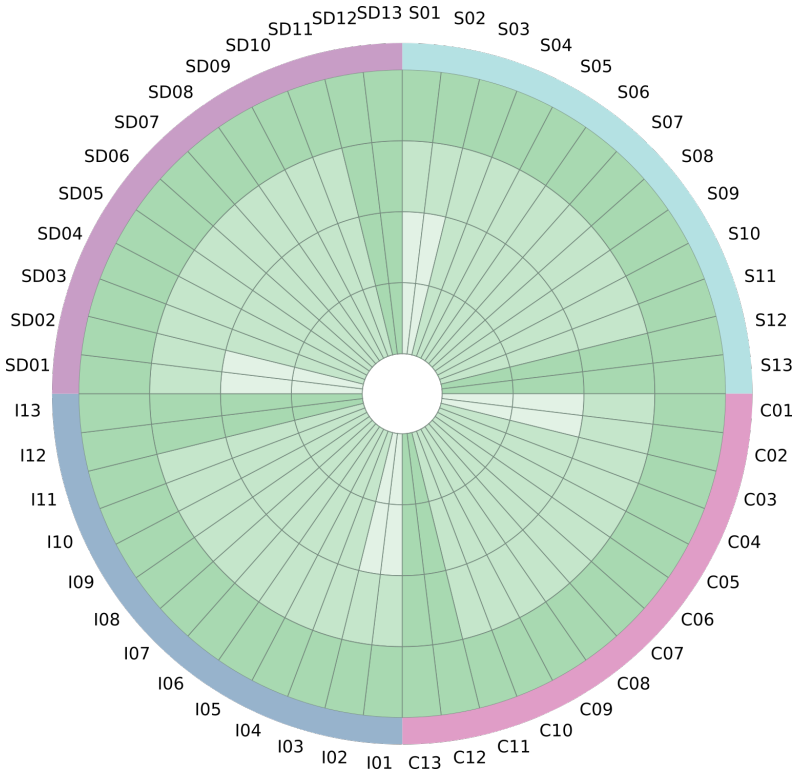

Figure 8: Design Thinking Capability Radar: a graphic example of a company's design thinking capability profile

The Design Thinking Capability Radar is an important tool to communicate a company's performance in design thinking since it provides a clear and graphic representation of their current capability profile in design thinking showing strengths and weaknesses and identifying gaps for improvement in design thinking implementation and management. In addition, the graph can also compare previous and current situations so that the improvements achieved over a certain period of time can be monitored.

Besides the DTCM Capability Radar, the Design Thinking Dashboard was also presented. Whereas the DTCM Capability Radar provides a more broad overview of the capability levels and practices, the dashboard presents the current status (i.e. critical, improved, no action required) of the success factors and dimensions based on the evolution level of the practices. In this way, the evolution level of each practice is also illustrated in the dashboard (see section 7.3.2 for a practical example of the DTCM Dashboard).

After the presentation of the results of the Design Thinking Capability Model, participants were asked to answer a questionnaire aimed at evaluating the DTCM application. Additional comments of the company concerning their experience with the DTCM application and further suggestions for improvement were also required.

4.3.4 Model application assessment

The goal of this section is to evaluate the application of the model at the company. In order to do that, an evaluation questionnaire was developed following the criteria proposed by Vernadat (1996) and adapted by Pigosso, Rozenfeld and McAloone (2013). Table 11 presents the criteria used to evaluate the application of the Design Thinking Capability Model and the justification for each criterion.

Table 11: DTCM application evaluation criteria

Criterion	Justification
Utility	Utility of the model in supporting the company in the selection of the most suitable design thinking practices to be applied.
Consistency	Consistency of the practices proposed.
Completeness	Completeness of the suggested roadmap for improvement.
Precision	Precision in the definition of the design thinking capability profile of each team.
Depth	Depth of the diagnosis of the current capability profile and proposition of design thinking practices.
Simplicity	Simplicity of the results presented (e.g. the Design Thinking Capability Radar).
Clarity	Clarity in which the results were presented.
Coherence	Coherence of the design thinking practices proposed by the Design Thinking Capability Model.
Forecast	Definition of the next steps to be taken to improve the design thinking implementation in the company.

A four-point Likert scale was adopted to measure the company's perception of the mentioned criteria: (1) "unsatisfactory", (2) "needs improvements", (3) "satisfactory", and (4) "very satisfactory". The evaluation questionnaire can be found on Appendix C.

According to Tashakkori and Creswell (2007), the quantitative phase in a sequential exploratory design approach can also include open-ended questions. Therefore, in order to capture a more in-depth perception of the participants on the model application and expand the quantitative findings, group discussions were also held. The results of the questionnaire, together with the group discussions enabled the verification of whether DTCM could offer support for companies to implement design thinking for product development.

Overall, the DTCM application method was developed and was aimed at guiding

the application of the model and establishing a continuous improvement framework for the incorporation of design thinking practices into strategy, culture, implementation, and skill development (the four dimensions for successful design thinking implementation).

5 Phase One - Model Development

This section presents the findings captured during Phase I - Model Development in accordance to the methodology and research structure presented in Chapter 4. This chapter discusses the findings presented in the papers listed as numbers from 1 to 4 in Appendix D.

First, the chapter analyses the interview findings from the Initial Exploration step from Phase I. The analysis enabled the identification of the critical success factors involved in the design thinking implementation for product development. Then, practices were derived from the success factors and classified into capability levels in order to build the DTCM Scorecard.

5.1 Initial exploration

This section presents the results of the interviews conducted during the initial exploration stage. All interviews were analysed in order to capture an initial understanding of how design thinking adds value to business organisations.

5.1.1 Interviews (1st round)

This section presents the results of the first round of interviews conducted during the initial exploration stage. The first round of interviews (N=10) aimed at capturing the interviewees' understanding of the value of design thinking to business organisations; more specifically, the outcomes produced by design thinking implementation and also how design thinking helps companies to identify user needs. The purpose of the first round of interviews was to explore the design thinking domain from a practitioner perspective in order to identify dimensions for design thinking implementation. In total, ten design thinking professionals were selected from organisations conducting pioneering work in the area of design thinking. Table 12 outlines the interviewees' background.

Table 12: Overview of interviewees' background (1st round).

Participant ID Code	**Highest educational qualification**	**Professional experience (years)**	**Role in project**
AB1	Masters	6-10	Program Lead
AB2	Masters	2-5	Coach
AB3	Masters	2-5	Coach
AB4	Masters	6-10	Coach
AB5	Masters	6-10	Coach
AB6	Masters	6-10	Coach
AB7	Masters	6-10	Coach
AB8	Bachelors	6-10	Coach
AB9	Masters	6-10	Program Lead
AB10	Masters	2-5	Coach

In total, ten design thinking professionals were selected from an educational institute, and also from a large company (name not disclosed due to privacy reasons). The educational institute aims to bring together multidisciplinary students to challenge them to solve real-world product development challenges, whereas the two other programs aim to teach students design thinking practices in which experienced design thinking coaches help them develop the mindset of design thinking. Finally, the selected large organisation is the leading provider of executive education in the fields of design thinking, IT-trends, and business innovation. The criterion to select the interviewees was based on their level of experience with design thinking (e.g., more than two years working with design thinking). All interviews were analysed in order to capture an initial understanding on how design thinking adds value to business organisations. The interview questions were adapted from Bohlmann et al. (2013) and split into three sections: (i) participants' background, (ii) value of design thinking, and (iii) user needs.

Participants' Background. Subjects were asked to explain their experience with design thinking. During the discussions, different definitions and applications of design thinking became apparent in the interviews. Subjects reported to have experienced implementing design thinking in different ways. From the interviewees' experience, companies are sometimes more interested in developing the mindset of design thinking, rather than following a specific process. According to interviewee AB9, *"(...) the mindset of DT is about shifting the user's frame of thought on a given problem from a personal or business point of*

view, to an understanding of other people's perspectives.". In other cases, companies follow a structured design thinking framework, which they then use to go through the entire process by following the steps that take them from understanding to testing. Another scenario is when a company is interested in using only one part of the process (e.g., ideation) or specific tools. In this way, design thinking is seen as toolbox that companies can use to select appropriate methods according to the project's needs. In terms of defining design thinking, the interviewees agreed that carrying out design thinking is not necessarily about following a process. Instead, it is when non-designers have the mindset to perform design activities that normally only designers would do.

Value of design thinking. Interviewees reported that one of the core elements of design thinking is empathy. Empathy allows the team to feel people's frustration to better understand the key issues associated with their beliefs – a prerequisite for a human-centred approach. Interestingly, some interviewees claimed that design thinking is not about the outcome, but the mindset towards understanding people's needs. In this way, design thinking guides the team to connect more deeply with users and non-users in order to discover opportunities for innovation. Additionally, collaboration was discussed as also being core to design thinking implementation. Design thinking is therefore not only for designers. Ideally, a design thinking team should be composed of people with different backgrounds from different departments in the company. The idea behind combining people who work in different stages of the development process is to make them familiar with the product concept at the early stages of the development. By doing that, the project moves from an individualistic way of thinking to a culture of shared creation, which has the potential to result in more innovative solutions. Overall, a good DT process is when teams learn how to work with design practices in a multidisciplinary team, and also when they discover a need that the user did not know about previously.

Using design thinking to discover users' needs. As one of the biggest promises of design thinking is to help teams identify users' hidden needs, the third question aimed at investigating how the subjects use design thinking to understand users needs. Regarding the user, a good solution should solve a need, be simple and practical. Moreover, it is necessary to consider different types of users (e.g., extreme users, normal users, and non-users). Designing for extreme users and non-users is the key to design thinking. Extreme users are important in understanding the reasons behind their passion for the proposed solution and how the solution is actually solving their problems. Moreover, the non-users might spark creativity by exposing the team to a scenario with a different problem to be solved. In the context of business and technology, ideas should be translated into solutions that drive growth and profitability.

Based on the analysis of the interviews, two dimensions on how design thinking adds value to business organisations were identified. Table 13 illustrates these two dimensions.

Table 13: Interview dimensions (1st round).

Dimension	Justification
Collaboration	To bring different point of views to problem-solving
Empathy	To understand people's feelings and behaviours in order to uncover hidden needs

From the interviewees' perspective, the greatest contribution of design thinking identified was centred on collaboration. As design thinking is not only for designers, ideally a design thinking team should be composed of people with different backgrounds from different departments in the company. The idea behind combining people who were supposed to work on the product in different stages is to make them familiar with the product concept at the early stages of the development. By doing that, the project moves from an individualistic way of thinking to a culture of shared creation, which has the potential to result in more innovative solutions. Additionally, the core of design thinking is about developing empathy to understanding people's feelings and behaviours. As a human-cantered approach, design thinking guides the team to connect more deeply with users and non-users in order to discover opportunities for innovation.

To compare the data from the interviews to the literature, the interviews were transcribed and the dimensions were re-analysed. A constant comparative method of data analysis (HARDING, 2013) was employed, which enabled a deeper investigation into the interview transcriptions to note connections, patterns, and juxtapositions. In this way, similarities and differences between the interview findings and literature emerged from the data collected. The outcome of this phase was the addition of five new dimensions: design thinking implementation, users' involvement, frequency of users' involvement, design thinking strategy, and design thinking capability. The dimensions identified in the interviews were renamed to design thinking awareness (Collaboration) and the importance in the fuzzy front-end (people's need).

5.1.1.1 Understanding the concept and value of design thinking

By comparing the data collected from the interviews to the literature, an initial set of five dimensions related to design thinking implementation was identified and organised into the first version of the Design Thinking Capability Model. Each dimension – design thinking implementation, collaboration, users' involvement, the importance of design

thinking in the front-end phase of the development process and design thinking strategy – has a five-item scale that companies can use to map their current design thinking situation. Figure 9 illustrates the first version of the Design Thinking Capability Model.

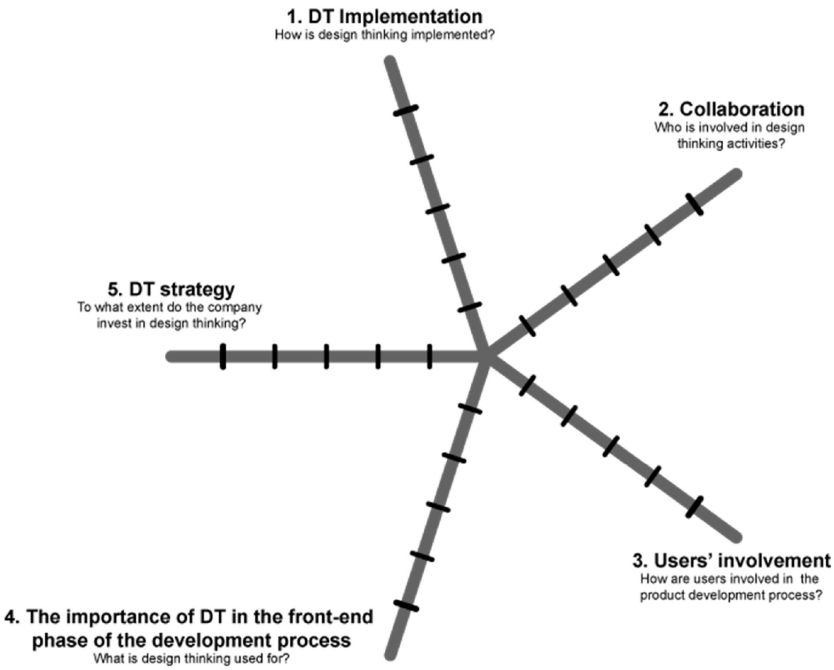

Figure 9: First version of the DTCM Model

Design thinking implementation. This dimension is particularly relevant due to the importance of understanding design thinking as a practice potentially valuable for improving innovation outcomes (LIEDTKA, 2015). As discussed before, this dimension focuses on the different representations design thinking can have in organisations, such as mind-set, iterative process, linear process, or only some specific tool/techniques. This is in line with interviewee AB4, who mentioned; *"I think we started initially thinking it more like tools and techniques and then as a process"*. Design thinking as an iterative process is when there is a process in place to serve as a guide for the teams and the team is experienced enough to use it in an iterative way, whereas in a linear process the team follows the process step-by-step without flexibility. Design thinking as mind-set describes when the company has the work attitude towards creative problem solving based on the following five principles: user focus, problem framing, experimentation, visualisation and diversity (CARLGREN; ELMQUIST; RAUTH, 2016B). Literature has perceived design thinking practices as a powerful tool to create breakthrough products and promote the success of organisations.

Collaboration. This aims to investigate how widespread design thinking is in the

company in terms of teams collaborating when doing DT-related activities. Companies encourage different types of collaboration, such as having cross-functional teams or just intra-department collaboration. In addition, collaboration could also happen on a cross-project level, which refers to when team members can collaborate with members from other projects. This dimension was created because one of the main contributions of DT is to support team collaboration in order to provide a common language for all departments involved in the product development process. As interviewee AB1 said: *"Once you teach everyone design thinking, which is fundamentally focused on the user need, we have a common language to talk about (...) so design thinking overcomes the semantic gap where we don't share common languages"*. Similarly, Carlgren, Elmquist and Rauth (2014B) mention that collaboration can promote better team dynamics in terms of increased energy, inspiration and motivation and a significant reduction in the classic divide between functions such as engineering and design. As interviewee AB9 said, *"(...) team fighting and picking the wrong product are the two major reasons start-ups fail and probably are the major reasons projects in large companies fail too*". A similar approach is suggested by interviewee AB8 who commented, *"Organisations that are typically late, are teams that are not collaborating well"*. This view is supported by Simons, Gupta and Buchanan (2011) who claim that having the entire team involved in decision-making and discussion creates more robust ideas, fewer design flaws leading to an easier product to support.

Users' involvement. Having users involved during the development process is critical and it is highly supported by design thinking literature and practice. Research claims that greater user inclusion within the design process results in a better solution (WILKINSON; ANGELI, 2014). Kallmann (2000) stresses the need to engage the users in the early stages of the design process as the way in which they interact with existing products can be used to identify problems and can spark creativity. Similarly, interviewee AB2 said *"it's very important to capture the quality of the interaction"*. This is in line with Storvang, Jensen and Christensen (2014) who point out the need to understand the difference between retrieving information from users (e.g., through questionnaires) and involving users in co-design processes and validation of design solutions in terms of the quality of information collected. Furthermore, Kim and Baek (2011) believe that it is through careful insight into customers' minds that a business can improve its product and its revenue. In light of this, this dimension aims to identify to what extent users are involved in the company's product development process.

The importance of design thinking in the front-end phase of the development process. Design thinking can be a driver for innovation, and it can take place at different stages in the company, with the front-end phase being a critical phase. Front-end consists of those activities that are conducted prior to actual development. It has been

argued that it's vital to pay close attention to this phase as it could lead to saving the most time at the lowest cost later on. The different phases covered during the early stages of the concept development phase: product vision, solution design, opportunity mapping and customer insights (KOEN et al., 2001)(SEIDEL; FIXSON, 2013). Product vision refers to when design thinking is relevant to identify the necessary product attributes to meet customer needs, solution design captures the relevance of design thinking to identify how an idea/concept may align customer needs, organisational competencies, and business goals. Opportunity mapping analyses the relevance of design thinking in identifying unarticulated customer needs, whereas customer insight explores the relevance of design thinking in identifying behaviours and attitudes that drive consumers and shape their cultures and communities. According to Markham (2013), the more thoroughly these activities prepare an idea, the better that idea should perform later on the next phases and, ultimately, in the marketplace. Therefore, it is imperative to understand how design thinking can help enhance the outcome of activities carried out at the earliest stages of conception. Based on evidence from the literature, "the importance of DT in the front-end phase of the development process" was added as the fourth dimension to the first version of the DTCM model.

Design thinking strategy. It has been suggested that an important element of studying design capability is finding out how to best support teams when building innovation capacity (STORVANG; JENSEN; CHRISTENSEN, 2014). By following that, the dimension DT strategy was created to investigate what strategy is being implemented by the company in order to facilitate design thinking adoption. According to Rosensweig (2011), it is necessary to analyse the effectiveness of design thinking in building a design capacity in support of a sustained competitive advantage in organisations. Additionally, Valencia, Person and Snelders (2013) claim that identifying the variety of roles that designers can fulfil in companies is pivotal to support the strategic utilisation of design, and to strengthen their product development processes. In order to support design thinking implementation, companies employ different investments, such as the train the trainer program, creating a collaborative creative space, encouraging workshops/mentoring and/or acquiring basic resources. Train the trainer refers to when the team has the competence to train inexperienced members of the team, collaborative creative space captures when the team has access to collaborative spaces. Workshops/mentoring is when the team has access to relevant training, whereas material is when the team has access to basic resources (post-its, whiteboards) necessary to perform some DT-related activities. In this way, Design thinking strategy was added as the fifth dimension of the first version of the DTCM model.

As a result of the analysis of the literature together with the findings from the interviews, the first version of the Design Thinking Capability model was developed. Since

the main goal of the first version of DTCM is to present the most relevant dimensions for design thinking implementation, the 5-item scales were not developed at this phase and are only illustrative. In order to develop the scales, it was necessary to have a consolidated list of dimensions and critical success factors. Because of that, a second round of interviews was conducted with ten new interviewees. The second round of interviews aimed at improving the initial set of dimensions presented in this section and also to identify critical success factors for each dimension.

5.1.2 Interviews (2nd round)

The first version of the DTCM model was then evaluated by a group of 10 design thinking experts through individual face-to-face interviews. The goal was to gather impressions and suggestions for improvements with emphasis on increasing the consistency of the model and also to identify critical success factors for each identified dimensions. Table 14 illustrates the interviewees' background.

Table 14: Overview of interviewees' background (2nd round).

Participant ID Code	**Highest educational qualification**	**Professional experience (years)**	**Role in project**
AC1	MBA	10+	Lecturer
AC2	PhD	10+	Senior Researcher
AC3	PhD	10+	Executive Director of Design
AC4	PhD	20+	Head of Learning Experience Design
AC5	Senior Researcher	10+	Head of Costumer Experience
AC6	Masters	5-10	Lecturer
AC7	PhD	5-10	Lecturer
AC8	PhD	20+	Associate Consulting Professor
AC9	BSEE	10+	Lecturer
AC10	Masters	20+	Adjunct Professor

In total, ten design thinking experts, who have experience with both academia and industry, from Stanford University and a large organisation based in the USA were

interviewed.

Stanford University was targeted, as they are recognised leaders design thinking. Scholars from Stanford University were selected based on the significant research they have conducted in the area and also on the vast experience they have in working as consultants for many large corporations on how to implement design thinking. The selected company was found in 1989 and has more 9000 employees. In order to build a more customer-focused company, they decided to implement design thinking and scale it across the organisation. In less than 10 years, the company managed to successfully integrate design thinking into the most relevant departments and also to develop specific metrics to measure its success. In order to understand and analyse the relevant factors considered by the company when implementing and measuring design thinking, the person responsible for implementing and scaling design thinking across the organisations was interviewed.

The interviews were transcribed and analysed, which enabled the refinement of the dimensions previously identified and also the identification of critical success factors for design thinking implementation for product development. Improvement opportunities elicited from these interviews were classified and analysed in order to identify similarities and/or contradictions. A final set of selected improvements were combined to develop the second version of the model.

5.1.2.1 Understanding design thinking critical success factors for product development

The differences between the first and second version of the model are substantial and reflect the analysis of the second round of interviews together with a comparison to the literature. Figure 10 illustrates the second version of the Design Thinking Capability Model.

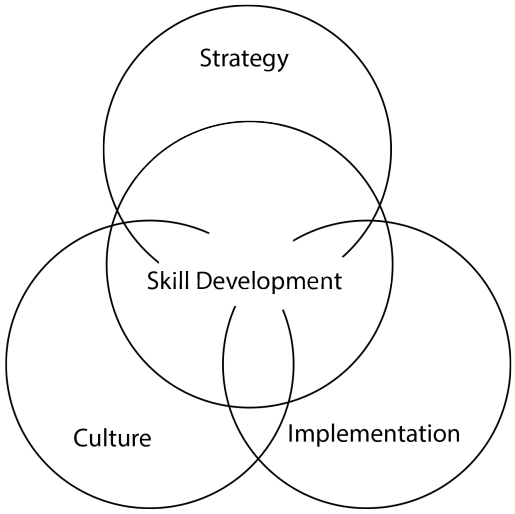

Figure 10: Second version of the DTCM model

The improvement made to the model is explained as follows. The five dimensions from the first version of the DTCM model were summarised in four for the second version. From the first version, Strategy remained as a dimension. The dimensions "users' involvement" and "collaboration" became Culture, whereas "the importance of DT in the front-end phase" was merged with "implementation". After the analysis of the second interview findings, the dimension "Skill Development" became apparent and necessary to be included. In this way, the second version of the Design Thinking Capability Model is composed of four dimensions that summarise relevant criteria that companies should consider when implementing design thinking. Each dimension contains specific factors that are a collection of practices related to design thinking implementation. Both the dimensions and the critical success factors were derived from the findings of the interviews and literature. Each one of the CSFs and dimensions are explained below. Table 15 contains the list of 20 identified critical success factors for a design thinking implementation.

Table 15: Overview of the critical success factors for DT implementation

Dimensions	Factors	Supported by
Strategy	Secure management support	in-depth interviews, Carlgren et al. (2016A), Holloway (2009), Rosensweig (2011), Hassi et al. (2011)
	Having fundamental guidelines for design thinking	in-depth interviews, Rosensweig (2011); Kimbell (2009); Hassi et al (2011)

Table 15: Overview of the critical success factors for DT implementation (continued)

Dimensions	**Factors**	**Supported by**
	Ensure funding for design thinking initiatives	in-depth interviews ,Carlgren et al. (2016A), Brown (2008);
	Having clear metrics	in-depth interviews, Carlgren et al. (2016), Liedtka (2011)
Culture	Diversity orientation	in-depth interviews, Holloway (2009), Rosensweig (2011) , Hassi et al. (2011)
	Foster empathy	in-depth interviews, Brown (2008), Kimbell (2009), Liedtka (2011), Lockwood (2009)
	Ability to handle ambiguous situations	Dunne & in-depth interviews, Martin (2006), Gloppen (2009), Sato et al (2010)
	Ability to handle complexity and uncertainty	in-depth interviews, Liedtka (2011), Bolland & Collopy (2004), Cooper et al. (2009), Dew (2007)
	Establish collaboration and cross-functional teams	in-depth interviews, Dunne & Martin (2006), Gloppen (2009), Sato et al. (2010)
Implementation	Provide necessary material	Micheli et al. (2012), in-depth interviews, Calrgren et al. (2014)
	Innovation spaces	in-depth interviews, Carlgren et al. (2014), Brown (2008)
	Establish flexible and responsive processes	in-depth interviews, Holloway (2009), Rosensweig (2011) Brenner et al (2016)
	Integrate DT into NPD and related processes	in-depth interviews, Micheli et al. (2012), Rosensweig (2011)

Table 15: Overview of the critical success factors for DT implementation (continued)

Dimensions	Factors	Supported by
	Apply lessons learned from past projects	in-depth interviews, Wölbling et al. (2012), Carlgren et al. (2016), Brenner et al. (2016)
	Access to the user	in-depth interviews, Brown (2008); Holloway (2009); Ward et al (2009)
Skill Development	Provide training on DT	in-depth interviews, Micheli et al. (2012), Carlgren et al. (2016), Rosensweig (2011)
	Collaborative initiative with key partners	in-depth interviews, Micheli et al. (2012), Rosensweig (2011)
	Create DT awareness	in-depth interviews, Dunne & Martin (2006), Sato et al. (2010), Carlgren et al. (2014)
	Enable the optimal team skills	in-depth interviews, Carlgren et al. (2016), Brown (2008), Seidel et al. (2013)
	Include DT principles into everyday work	in-depth interviews, Carlgren et al. (2016), Brown (2008), Liedtka (2011)

Strategy. The first category to emerge from analysis is strategy. This category aims to identify what practices can support companies when developing a design thinking strategy. Brown (2009b) states that it is important to bring DT's principles, methods and tools to management and business. DT can provide project management with new perspectives for addressing innovation challenges. Most importantly, in order to effective inject DT into organisations; it is imperative to help leaders understand and appreciate the value and contribution of designers, design, and DT (GLOPPEN, 2009). Many researchers discuss top management support to be critical to the success of DT implementation (LIEDTKA, 2011)(MARTIN, 2009). Since DT challenges, not only organisation of work but also power structures, managers that want to truly engage in DT need to firmly communicate their support and encourage their employees to engage in its implementation (CARLGREN; RAUTH; ELMQUIST, 2016C). Having management support is a critical success factor, also supported by interviewee AC6, who stated, *"So that to me is kind of the ideal set up, where you have someone who is high enough up in the organisation to*

be a champion and a voice for it [design thinking] but that like the actual practice of it is residing with a pretty small and localised team, that's enough to kind of get it going and growing organically.". In this way, the need to improve the link between DT and strategy is highlighted by recent research. Carlgren, Rauth and Elmquist (2016C) note that ensuring management support is imperative if teams want to have the necessary resources to perform DT-related activities. Together with securing management support, it is also important to secure funding for design thinking initiatives. As interviewee AC2 stated, *"(...) there might be more upfront costs because doing qualitative user research is exploratory"*.

Another core element necessary to enhance design thinking initiatives is to have clear metrics. According to interviewee AC7, *"some companies don't want to do design thinking because they don't see the immediate bottom line impact and that's an ongoing question that I think people have raised since design thinking has become even more popular"*. Nowadays, there is no single accepted set of metrics for design thinking. In order to overcome that limitation, some companies are developing their own metrics. For instance, interviewee AC3 pointed out that *"we look more at like how many users were interviewed in the process? How many concepts or prototypes were developed before you got to the final one? (...) how fast were you were able to work before, like did you use 6 months before a product went to market or did you use 3 years before the product went to market"*. Similarly, interviewee AC9 stated, *"measuring like cross departmental inefficiencies and how communication works between departments"*.

Culture. Culture is considered an essential element to manage knowledge (TORRACO, 2000). According to Schein (1984), culture is a systemic phenomenon rooted in the organisation's basic assumptions that influences the essential processes used for organisational adaptation, growth, and self-renewal. Leaders face a formidable challenge in creating an organisational culture that truly encourages the creation, sharing, and use of knowledge (ROBINSON; STERN, 1998). This dimension represents the core values of the company and affects all the development of the projects. Under the dimension 'culture', the practices that are necessary in order to foster a DT culture inside a company are summarised.

One of the most prominently emphasised elements of DT is its inherently and thoroughly human-centred approach - "putting people first" (BROWN, 2009b)(PORCINI, 2009)(WARD; RUNCIE; MORRIS, 2009). DT helps to more-deeply understand customers' wants and needs (spoken and unspoken) and link them to the capabilities of globally integrated enterprises (CLARK; SMITH, 2008). According to interviewee AC10, *"it's not asking a customer what they need, it's we're saying it to them with empathy and discovering*

what those unarticulated customer needs are and I think that's a skill that's really valuable". By developing empathy, companies can develop products that are more likely to meet the customers' needs and make profit. In this line, interviewee AC7 stated, *"sales increased by customer empathy, and that was a benchmark for [company's name omitted due to privacy reasons]"*. In this way, authors are extremely consistent in emphasising developing empathy towards and understanding of the customer/users (CLARK; SMITH, 2008)(DUNNE; MARTIN, 2006)(HOLLOWAY, 2009)(LOCKWOOD, 2009). Additionally, it has been argued that in order to perform DT-related activities it is necessary to foster a culture that promotes empathy towards co-workers (BROWN, 2009a) as interviewee AC9 stated, *"having empathy can reduce the friction between departments"*.

Beyond empathising and understanding the user needs, collaboration and team diversity are also suggested as being critical factors to foster a DT culture (BOLAND; COLLOPY, 2004) (BROWN, 2009b). This is confirmed by interviewee AC9, who stated *"I think you have to create a culture that supports diversity to be good as a design thinking team"*. Authors also emphasise that thinking is not something done exclusively inside one's head, but is often accomplished in interaction with other people (BOLAND; COLLOPY, 2004), using expressions such as collaborative integrative thinking (DUNNE; MARTIN, 2006). Building a community and working across professional borders is an important residue of DT (CLARK; SMITH, 2008). The benefits of focusing on collaboration through cross-functional teams associated with DT are many. Interviewee AC7 stated how powerful it is to have cross functional collaboration, *"I'm so glad I got the opportunity to work with people that I don't normally work with because it's helped me to understand just really subtle things"*. Additionally, it is seen as enhancing collective creative problem solving by bringing to conversations diverse points of view (CARLGREN; RAUTH; ELMQUIST, 2016C). By using interdisciplinary teams, DT incorporates diversity and leverages different paradigms and tool sets from each profession to analyse, synthesise, and generate insights and new ideas. According to interviewee AC9, *"having a diverse team would get [the product] there [to the market] earlier"*. The interdisciplinary nature of DT also ensures that innovations are naturally balanced between the technical, business, and human dimensions (HOLLOWAY, 2009). Finally, a collaborative work style is seen as important in tackling complex and "wicked" problems through gaining knowledge from many fields and disciplines (GLOPPEN, 2009), promoting diverse perspectives and merging them in a meaningful and novel way (DUNNE; MARTIN, 2006).

Another core factor of design thinking is that it requires a high tolerance for ambiguity and uncertainty. Liedtka (2015) states that contexts in which there are high uncertainties and ambiguity can benefit from an experimental approach that explores multiple solutions. Ambiguity is accepted as a natural part of the process (RYLANDER,

2009) as the inquiry is more emerging than deterministic (COOPER; JUNGINGER; LOCKWOOD, 2009). Therefore, a key feature of the design thinkers' mentality is being comfortable with the ambiguity (DREWS, 2009), and maintaining the ability to work in the face of such ambiguity. Indeed, managers and executives especially have to deal with decisions under circumstances of uncertainty and ambiguity. As they address messy and ill-structured situations, they can therefore benefit from DT as a way to approach indeterminate organisational problems (MARTIN, 2009).

Implementation. The dimension Implementation combines practices that aim to support employees in the different ways they can apply DT.

Contemporary scholarship has suggested that integrating DT into the new product development is essential for its successful application (MAHMOUD-JOUINI; MIDLER; SILBERZAHN, 2016). Best (2006) notes that integrating the DT process into the other product development strategies by which an organisation plans to achieve its goals will improve its competitive position. Interviewee AC6 confirm the importance of integrating DT into the NPD process, *"I think you definitely get a product to the market a lot faster using design thinking."*. Overall, interviewee AC6 agrees that the benefits of integrating DT into the NPD include a more user-focused product and quicker development process, *"So you're designing a more effective product, that's probably better satisfying customer needs and you're doing it more quickly"*

However, there are different ways of integrating DT into the product development process. In order to understand the potential that DT may have for product development, it is necessary to understand all the different ways that DT manifests itself. Authors suggest that the DT application can have three different natures: as a mindset, as a process or as toolbox (WÖLBLING et al., 2012)(BRENNER; UEBERNICKEL; ABRELL, 2016). As a mindset, DT is characterised by several key principles, such as a strong orientation to both obvious and hidden needs of customers and users, and prototyping (BRENNER; UEBERNICKEL; ABRELL, 2016). By following this line, authors also suggest that applying the principles alone - without structure - is too demanding for novices (BRENNER; UEBERNICKEL; ABRELL, 2016). In this way, in some cases it is necessary to follow a structured process in order for novices to understand what DT is and how it can contribute to the product development process. Additionally, there are different design collections of tools, both aimed at practitioners (STICKDORN et al., 2011) and academics (HASSI; LAAKSO, 2011a).

This is also reflected in the interviews. According to interviewee AC5, *"I can use certain techniques when I want to (...) yes, and it's part of a larger process and then keep*

iterating. I use the techniques continually in different orders based on the project needs". Interviewee AC5 also said *"I think you might find people that say oh yeah we use design thinking for ideating and prototyping but we don't use it for creating the problem definition and I don't think that project has better concept development than people who have only used problem definition in design thinking. So to me this is the highest important part of design thinking"*. On the other hand, interviewee AC8 highlighted the importance of developing the mindset of design thinking over just using some tools/techniques, *"and I think that when that mindset becomes part of your culture you definitely see differences in creativity"*. Being flexible and able to deploy appropriate methods is one of the core success factors of DT projects (BRENNER; UEBERNICKEL; ABRELL, 2016), therefore it is imperative that teams fully understand how to apply them. Regardless of the which way teams implement design thinking, having access to the user is fundamental. According to interviewee AC1, *"But yes definitely users' involvement in terms of testing and prototyping and being interviewed and observed and ... is very, very critical"*. Overall, it is essential that teams learn from past projects what is the best possible way of integrating DT into the product development process in order to address the project's goals and also that they have access to the user throughout the development process.

Skill Development. Employees and their competences are also critical components for companies and critical resources for their innovation capability (CARLGREN; ELMQUIST; RAUTH, 2014B). A number of studies have investigate the potential of design thinking being used by non-designers. According to Liedtka, King and Bennett (2013), all professional roles should learn from the way designers think. Authors discuss many different ways that DT can contribute to organisations. Design thinkers are said to pose questions and explore constraints in creative ways that proceed in entirely new directions (BROWN, 2009b). In addition, important skills in DT include imagination, creativity, innovation, and value creation (GLOPPEN, 2009). Based on that, Brown (2009a) calls for DT to be dispersed throughout the organisation and beyond the sole designers. Design professionals could redefine their leadership by being catalysts to help other parts of the organisation use and embrace DT (CLARK; SMITH, 2008).

This is line with what interviewee AC1 stated, *"(...) a lot of time is in training before they actually do something"*. The findings from the interviews also confirm the need to train employees in design thinking and spread it across the company as interviewee AC4 pointed out , *"But then I was also thinking there's sort of like the model words like 'train the trainer' so there's like having someone who is doing it with people versus training your own people and having internal coaches and like that's spreading so (...)"*. According to interviewee AC5's experience, *"I think the most common model is to train up a group of people that work together, whether that's five people, ten people, twenty or thirty people,*

and give them a kind of ... we call it a boot camp experience which is like the first, a longer workshop, where you really get ... you're doing a project with the methods and you have a coach. After they have had that experience then to quickly get that team that's already working together and now you have a common group of people who have shared behaviours who have been through that same experience".

Therefore, it is fundamental to promote awareness of DT implementation among all functions in the company. In order to spread DT, some companies make investments in different strategies such as providing workshops, mentoring, and training. This is in line with Seidel and Fixson (2013) who claim that managers promoting DT in their organisations should ensure that teams using design methods receive additional guidance.

Securing collaborative support from key partners can be a way to improve employees' design thinking competence (ROSENSWEIG, 2011). In this way, companies could promote projects in partnership with universities and/or research institutes. Another core element of design thinking is the ability to combine the different skills through multidisciplinary teams in order to bring different perspectives to project development (SEIDEL; FIXSON, 2013). In this way, investigating the team behaviour in order to enable the optimal team skills is also considered important as interviewee AC5 stated, *"(...)so it's definitely an early marker of success to me just seeing the team behaviours and I would bet that given enough time if most teams continue to work that way they will get to eventual success".*

However, providing only training in DT is not enough to ensure teams learnt how to apply it correctly. As interviewee AC5 stated, *"So they'll run a 2 or 3 hour workshop that's an introduction to design thinking. While I don't think that's bad we don't get really excited about that because we don't think those people in a really quick workshop are able to use those methods over time and they haven't used it on a real project, they have used it on a learning project".* In this way, it is also important to propose actions to encourage employees to include design thinking in their everyday work. According to interviewee AC5's experience, *"the people who made behaviour changes and started using it right away were the same graduates who would make long term impact. But the people who went back and said oh this week is a really busy for me but I'm going to do a workshop the next week, that very rarely lead to change behaviour and change product outcome.".*

5.2 Model definition

From the previous analysis, 20 critical success factors for a successful design thinking implementation in business organisations have been identified from the literature and semi-structured interviews with design thinking professionals. As mentioned before, the critical

success factors were organised into four different dimensions: Strategy, Implementation, Culture, and Skill Developmen. The CSFs and dimensions were fundamental to the definition of the DTCM Components. In order to identify all the components necessary to develop a model aimed at measuring a design thinking capability, well-established Capability Maturity models and their respective theoretical lenses were also investigated. In this section, the theoretical lenses and Capability Maturity Models that served as the basis for the definition of the DTCM components are explained.

One of the earliest capability maturity models was proposed by Crosby (1979) for the field of quality management. Crosby's Quality Management Maturity Grid (QMMG) categorises the "maturity" of a company in six aspects of quality management suggesting that companies were likely to evolve through five phases – Uncertainty, Awakening, Enlightenment, Wisdom, and Certainty – in their ascent to quality management excellence. Many capability maturity models were derived from Crosby's Quality Management Maturity Grid (QMMG), such as the Capability Maturity Model Integration for Development (CMMI-Dev) (PAULK et al., 1993b) and also the EcoDesign Maturity Model (EcoM2) (PIGOSSO; ROZENFELD; MCALOONE, 2013). Nowadays, the CMMI-Dev is in the version 1.3 (TEAM et al., 2010). Both capability maturity models (PIGOSSO; ROZENFELD; MCALOONE, 2013)(TEAM et al., 2010) were used as a basis in the development of the Design Thinking Capability Model. Essential elements from each model were identified and used to construct the components of the Design Thinking Capability Model (DTCM). In this section, the theoretical basis of the DTCM Components is explained.

Maturity is *"the extent to which a process is explicitly defined, managed, measured, and continuously improved"* (PAULK et al., 1993a). A maturity model is a conceptual framework made up of parts that define maturity in a particular area of interest (PIGOSSO; ROZENFELD; MCALOONE, 2013). Capability Maturity models can be used as a descriptive tool that allows an assessment of strengths and weaknesses of the company, as a prescriptive tool that enables the development of a roadmap for improvement and as a comparative tool that enables the evaluation of the company compared to standards and best practices of other organisations (PIGOSSO; ROZENFELD; MCALOONE, 2013). Although a number of different types of capability maturity models have been proposed, they share some similarities. Table 16 illustrates some of the common components among Capability Maturity Models.

Table 16: Principal components of capability maturity models

Capability Maturity Models Components	**Definition**
Process Areas	A process area is a collection of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making improvements in that area.
Goals	Goals are used to help determine whether a process area is satisfied.
Practices	Practices describe the activities that are expected to result in the achievement of the specific goals of a process area.
Evolutionary Levels	Each activity can be assessed on an evolutionary path described by a number of levels (typically 3-6).
Capability Levels	Continuous improvement across multiple process areas.
Maturity Levels	Continuous improvement in individual process areas.

The data from the table led to the definition of the main components of the Design Thinking Capability Model, which are (1) Dimensions, (2) Capability Levels, (3) Goals, (4) Practices, and (5) Evolution Levels. Since the Design Thinking Capability is a capability model, and not a capability maturity model, the component "Maturity Level" was not adopted. For DTCM, the component "Process Area" is called "Dimension."

5.2.1 Dimensions and capability levels

DTCM is composed of four dimensions: Strategy, Implementation, Culture, and Skill Development. These dimensions are explained in the previous section.

Capability Levels are a prescriptive set of successive levels for the incorporation of design thinking practices into the product development processes. In the EcoDesign model, there are six capability levels, whereas in the CMMI-Dev 1.3 (TEAM et al., 2010), there are four capability levels. For this study, the former was adopted. Each level is the foundation for ongoing process improvement. The four capability levels are designated by the numbers, 0-3. Table 17 presents the definition of the capability levels according to Team et al. (2010):

Table 17: CMMI 1.3 - Capability Levels

Capability Level	**Definition**
Capability level 0 (Incomplete)	An incomplete process is a process that is not applied or applied incompletely by the company.
Capability level 1 (Performed)	A performed process is a process that accomplishes the needed work to produce work products; the specific goals of the process area are satisfied.
Capability level 2 (Managed)	A managed process is a performed process that is planned and executed in accordance with policy; employs skilled people having adequate resources to produce controlled outputs; involves relevant stakeholders; is monitored, controlled, and reviewed; and is evaluated for adherence to its process description.
Capability level 3 (Defined)	A capability level 3 process is characterised as a defined process. A defined process is a managed process that is tailored from the organisation's set of standard processes according to the organisation's tailoring guidelines; has a maintained process description; and contributes process related experiences to the organisational process assets.

5.2.2 Goals

It aims to address each specific capability level. The goals evolve so that each goal provides a foundation for the next. For DTCM, the goals are numbered G1 through G3 as shown in Table 18. Each number corresponds to a capability level from 1 to 3.

Table 18: DTCM Goals

Goals	**Definition**
G1.1 Perform	Perform specific practices
G2.1 Assign	Assign responsibility for performing design thinking-related activities.
G2.2 Inform	Inform - Disseminate knowledge to promote design thinking development in the company
G2.3 Provide	Provide adequate resources to conduct the activities related to design thinking
G2.4 Measure	To measure the impact of the proposed practices on the company
G2.5 Learn	To measure the impact of the proposed practices on the company
G3.1 Establish	Establish design thinking as a fully integrated process in the company

The purpose of G1.1 is to implement some specific design thinking-related activities without any formalisation or systematisation, whereas the purpose of G3.1 is to establish design thinking as a fully integrated process in the company. In order to move from an informal process (G1.1) to an established process (G3.1), there are a set of five goals (G2.1 to G2.5) that need to be addressed so the company could achieve the level of a managed process (Capability Level 02).

This study borrows best practices from knowledge management capability theory to structure the five goals necessary for a managed process. Knowledge management capability (KMC) is the process of knowledge creation, validation, presentation, distribution, and application (BHATT, 2001). It is a multidimensional concept that shows itself in the form of individuals with domain expertise, lessons learned from past similar experiences, documents, routines, methods, etc (KULKARNI; FREEZE, 2004). By following best practices from knowledge management capability, the this study uses a a life-cycle of Do-Measure-Learn (TORRACO, 2000) to help companies move from an informal process (G1.1) to an established process (G3.1). By following a life-cycle of Do-Measure-Learn, it allows an organisation to learn, reflect, and unlearn and relearn, usually considered essential for building and maintaining core-capabilities. The step Do (*Do*-Measure-Learn life-cycle) consists of G2.1 Assign, G2.2 Inform and G2.3 Provide, whereas Measure (Do-*Measure*-Learn life-cycle) consists of G2.4 Measure. Finally, Learn (Do-Measure-*Learn* life-cycle) consists of G2.5 Learn. In this way, the DTCM goals were structured following well-established capability maturity models and also theories for knowledge management.

5.2.3 Practices

The design thinking management practices correspond to the best design thinking practices for product development. It describes what (*not how*) activities should be performed in order to address each goal. In general, the design thinking management practices are those related to the management of design thinking implementation. The Design Thinking capability Model contains a set of 52 Design Thinking Management Practices derived from the critical success factors identified in the Initial Exploration step of Phase I. Table 19 illustrates the design thinking management practices organised by dimensions.

Table 19: Practices organised by dimensions

ID	Practices
	Strategy
S01	Secure management support for design thinking initiatives

Table 19: Practices organised by dimensions (continued)

ID	Practices
S02	Share success stories about design thinking implementation
S03	Assign responsibility for defining a strategic plan for design thinking initiatives
S04	Inform employees about fundamental guidelines for effective design thinking implementation
S05	Ensure that the organisational culture nurtures the design thinking initiatives
S06	Ensure design thinking initiatives are well-funded
S07	Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement).
S08	Establish indicators that measure design thinking's impact on development time
S09	Establish indicators that measure design thinking's impact on the product's time-to-market
S10	Publish the performance metrics
S11	Analyse how the performance metrics change over time
S12	Customise metrics based on lessons learnt
S13	Customise the guidelines for effective design thinking implementation based on lessons learnt
	Culture
C01	Encourage teams to collaborate (e.g. idea generation, discussions)
C02	Ensure cultural diversity in teams
C03	Assign responsibility for promoting design thinking principles in the company
C04	Inform employees, from different unities, of design thinking principles
C05	Establish collaborative initiatives with key partners (e.g. universities)
C06	Establish an environment that fosters empathy for co-workers' needs
C07	Establish an environment that foster empathy for the user

Table 19: Practices organised by dimensions (continued)

ID	Practices
C08	Enable cross-functional collaboration in the product development process
C09	Establish a work environment where teams feel comfortable in working with ambiguity
C10	Measure how the culture of the organisation changes (due to DT initiatives) over time
C11	Analyse how the culture of the organisation changes (due to DT initiatives) over time
C12	Establish a dynamic work environment that can change to meet current needs
C13	Establish an organisational culture that effectively promotes design thinking principles (based on lessons learnt from past projects)
	Implementation
I01	Ensure teams have access to materials to conduct design thinking practices
I02	Perform specific design thinking practices
I03	Assign responsibility for design thinking implementation
I04	Select appropriate design thinking practices that meet the project's needs
I05	Define a design thinking process
I06	Ensure design thinking's principles are embodied in the company
I07	Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum, etc.)
I08	Ensure product attributes are aligned to the users' needs
I09	Enable employees to come together in innovation spaces to work on projects
I10	Measure how the design thinking implementation changes over time
I11	Ensure the design thinking implementation is reviewed
I12	Customise design thinking practices based on lessons learnt from past projects

Table 19: Practices organised by dimensions (continued)

ID	Practices
I13	Customise resources for design thinking practices based on lessons learnt from past projects
	Skill Development
SD01	Inform employees of opportunities to apply design thinking in their projects
SD02	Encourage employees to include design thinking practices in their daily work
SD03	Assign responsibility for spreading design thinking in the company
SD04	Disseminate knowledge on how to perform design thinking practices
SD05	Provide appropriate training in design thinking practices when needed
SD06	Encourage employees to bring lessons learnt from the trainings to everyday work
SD07	Encourage team members to help inexperienced co-workers with design thinking practices
SD08	Enable employees to have access to mentoring on design thinking when needed
SD09	Engage practitioners and researchers aiming to foster the development of design thinking in the company
SD10	Evaluate the impact of the training on the team's performance
SD11	Evaluate the impact of design thinking on the employees' innovation capability
SD12	Establish a workplace that fosters the development of design thinking in the company
SD13	Establish a customised design thinking training program based on lessons learnt from past projects

In order to enable the easy update and addition of new practices, a code was assigned to each design thinking management practice. Table 20 illustrates how the practices are related to the goals and capability levels previously discussed.

Table 20: Capability Levels, Goals, and Practices ID

Capability Level	Goals	Practice
1	G1.1	S01- S02; C01 - C02; I01-I02; SD01 - SD02
2	G2.1 Assign	S03 ; C03 ; I03 ; SD03
	G2.2 Inform	S04 ; C04 ; I04 - I08 ; SD04 ; SD06 ; SD07
	G2.3 Provide	S05 - S06 ; C05 - C09 ; I09 ; SD05 ; SD08 - SD09
	G2.4 Measure	S07 - SD10 ; C10 ; I10 ; SD10
	G2.5 Learn	S11 ; C11 ; I11; SD11
3	G3.1	S12 - S13 ; C12 - C13 ; I12 - I13 ; SD12 - SD13

Each practice has a code related to their specific dimension and level of progression within the dimension. Each dimension contains 13 practices. For instance, "[S01]" means that this practice is part of the dimension Strategy and is located in the first position within this dimension, whereas the "[C01]" is part of the dimension Culture and is located in the first position within this dimension. The practice code "[I01]" means that this practice is part of the dimension Implementation and is located in the first position within this dimension, whereas "[SD01]" is part of the dimension Skill Development and is located in the first position within this dimension.

As it can be noted from the table, the practices have a level of progression that follows the same progression as the goals, and consequently the capability levels. The first two practices from each dimensions are always the necessary practices to achieve G1.1 From the third to the eleventh practices are always the necessary practices to achieve G2.1 - G2.5. Finally, the twelfth and thirteenth practices are necessary practices to achieve G3.1.

After defining the dimensions, goals and practices of the Design Thinking Capability Model, the DTCM Scorecard was developed. The purpose of the scorecard is to use the components of the Design Thinking Capability to measure a company's design thinking capability.

5.2.4 DTCM Scorecard and evolution levels

In terms of assessing the performance (i.e. capability) of these practices, a 1-5 Likert scale questionnaire was used as recommended by other researchers (FRASER; MOULTRIE; GREGORY, 2002). For this study, the questionnaire is called DTCM Scorecard and it aims to operationalise the Design thinking Capability Model. In this case, the 'question' in the questionnaire is simply a statement of a practice and the respondent is asked to

score the relative performance of a unit of analysis (e.g. project, department, organisation) on a scale from 1 to 5 (FRASER; MOULTRIE; GREGORY, 2002). In this way, different practices may be scored to be at different evolution levels.

Evolution Levels aims to capture a company's own perception of how well the teams perform each practice on a 1-5 scale. In order to move from between capabilities, teams have to rate specific evolution levels. For instance, in order to achieve capability level 1, the company must perform each practice associated with capability level 1 at least on a scale of 3 out of 5. In order to achieve capability level 2, the company must perform each practice associated with capability level 1 and capability level 2 at least on a scale of 4 out 5. In order to achieve capability level 3, the company must perform all practices related to all capability levels on a scale of 5 out of 5.

Table 21 illustrates the final version of the DTCM scorecard. Section 6.4 explains in detail the definition of each practice and how they measure their respective construct. In terms of application of the DTCM Scorecard, Fraser, Moultrie and Gregory (2002) indicate that capability maturity assessments can be performed by an external auditor or by self-assessment. For this study, a self-assessment method was employed.

Table 21: DTCM Scorecard

Please rate your unit with regards to the following statements where 1 represents "not performed" and 5 represents "excellently performed".					
Statement	**Score**				
Strategy					
1. Our design thinking initiatives are supported by management	1	2	3	4	5
2. We are aware of success stories about design thinking	1	2	3	4	5
3. We have a strategic plan for design thinking initiatives	1	2	3	4	5
4. We are aware of fundamental guidelines for effective design thinking implementation	1	2	3	4	5
5. Our organisational culture nurtures design thinking initiatives	1	2	3	4	5
6. Our design thinking initiatives are well-funded	1	2	3	4	5
7. Our indicators measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)	1	2	3	4	5

Table 21: DTCM Scorecard (continued)

Please rate your unit with regards to the following statements where 1 represents "not performed" and 5 represents "excellently performed"					
Statement	**Score**				
8. Our indicators measure design thinking's impact on development time	1	2	3	4	5
9. Our indicators measure design thinking's impact on the product's time-to-market	1	2	3	4	5
10. Our performance metrics are accessible	1	2	3	4	5
11. How our performance metrics change over time is analysed	1	2	3	4	5
12. Our metrics are customised based on lessons learnt from past projects	1	2	3	4	5
13. Our guidelines for effective design thinking implementation are customised based on lessons learnt from past projects	1	2	3	4	5
Culture					
1. We are encouraged to collaborate (e.g. idea generation, discussions)	1	2	3	4	5
2. We are a diverse team (i.e. age, gender, religion, nationality, etc.)	1	2	3	4	5
3. We promote design thinking principles in the company	1	2	3	4	5
4. We are well informed of design thinking principles	1	2	3	4	5
5. We have collaboration with key partners (e.g. universities)	1	2	3	4	5
6. Our team feels empathy for co-workers' needs	1	2	3	4	5
7. Our team feels empathy for the user	1	2	3	4	5
8. Our team is cross-functional	1	2	3	4	5
9. Our team feels comfortable in working with ambiguity	1	2	3	4	5
10. How our organisational culture changes (due to DT initiatives) over time is measured	1	2	3	4	5
11. The changes in our organisational culture (due to DT initiatives) are analysed	1	2	3	4	5

Table 21: DTCM Scorecard (continued)

Please rate your unit with regards to the following statements where 1 represents "not performed" and 5 represents "excellently performed"					
Statement	**Score**				
12. Our work environment is flexible to meet current needs	1	2	3	4	5
13. Our culture effectively promotes design thinking principles	1	2	3	4	5
Implementation					
1. We have access to materials to conduct design thinking practices	1	2	3	4	5
2. We perform some design thinking practices	1	2	3	4	5
3. We are encouraged to implement design thinking	1	2	3	4	5
4. We select design thinking practices according to the project's needs	1	2	3	4	5
5. We follow a design thinking process	1	2	3	4	5
6. Design thinking's principles are embodied in our team	1	2	3	4	5
7. Our design thinking process is effectively integrated with other approaches (e.g. Lean, Scrum)	1	2	3	4	5
8. Our product attributes are aligned to the users' needs	1	2	3	4	5
9. We come together in innovation spaces to work on projects	1	2	3	4	5
10. How design thinking implementation changes over time is measured	1	2	3	4	5
11. The way we implement design thinking is reviewed	1	2	3	4	5
12. The way we implement design thinking is customised based on lessons learnt from past projects	1	2	3	4	5
13. Our resources (e.g. physical spaces, material) for design thinking practices are customised based on lessons learnt from past projects	1	2	3	4	5
Skill Development					
1. We are informed of opportunities to apply design thinking in our project	1	2	3	4	5

Table 21: DTCM Scorecard (continued)

Please rate your unit with regards to the following statements where 1 represents "not performed" and 5 represents "excellently performed"					
Statement	**Score**				
2. We are encouraged to include design thinking practices into our daily work	1	2	3	4	5
3. We help to spread design thinking practices in the company	1	2	3	4	5
4. We are well informed of how to perform design thinking practices	1	2	3	4	5
5. We receive appropriate training in design thinking practices when needed	1	2	3	4	5
6. We implement lessons learnt into everyday work	1	2	3	4	5
7. We help inexperienced co-workers with design thinking practices	1	2	3	4	5
8. We have access to mentoring on design thinking when needed	1	2	3	4	5
9. We engage with researchers to foster the development of design thinking	1	2	3	4	5
10. How design thinking training impacts our team's performance is evaluated	1	2	3	4	5
11. How design thinking improves our innovation capability is analysed	1	2	3	4	5
12. Our workplace fosters the development of design thinking	1	2	3	4	5
13. Our design thinking training program is customised based on lessons learnt from past projects	1	2	3	4	5

6 The Design Thinking Capability Model

This section presents the Design Thinking Capability Model (DTCM), in accordance with the research process described in chapter 4. The Design Thinking Capability Model (DTCM) is a framework aimed at supporting companies in the effective selection of design thinking practices to be integrated into the product development process. In the next sections, the main concepts and components of the DTCM will be presented.

6.1 Understanding DTCM Dimensions

In total, 52 practices for a successful design thinking integration into the product development have been identified from academic research and interviews with design thinking practitioners. The practices were organised into four different dimensions: Strategy, Culture, Implementation, and Skill development. Figure 11 illustrates the dimensions.

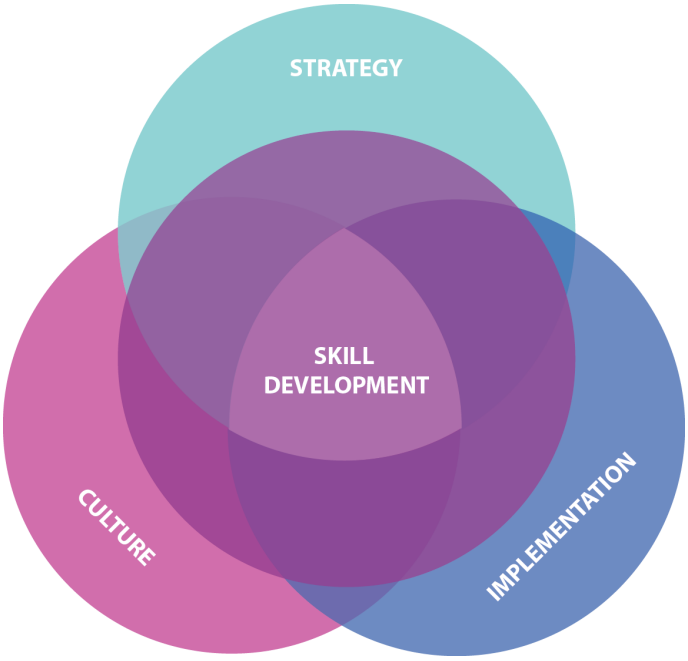

Figure 11: Dimensions for design thinking implementation

Strategy: This dimension contains a list of 13 practices aimed to support companies when developing a design thinking capability.

- Guidelines: management support, strategic plan, fundamental guidelines, funding, and organisational culture.
- KPIs: team morale, development time, and product's time-to-market.

Culture: This dimension contains a list of 13 practices aimed to support companies to develop a design thinking culture. It consists of two subcategories:

- Individual-level: ambiguity and empathy.
- Organisational-level: collaboration and diversity.

Implementation: This dimension combines 13 practices that aim to support employees in the different ways they can apply DT. This dimension includes two subcategories: Manifestations and Resources.

- Manifestations of design thinking: as a toolbox, as a process, as a mindset.
- Resources: spaces and material.

Skill Development: This dimension contains a list of 13 practices to develop the necessary skills for applying design thinking. This dimension is related to ways of creating knowledge (e.g. mentoring, training, etc.) and of providing the appropriate environment for the knowledge to be applied. In this way, this dimension includes two subcategories: Knowledge Creation and Environment.

- Knowledge creation: training, train the trainer, mentoring.
- Environment: to use the skills, to create awareness.

6.2 Understanding the DTCM Capability Levels

In order to understand how the success factors could be organised into practices for each capability level, the concepts and descriptions of the capability levels proposed by the Capability Maturity Model Integration (TEAM et al., 2010) were used. According to the CMMI-Dev 1.3, there are four relevant levels when measuring capability: not performed, performed process, managed process, and defined process. Each capability level from the CMMI-Dev was adapted to be used in a design thinking scenario. The four capability levels are designated by the numbers 0 through 3.

0. Not Performed
1. Performed
2. Managed
3. Defined

Capability Level 0: Not Performed Process

Design thinking practices are not applied or are applied incompletely by the company.

Capability Level 1: Performed Process

A performed process is a process that accomplishes the work necessary to satisfy specific projects' goals.

Capability Level 2: Managed Process

A managed process is a performed process that is planned and executed in accordance with policy; where it is monitored, controlled and evaluated. Employees are trained and have adequate resources to perform design thinking-related tasks.

Capability Level 3: Defined Process

A defined process is a managed process that is fully integrated into a company's product development process and is also tailored to a company's needs.

6.3 Understanding DTCM Capability Levels and Goals

This section describes all the goals and how they are related to the capability levels. The goals are organised in numerical order G1 through G3 as shown in Table 22. However, since there are no goals under capability level 0, this capability level was omitted in this section.

Table 22: Capability Levels and Goals

Goal	Definition
01	G1.1 Perform specific practices
02	G2.1 Assign
	G2.2 Inform
	G2.3 Provide
	G2.4 Measure
	G2.5 Learn
03	G3.1 Establish design thinking as a fully integrated process in the company

Capability Level 1: Performed Process

Goal 1.1 - Perform specific practices

Description: Design thinking is applied in an ad hoc way, i.e. to correct a problem or to accomplish a specific task by some individuals in the company, but not yet in a formalised and systematised way.

Purpose: The purpose of this goal is to produce the work that is expected by performing (i.e., executing) some tools/techniques associated with design thinking. These tools/techniques can be done informally without following a documented process description or plan. The rigour with which these practices are performed depends on the individuals managing and performing the work and can vary considerably.

Capability Level 2: Managed Process

Goal 2.1 - Assign

Description: Assign responsibility for performing design thinking-related activities.

Purpose: The purpose of this goal is to ensure that there is accountability for performing the process and achieving the specified results throughout the life of the process. The people assigned must have the appropriate authority to perform the assigned responsibilities.

Goal 2.2 - Inform

Description: Disseminate knowledge to promote design thinking development in the company

Purpose: The purpose of this goal is to define the organisational expectations for the process and make these expectations visible to those members of the organisation who are affected. In general, senior management is responsible for establishing and communicating guiding principles, direction, and expectations for the organisation.

Goal 2.3 - Provide

Description: Provide adequate resources to conduct the activities related to design thinking

Purpose: The purpose of this goal is to ensure that the resources necessary to perform the process as defined by the plan are available when they are needed. Resources include adequate funding, appropriate physical facilities, skilled people, and appropriate tools. The concept of "adequate resources" can change over time depending on a company's needs. The purpose of this goal is to ensure that people have the necessary skills and expertise to perform the process. Appropriate training is provided to those who will be performing the work. Overview training is provided to orient people who interact with those who perform the work.

Goal 2.4 - Measure

Description: To measure the impact of the proposed practices on the company.

Purpose: The purpose of this goal is to measure different aspects of design thinking application in order to identify areas for improvement.

Goal 2.5 - Learn

Description: To learn how to improve design thinking initiatives based on metrics from past projects

Purpose: The purpose of this goal is to analyse past projects and propose improvements to the design thinking initiatives.

Capability Level 3: Defined Process

Goal 3.1 - Establish design thinking as a fully integrated process in the company

Description: Ensure alignment among all strategic and operational practices concerning design thinking initiatives.

Purpose: The purpose of this goal is to establish and maintain design thinking initiatives that are tailored from the organisation's set of standard processes to address the project's needs.

6.4 Understanding DTCM levels, Goals and Practices

This section describes all the goals and practices and how they are related to the capability levels. The goals are organised in numerical order G1 through G3. However, since there are neither goals nor practices under capability level 0, this capability level was omitted in this section. The practices are organised in numerical order under the design thinking dimension they support (see Table 19).

Capability Level 1: Performed Process

Goal 1.1 - Perform specific practices

Design thinking is applied in an ad hoc way, i.e. to correct a problem or to accomplish a specific task by some individuals in the company, but not yet in a formalised and systematised way.

Practice: [S01] Secure management support for design thinking initiatives

Managers that want to truly engage in design thinking need to firmly communicate their support and encourage their employees to engage in its implementation.

Practice: [S02] Share success stories about design thinking implementation

One of the core elements for design thinking survival is to identify how it can be measured in order to understand its benefits. When there are no metrics available, sharing success stories about design thinking will give employees initial insights of how and where design thinking adds value to organisations.

Practice: [C01] Encourage teams to collaborate (e.g. idea generation, discussions)

The focus on collaboration through cross-functional teams associated with design thinking is seen as enhancing collective creative problem solving by bringing to conversations diverse points of view. In this way, it is important to propose different activities for teams to "get together" and collaborate. For instance, idea generation, discussions, prototype sessions, etc.

Practice: [C02] Ensure cultural diversity in teams (e.g. age, gender, religion, nationality)

Teams should be diverse (e.g. demographic, job expertise). By using diverse teams, DT leverages different paradigms and tool sets from each profession to analyse, synthesise, and generate insights and new ideas.

Practice: [I01] Ensure teams have access to materials to conduct design thinking practices

Using artefacts (e.g. Post-Its, Lego) to express ideas can be used for communication, alignment, and living requirement specifications to provide clarity and transparency during the development of the solution.

Practice: [I02] Perform specific design thinking practices

Some specific goals of the project are supported by some design thinking practices (e.g. prototype techniques). These practices can be done informally without following a documented process description or plan.

Practice: [SD01] Inform employees of opportunities to apply design thinking in their projects

It is fundamental to promote awareness of design thinking implementation among relevant functions in the company. The purpose of this practice is to define organisational expectations for design thinking implementation and make these expectations visible to those members of the organisation who are affected.

Practice: [SD02] Encourage employees to include design thinking practices in their daily work

When having specific knowledge about how to implement specific practices related to design thinking, employees should be encouraged to perform these practices. By doing that, the company will be promoting the necessary changes in the organisational culture for DT to happen.

Capability Level 2: Managed Process

Goal 2.1 - Assign

Practice: [S03] Assign responsibility for defining a strategic plan for design thinking initiatives

Responsibility is assigned to those who understand how to ensure that employees are working towards common goals and also how to adjust the organisation's direction in response to a dynamic environment.

Practice: [C03] Assign responsibility for promoting design thinking principles in the company

Responsibility is assigned to those who understand the core principles of design thinking and are able to disseminate those principles in the company. The purpose of this practice is to identify what specific design thinking principles are more relevant to specific functions in the company.

Practice: [I03] Assign responsibility for design thinking implementation

Responsibility is assigned to those who understand the different ways design thinking can be implemented (e.g. as a toolbox, process, mindset) and are able to deploy appropriate methods in order to have a flexible and responsive implementation to different projects' needs. The purpose of this practice is to monitor and control how design thinking is implemented.

Practice: [SD03] Assign responsibility for spreading design thinking in the company

Responsibility is assigned to those who can disseminate knowledge on how to perform design thinking implementation. The purpose of this practice is to monitor and control where design thinking is implemented in the company in order to spread it in the company.

Goal 2.2 - Inform

Practice: [S04] Inform employees about fundamental guidelines for effective design thinking implementation

Regularly inform relevant stakeholders about the plans and status for selecting and deploying improvement strategies for design thinking implementation.

Practice: [C04] Inform employees, from different unities, of design thinking principles

Actions should be taken to inform employees about design thinking principles, such as promoting discussions, workshops, etc. The purpose of this practice is to make employees aware of what specific design thinking principles are more relevant to their functions in the company.

Practice: [I04] Select appropriate design thinking practices that meet the project's needs

Actions should be taken to inform employees about how to deploy appropriate design thinking practices, during the product development process, in order to meet specific project goals. The purpose of this practice is to ensure that the product development process is flexible and responsive to change.

Practice: [I05] Define a design thinking process

Inform employees on how to perform a design thinking process.

Practice: [I06] Ensure design thinking's principles are embodied in the company

Inform employees about how to develop a design thinking mindset. To develop a design thinking mindset, relevant characteristics include being experimental, collaborative, optimistic and empathetic. We define mindset as the ideas and attitudes with which a person approaches a situation.

Practice: [I07] Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum, etc.)

Inform employees how to integrate design thinking into relevant processes related to product development.

Practice: [I08] Ensure product attributes are aligned to the users' needs

Inform employees about how to ensure that the product offers what the users need.

Practice: [SD04] Disseminate knowledge on how to perform design thinking practices

Actions should be taken to inform employees about how to implement design thinking. The purpose of this practice is to develop the employees' ability to perform design thinking practices.

Practice: [SD06] Encourage employees to bring lessons learnt to everyday work

Actions should be taken to encourage employees to apply lessons learnt from the skill development practices (e.g. mentoring, training).

Practice: [SD07] Encourage team members to help inexperienced co-workers with design thinking practices

Establish a program to encourage team members to inform inexperienced co-workers about how to perform the design thinking practices.

Goal 2.3 - Provide

Practice: [S05] Ensure that the organisational culture nurtures the design thinking initiatives

Include in the strategic plan how to make the organisational environment facilitate design thinking initiatives

Practice: [S06] Ensure design thinking initiatives are well-funded

Estimate costs of the development of design thinking and provide funding for deployment.

Practice: [C05] Establish collaborative initiatives with key partners (e.g. universities)

Provide teams with access to key partners to collaborate in projects.

Practice: [C06] Establish an environment that fosters empathy for co-workers' needs

Provide an environment where employees feel comfortable to express their ideas and beliefs.

Practice: [C07] Establish an environment that fosters empathy for the user

Provide an environment where employees feel empathy for the user. Actions might include immersion into the users' world, observations and interviews techniques.

Practice: [C08] Enable cross-functional collaboration in the product development process

Provide teams with different expertise from different departments. The purpose of this practice is to enhance collective creative problem solving by bringing to conversations diverse points of view.

Practice: [C09] Establish a work environment where teams feel comfortable in working with ambiguity

Provide an environment where teams are able to make decisions without having all the necessary information. The purpose of this practice is to make teams feel comfortable with exploring a problem without knowing the answer.

Practice: [I09] Enable employees to come together in innovation spaces to work on projects

Provide teams with innovation spaces and encourage them to make use of them. The purpose of this practice is to use space to strengthen collaboration.

Practice: [SD05] Provide appropriate training in design thinking practices when needed

Appropriate training is provided to those who will be performing design thinking practices. Overview training is provided to orient people who interact with those who will perform the design thinking practices. The purpose of this practice is to ensure that people have the necessary skills and expertise to implement design thinking.

Practice: [SD08] Enable employees to have access to mentoring on design thinking when needed

Appropriate mentoring is provided to those who will be performing design thinking practices. The purpose of this practice is to ensure that people have the necessary skills and expertise to implement design thinking

Practice: [SD09] Engage practitioners and researchers aiming to foster the development of design thinking in the company

Appropriate collaboration between employees and research institutes should be encouraged. The purpose of this practice is to enable Industry-Academia collaboration in order to keep teams up-to-date with the new science discoveries in the field of design, management, and product development.

Goal 2.4 - Measure

Practice: [S07] Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)

Measure the impact of design thinking on employees' morale. Design thinking has potential to excite and inspire employees to be creative.

Practice: [S08] Establish indicators that measure design thinking's impact on development time

Measure the impact of design thinking on the time it takes for the product to move from concept creation to a commercially viable product.

Practice: [S09] Establish indicators that measure design thinking's impact on the product's time-to-market

Measure the impact of design thinking on the time it takes for the product to complete the design, development, and testing processes.

Practice: [S10] Publish the performance metrics

The performance metrics of the established indicators should be available for team members to access. The purpose of this practice is to monitor how the metric results change over time in order to keep improving the strategic plan for design thinking.

Practice: [C10] Measure how the culture of the organisation changes (due to DT initiatives) over time

The purpose of this practice is to understand how implementing design thinking over time can change some aspects of the culture in the company.

Practice: [I10] Measure how the design thinking implementation changes over time

Measure how the results change depending on how design thinking is implemented (e.g. as a toolbox, process, mindset). The purpose of this practice is to be able to analyse

the project needs and predict what design thinking practices are necessary to fulfil those needs.

Practice: [SD10] Evaluate the impact of the design thinking training on the team's performance

Assess how design thinking training impacts how well the teams perform. The purpose of this practice is to offer employees relevant training according to the current needs.

Goal 2.5 - Learn

Practice: [S11] Analyse how the performance metrics change over time

Understand how the performance metrics of the established indicators change over time. The purpose of this practice is to learn how the metric results change over time in order to keep improving the strategic plan for design thinking.

Practice: [C11] Analyse how the culture of the organisation changes (due to DT initiatives) over time

Understand how unquantified benefits of design thinking (e.g. the happiness of the employees, increased collaboration, team alignment) change over time. The purpose of this practice is to learn how implementing design thinking over time can change some aspects of the culture in the company.

Practice: [I11] Ensure design thinking implementation is reviewed

Review how the results change depending on how design thinking is implemented (e.g. as a toolbox, process, mindset). The purpose of this practice is to be able to analyse the projects' needs and predict what design thinking practices are necessary to fulfil those needs.

Practice: [SD11] Evaluate the impact of design thinking on the employees' innovation capability

Analyse how design thinking training affects how teams innovate. Employee innovation capability is defined as the propensity of employees to generate new ideas, promote these new ideas, and implement these new ideas to achieve organisational goals. The purpose of this practice is to understand how to offer employees relevant training to enhance their innovation capability.

Capability Level 3: Defined Process

Goal 3.1 - Establish design thinking as a fully integrated process in the company

Practice: [S12] Customise metrics based on lessons learnt

The purpose of this practice is to tailor the metrics according to the company's needs. The organisation should be able to identify indicators to measure relevant aspects of the company.

Practice: [S13] Customise the guidelines for effective design thinking implementation based on lessons learnt

The purpose of this practice is to tailor the strategy of design thinking implementation based on lessons learnt from previous projects. The company is thus able to identify where the design thinking strategy needs improvement and how to propose those changes.

Practice: [C12] Establish a dynamic work environment that can change to meet current needs

The purpose of this practice is to have a work environment that can be easily tailored to meet current needs.

Practice: [C13] Establish an organisational culture that effectively promotes design thinking principles (based on lessons learnt from past projects)

The company is able to identify how design thinking affects the organisational culture, where it needs improvement and how to efficiently tailor the environment to foster a culture that promotes design thinking principles.

Practice: [I12] Customise design thinking practices based on lessons learnt from past projects

The purpose of this practice is to tailor the design thinking practices based on lessons learnt from past projects. The company is able to identify what practices should be implemented, how to implement them, and how to adapt them when necessary.

Practice: [I13] Customise resources for design thinking practices based on lessons learnt from past projects

The purpose of this practice is to tailor the resources - i.e. material and spaces - based on lessons learnt from past projects. The company is able to identify what resources should be used for specific scenarios, how to implement them and how to adapt them when necessary.

Practice: [SD12] Establish a workplace that fosters the development of design thinking in the company

The purpose of this practice is to establish a work environment that facilitates how design thinking can grow in the company.

Practice: [SD13] Establish a customised design thinking training program based on lessons learnt from past projects

The purpose of this practice is to enable teams to have access to a consolidated training program that is tailored to current needs.

6.5 Advancing through DTCM Capability Levels (Understanding the evolution level in design thinking)

In order to measure the design thinking capability, relevant employees are required to rate how well the organisation perform each practice on a 1-5 scale. Figure 12 illustrates the 1-5 scale on the left (evolution level in the design thinking practices), with the capability levels represented by their correspondent numbers.

		Capability Level in Design Thinking		
Evolution level in the Design Thinking practices	5	3	3	3
	4	2	2	3
	3	1	2	3
	2	1	2	3
	1	1	2	3

Figure 12: Advancing through the capability levels

In order to achieve capability level 1, the company must perform each practice associated with capability level 1 at least on a scale of 3 out of 5. In order to achieve capability level 2, the company must perform each practice associated with capability level 1 and capability level 2 at least on a scale of 4 out 5. In order to achieve capability level 3, the company must perform all practices related to all capability levels on a scale of 5 out of 5.

7 Phase Two - Model Application

In this section, the results of the application of the final version of the Design Thinking Capability model in one case study are presented. As previously mentioned, the domain in which the Design Thinking Capability Model (DTCM) is applicable is composed of companies that have a structured product development process and also experience in implementing design thinking. Moreover, a pre-requisite for the company to be included as case study is to aim at improving their design thinking implementation. In order to test the Design Thinking Capability Model, a large company inside this domain was selected. For this study, the selected company's name is omitted due to privacy reasons and, as such, will be referred to as "Company D".

Company D is one of the world's largest financial services company, with over 70,000 employees. The motivation for the application of the DTCM came from the need of the company to develop/apply design thinking practices that could support the product development process. In order to use the Design Thinking Capability Model to measure Companys D's design thinking capability profile, the following steps were carried out: (1) Analysis of Context and Purpose, (2) Diagnosis of the current capability profile, and (3) Actionable Plan. The total duration of the case study was approximately four months.

7.1 Analysis of context and purpose

The first step of the DTCM application method is to conduct an analysis of how design thinking is implemented in the company. The goal of this initial analysis aimed to define the application scope (i.e. where in the company and how the model would be applied) and also to identify key employees to answer the survey. As a result, it was defined that three different teams would be measured: Team D.1, Team D.2, and Team D.3. Table 23 iillustrates the codes for the teams and the average professional experience in design thinking of the team members within each team.

Table 23: Company D - Overview of teams' background

Team ID	Professional experience (in years)
Team D.1	5 - 10
Team D.2	1 - 5
Team D.3	1 - 5

As it can be seen from the table, employees from the three teams had relevant experience in design thinking. The department of the team members include design, human resources and sales. Since the survey was applied anonymously, it was not possible to be more specific in terms of the profile of the respondents.

Team D.1 was involved in a 7-week project, which had the design challenge "How might we improve customer experience and create added value for small entrepreneurs?". The goal of the project was to use design thinking methods to identify and solve flaws in the company's current service and also to understand how to deliver more value to their clients. Company D targets different profiles of users. For this project, the focus was on clients that are entrepreneurs.

Team D.2 was involved in a 8-week project, which had the following design challenge: "How might we improve the retention of our motor companies?". The goal of this project was to focus on a different niche of users. In this case, the target users were car companies that hire Company D's service.

Team D.3 was involved in a 20-week project, which had the design challenge "How might we design our services for the brokers in a way that they recommend us positively?". The goal of the project was to scale the services to more users by convincing insurance brokers to recommend Company D's service to their clients.

7.2 Diagnosis of the current capability profile

The goal of this step is to identify which design thinking practices are applied by the company and at which capability level. In order to do that, the DTCM ScoreCard was applied to the employees from the three selected teams. Each team member answered the DTCM Scorecard, in which they rated each design thinking management practice on a 1-5 scale.

In order to achieve capability level 1, teams would have to rate each practice associated with capability level 1 on a scale of at least 3 out of 5. In order to achieve capability level 2, teams would have to rate each practice associated with capability level 1 and capability level 2 on a scale of at least 4 out 5. In order to achieve capability level 3, teams would have to rate each practice related to all capability levels on a scale of 5 out of 5. Based on the answers, the capability profile of each time was defined. In this way, the capability level for each team is a reflection of the employees' perception of "how well" the team implemented the design thinking management practices.

7.3 Actionable plan

The data obtained from the surveys were analysed. Based on the analysis, the design thinking management practices were evaluated according to their evolution level of application in order to determine the current capability profile of the company. In order to illustrate the results, an Actionable Plan Document was developed and presented to Company D. This document aims to provide an assessment of strengths and weaknesses in Company D's design thinking implementation and a roadmap to achieve the next capability level.

7.3.1 Team D.1 - Design thinking capability profile

Team D.1's project aimed to improve customer experience and understand how they could create added value for small entrepreneurs. The duration of the project was seven weeks where the teams would meet two days per week. The design thinking team was composed of two people: the design thinking coach who is responsible for design thinking implementation at Company D and another employee who had less than five years of experience doing design thinking. In order to define the capability profile of the teams, the DTCM scorecard was used as a mechanism to capture data and the respondents were required to assess their current situation (AS IS).

Based on the analysis of the DTCM Scorecard results, Team D.1 was capability level 01, which means that all practices from capability level 01 were implemented by the team on an evolution level of at least 03. Figure 13 summarises the results of the survey through the Design Thinking Capability Radar. The line inside the radar represents which design thinking practices were applied and at which evolution level.

The analysis of the Design Thinking Capability Radar provides evidence on the application of the several design thinking practices with high evolution levels (27% of the practices were evolution level 4 or 5).

Strategy. From the 13 practices under this, there is no practice with evolution level 05 and only one practice with evolution level 04. All the other 12 practices are either evolution 3 or lower. The only practice that scored an evolution level 04 was "S01 - Secure management support for DT initiatives", which is the first practice of this dimension. In this sense, the design thinking capability profile of Team D.1 shows that there was a lack of deployment of the strategic design thinking issues into the project. More specifically, deficiencies in adequate funding, the creation of a strategic plan, guidelines for design thinking implementation and adequate metrics are clear from the data.

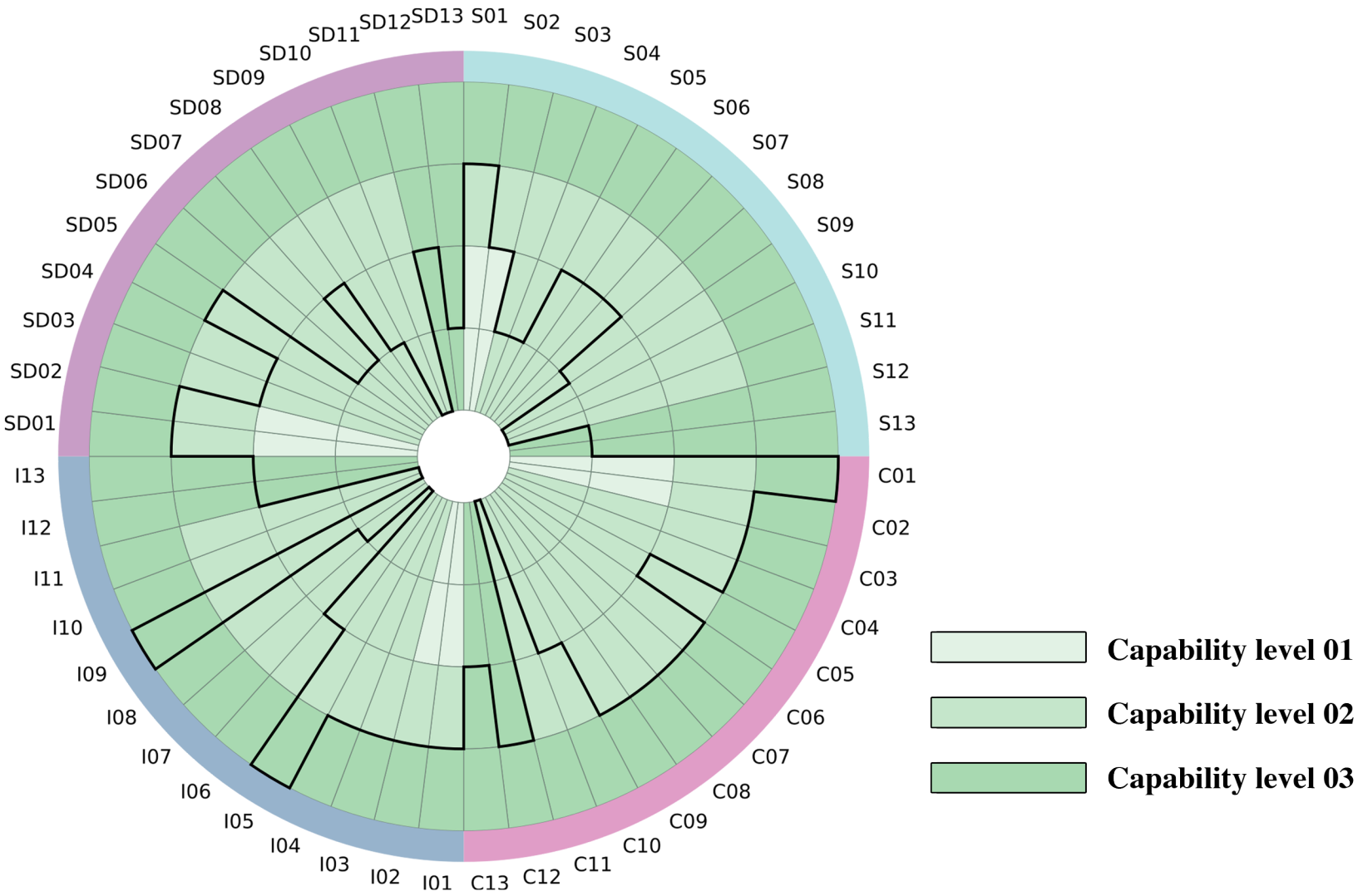

Figure 13: The Design Thinking Capability Radar - Team D.1

Culture. From the 13 practices under this dimension, one practice is evolution level 05 and eight practices are evolution level 04, which means that only four practices are lower than evolution level 04. More specifically, the team scored high in the practices related to collaboration, diversity, empathy, and ambiguity. The practice with the highest evolution level was "C01 - Encourage teams to collaborate (e.g. idea generation, discussions)", which is the first practice under this dimension. However, under the umbrella of collaboration, the data shows that the lowest scored practice was C05-Establish collaborative initiatives with key partners, which means that more collaboration with external partners (e.g. universities) should be considered. To sum up, the design thinking capability profile of Team D.1 shows that the team implemented the design thinking practices related to Culture in a higher evolution level when compared to Strategy. In order to reach capability level 02, improvements should be made in terms of how to monitor and control how the organisational culture changes over time due to DT initiatives.

Implementation. From the 13 practices under this dimension, two practices are evolution level 05 and seven practices are lower than evolution level 04. The team scored the highest evolution level in the practices related to: following a design thinking process (I05) and having a collaborative evolution space to work on the project (I09). Although the team stated that they have an excellent design thinking process, they also pointed out that the design thinking process is not effectively integrated with other approaches (I07). In this sense, the design thinking capability profile of Team D.1 shows that it is necessary to disseminate more knowledge to promote design thinking development in the company in terms of integrating it to existing processes. To sum up, the design thinking capability profile of Team D.1 shows that the team implemented the design thinking practices related to Implementation in a higher evolution level when compared to Strategy, but lower when compared to Culture. In order to reach capability level 02, improvements should be made in terms of informing employees how to better embed design thinking in the project, how to monitor and control how the design thinking implementation changes over time due to the DT initiatives.

Skill Development. From the 13 practices under this dimension, there is no practice with evolution level 05, whereas ten practices are lower than evolution level 04. The team scored evolution level 04 in the practices related to: creating knowledge through training (SD05), being informed of opportunities to apply design thinking (SD01) and being encouraged to include design thinking practices in their daily work (SD02). Although the team pointed out that training is excellently performed, there is a lack of metrics on how to evaluate the impact of the training on the team's performance (SD10) and also the impact of design thinking on the employees' innovation capability (SD11). In this sense, the design thinking capability profile of Team D.1 shows that it is necessary to

establish indicators to assess how design thinking training influences how well the teams innovate. To sum up, the design thinking capability profile of Team D.1 shows that the team implemented the design thinking practices related to Skill Development in a higher evolution level when compared to Strategy and Implementation,but lower when compared to Culture. In order to reach the next capability level, improvements should be made in terms of informing employees of different ways to acquire more design thinking traits and also how to monitor and control how design thinking training impact on team performance.

In the next section, a more detailed overview of the capability profile of Team D.1 is discussed. In particular, what practices need be improved in order to reach capability level 02 are discussed. In addition, suggestions on how to improve the practices are also proposed.

7.3.2 Team D.1 - Roadmap for improvement

Once the current design thinking capability profile of Team D.1 was determined, all practices that did not have the ideal evolution level to reach the next capability level were identified in order to develop a roadmap for improvement. The identified practices are illustrated in Table 24. In order to reach capability level 02, the team would have to perform all the practices illustrated in Table 24 on an evolution level of at least 04 out of 05. Furthermore, the table also provides comments about how to perform each practice. It is important to point out that the purpose of the Design Thinking Capability Model is to describe what (not how) activities should be implemented in order to reach the next capability level. Therefore, these comments are only suggestions and a more detailed analysis of the company would need to be undertaken in order to propose more tailored suggestions

In order to facilitate the visualisation of the road map for improvement, the DTCM Dashboard was also presented. Figure 14 illustrates the DTCM Dashboard for Team D.1. The dashboard is an information management tool that summarises the proposed practices organised by the critical success factors and dimensions they represent. The circles presented in the dashboard represent the current status of each dimension and success factor. The colours follow a traffic light system. The red circle (or the darkest colour) represents critical practices that are "in need of action", the yellow circle (or mid colour) represents "to be improved" and the green circles (or lightest colour) represents "no action required". This dashboard illustrate a roadmap of improvement for Team D.1 to understand how they could reach capability level 02.

Strategy

Secure management support
- ⇒ S01 Secure management support for design thinking initiatives

Have design thinking guidelines
- ⇒ S03 Assign responsibility for defining a strategic plan for design thinking initiatives
- ⇒ S04 Inform employees about fundamental guidelines for effective design thinking implementation
- ⇒ S05 Ensure that the organisational culture nurtures the design thinking initiatives

Ensure funding
- ⇒ S06 Ensure design thinking initiatives are well-funded

Have clear metrics
- ⇒ S02 Share success stories about design thinking implementation
- ⇒ S07 Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)
- ⇒ S08 Establish indicators that measure design thinking's impact on development time
- ⇒ S09 Establish indicators that measure design thinking's impact on the product's time-to-market

Monitor and control
- ⇒ S10 Publish the performance metrics
- ⇒ S11 Analyse how the performance metrics change over time

Define
- ⇒ S12 Customise metrics based on lessons learnt
- ⇒ S13 Customise the guidelines for effective design thinking implementation based on lessons learnt

Implementation

Provide material
- ⇒ I01 Ensure teams have access to materials to conduct design thinking practices

Establish a flexible and responsive DT implementation
- ⇒ I02 Perform specific design thinking practices
- ⇒ I03 Assign responsibility for design thinking implementation
- ⇒ I04 Select appropriate design thinking practices that meet the project's needs
- ⇒ I05 Define a design thinking process
- ⇒ I06 Ensure design thinking's principles are embodied in the company

Integrate DT into NPD and related processes
- ⇒ I07 Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum)

Access to the user
- ⇒ I08 Ensure product attributes are aligned to the users' needs

Provide innovation spaces
- ⇒ I09 Enable employees to come together in innovation spaces to work on projects

Monitor and control
- ⇒ I10 Measure how the design thinking implementation changes over time
- ⇒ I11 Ensure the design thinking implementation is reviewed

Define
- ⇒ I12 Customise design thinking practices based on lessons learnt from past projects
- ⇒ I13 Customise resources for design thinking practices based on lessons learnt from past projects

Culture

Encourage collaboration and cross-functional teams
- ⇒ C01 Encourage teams to collaborate (e.g. idea generation, discussions)
- ⇒ C03 Assign responsibility for promoting design thinking principles in the company
- ⇒ C04 Inform employees, from different unities, of design thinking principles
- ⇒ C05 Establish collaborative initiatives with key partners (e.g. universities)
- ⇒ C08 Enable cross-functional collaboration in the product development process

Promote diversity
- ⇒ C02 Ensure cultural diversity in teams

Foster empathy
- ⇒ C06 Establish an environment that fosters empathy for co-workers' needs
- ⇒ C07 Establish an environment that foster empathy for the user

Be able to handle ambiguous situations
- ⇒ C09 Establish a work environment where teams feel comfortable in working with ambiguity

Monitor and control
- ⇒ C10 Measure how the culture of the organisation changes (due to DT initiatives) over time
- ⇒ C11 Analyse how the culture of the organisation changes (due to DT initiatives) over time

Define
- ⇒ C12 Establish a dynamic work environment that can change to meet current needs
- ⇒ C13 Establish an organisational culture that effectively promotes design thinking principles (based on lessons learnt from past projects)

Skill Development

Create DT awareness
- ⇒ SD01 Inform employees of opportunities to apply design thinking in their projects
- ⇒ SD03 Assign responsibility for spreading design thinking in the company
- ⇒ SD04 Disseminate knowledge on how to perform design thinking practices

Include DT principles into everyday work
- ⇒ SD02 Encourage employees to include design thinking practices in their daily work
- ⇒ SD06 Encourage employees to bring lessons learnt from the trainings to everyday work

Enable the optimal team skills
- ⇒ SD07 Encourage team members to help inexperienced co-workers with design thinking practices

Provide training on design thinking
- ⇒ SD05 Provide appropriate training on design thinking practices when needed
- ⇒ SD08 Enable employees to have access to mentoring on design thinking when needed

Establish collaboration with key partners
- ⇒ SD9 Engage practitioners and researchers aiming to foster the development of design thinking in the company

Monitor and control
- ⇒ SD10 Evaluate the impact of the training on the team's performance
- ⇒ SD11 Evaluate the impact of design thinking on the employees' innovation capability

Define
- ⇒ SD12 Establish a workplace that fosters the development of design thinking in the company
- ⇒ SD13 Establish a customised design thinking training program based on lessons learnt from past projects

Figure 14: DTCM Dashboard - Team D.1

Table 24: Proposed Design Thinking Practices - Team D.1

ID	**Practice**	**Evolution Level**	
		Current	**Goal**
S03	Assign responsibility for defining a strategic plan for design thinking initiatives	02	04
Comments			
Responsibility can be assigned using a detailed job description or in a document, such as the general plan for creating a strategic plan for design thinking. Dynamic assignment of responsibility is another way to implement this practice. In this case, for each project, a new person is assigned. Strategic planning typically looks two to five years into the future.			

ID	**Practice**	**Evolution Level**	
		Current	**Goal**
S04	Inform employees about fundamental guidelines for effective design thinking implementation	02	04
Comments			
Regularly inform relevant stakeholders about the plans and status for selecting and deploying improvement strategies for design thinking implementation.			

ID	**Practice**	**Evolution Level**	
		Current	**Goal**
S05	Ensure that the organisational culture nurtures the design thinking initiatives	03	04
Comments			
The process of design thinking requires (and encourages) principles such as open collaboration, divergent thinking, experimentation, etc. In this way, the organisational culture should break down department silos and gather a range of perspectives to find good solutions to complex challenges. In addition, it should also encourage the use of creative methods from other disciplines, e.g. improv, to boost divergent thinking. Finally, by reframing failures as opportunities, team members are more open to experiment new ideas, which allows employees to take the risks necessary for innovation.			

ID	Practice	Evolution Level	
		Current	**Goal**
S06	Ensure design thinking initiatives are well-funded	03	04
Comments			
Estimate costs of the development of design thinking and prepare the necessary funding for relevant resources, such as material, spaces, training, etc. For this practice, there was a discrepancy of two points between the two respondents. Respondent D-1.1 scored this practice evolution level 02, whereas respondent D-1.2 scored this practice evolution level 04. This might indicate that there is lack of agreement between the two respondents in terms of how well funded this specific project was.			

ID	Practice	Evolution Level	
		Current	**Goal**
S07	Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)	03	04
Comments			
Possible indicators might be how motivated and engaged team members are to solve problems.			

ID	Practice	Evolution Level	
		Current	**Goal**
S08	Establish indicators that measure design thinking's impact on development time	02	04
Comments			
A possible indicator might be to check development costs by monitoring the time spent in rework issues and hand-over tasks. For this practice, there was a discrepancy of two points between the two respondents. Respondent D-1.1 scored this practice evolution level 03 whereas respondent D-1.2 scored this evolution practice level 01. This might indicate that there is lack of agreement between the two respondents in terms of how well this practice is implemented.			

ID	Practice	Evolution Level	
		Current	**Goal**
S09	Establish indicators that measure design thinking's impact on the product's time-to-market	01	04
Comments			
Possible indicators might be to check the project finances by monitoring the time spent in gathering requirements, rework issues, hand-over task, and design defects. For respondent D-1.2 this practice was not performed (level 1), whereas respondent D-1.1 scored the performance of this practice at evolution level 03. This might indicate that this metric was not clear to all team members and perhaps more discussions should be proposed in terms of the different ways it would be possible to measure design thinking's impact on the product's time-to-market			

ID	Practice	Evolution Level	
		Current	**Goal**
S10	Publish the performance metrics	01	04
Comments			
The metric results should be stored in a repository, which is accessible to employees. Examples of repositories include library, databases, web analytics, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
S11	Analyse how the performance metrics change over time	01	04
Comments			
Regularly communicate the results of comparing business performance against the business objectives. Prepare and distribute a summary of improvement selection and deployment activities. Examples of relevant information include development time for projects where DT was implemented in different ways, the effort expended when performing the design thinking practices, defects injected or removed in a particular activity, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
C05	Establish collaborative initiatives with key partners (e.g. universities)	03	04
Comments			
Establishing collaborative initiatives with key partners can help team members to enhance product innovativeness and the product development process. Examples of key partners include research institutes, companies from different market segments, start-ups, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
C10	Measure how the culture of the organisation changes (due to DT initiatives) over time	03	04
Comments			
Measure unquantified benefits of design thinking, e.g. the happiness of the employees, increased collaboration, team alignment, etc. For this practice, there was a discrepancy of four points between the two respondents. For respondent D-1.2 this practice was not performed (evolution level 1), whereas respondent D-1.1 indicated that this practice was excellently performed (evolution level 5). This might indicate that this metric was not clear to all team members and perhaps more discussions should be proposed in terms of the different ways it would be possible to measure how the culture of the organisation changes due to DT initiatives over time.			

ID	Practice	Evolution Level	
		Current	**Goal**
C11	Analyse how the culture of the organisation changes (due to DT initiatives) over time	01	04
Comments			
Analyse how the unquantified benefits of design thinking change over time. For instance, how the different ways of implementing DT is correlated to employees' motivation to work on projects.			

ID	Practice	Evolution Level	
		Current	**Goal**
I06	Ensure design thinking's principles are embodied in the company	03	04
Comments			
Inform employees about how they can have a design thinking mindset. Actions should be proposed to support employees to develop traits that are relevant to create design thinking mindset. For instance, activities that promote empathy and collaboration.			

ID	Practice	Evolution Level	
		Current	**Goal**
I07	Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum, etc.)	01	04
Comments			
Inform employees about how teams can integrate design thinking into relevant processes related to product development. For instance, teams could implement the InnoDev model, which provides a comprehensive understanding of how to integrate design thinking, scrum, and lean start-up.			

ID	Practice	Evolution Level	
		Current	**Goal**
I08	Ensure product attributes are aligned to the users' needs	02	04
Comments			
Having discussions early in the development process can help teams to ensure that product reflects what the user needs. For instance, techniques include user story mapping, prototype to test ideas, etc. For this practice, there was a discrepancy of two points between the two respondents. Respondent D-1.1 scored this practice evolution level 04, whereas respondent D-1.2 indicated that this practice is evolution level 02. This might indicate that the product developed might not be very well aligned with the users needs.			

ID	Practice	Evolution Level	
		Current	**Goal**
I10	Measure how the design thinking implementation changes over time	01	04
Comments			
Measure how the results change depending on how design thinking is implemented (e.g. as a toolbox, process, mindset). For instance, it might be relevant to measure the impact of applying design thinking as a toolbox on the product development process versus as a process. Possible indicators might be development time, design time, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
I11	Ensure design thinking implementation is reviewed	01	04
Comments			
Review how the indicators of I10 change over time. Learn how to predict what design thinking tools and techniques would be ideal for a new project.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD03	Assign responsibility for spreading design thinking in the company	03	04
Comments			
Actions to perform this practice include different strategies, such as providing workshops, mentoring, and training.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD04	Disseminate knowledge on how to perform design thinking practices	03	04
Comments			
Actions should be taken to inform employees about how to implement design thinking, such as, workshops, researchers, experienced practitioners.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD06	Encourage employees to bring lessons learnt to everyday work	02	04
Comments			
Actions should be taken to encourage employees to apply lessons learnt from mentoring, training, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD07	Encourage team members to help inexperienced co-workers with design thinking practices	02	04
Comments			
Establish a program to encourage team members to inform inexperienced co-workers about how to perform the design thinking practices. For instance, a collaborative program aimed at discussing training needs and training effectiveness to ensure that employees also have the capability to deliver training. For this practice, there was a discrepancy of two points between the two respondents. Respondent D-1.2 scored this practice evolution level 04, whereas respondent D-1.2 scored this practice evolution level 02. This might indicate that the respondents feel differently in terms of how well they are encouraged to help inexperienced co-workers with design thinking practices and perhaps different actions should be proposed to encourage them to feel more comfortable in implementing this practice. For instance, a “welcome buddy” program could be suggested, in which one experienced person is assigned to help one inexperienced person for a specific amount of time.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD08	Enable employees to have access to mentoring on design thinking when needed	03	04
Comments			
Appropriate mentoring can expand employees' knowledge and skills, and it can happen in many different ways, which includes helping employees to solve an existing problem or to give employees the necessary information to solve future problems. Mentors should discuss with mentees a reasonable schedule for the meetings. A different approach would be to have mentorships before the beginning of a new project. For this practice, there was a discrepancy of three points between the two respondents. Respondent D-1.2 scored this practice evolution level 05, whereas respondent D-1.2 scored this practice evolution level 02. This might indicate that the respondents feel differently in terms of how much mentoring they had when the project was running,			

ID	Practice	Evolution Level	
		Current	**Goal**
SD09	Engage practitioners and researchers aiming to foster the development of design thinking in the company	02	04
Comments			
Industry-Academia collaboration can help to keep teams up-to-date with the new science discoveries in the field of design, management, and product development. Collaboration could happen in terms of how to improve the process, how to test new tools/techniques, how to integrate new methodologies, etc.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD10	Evaluate the impact of the design thinking training on the team's performance	01	04
Comments			
Assess how design thinking training affects how well the teams perform. Metrics might include, leadership skills, employees turn over, productivity, etc. The team can also be trained to develop their own metrics.			

ID	Practice	Evolution Level	
		Current	**Goal**
SD11	Evaluate the impact of design thinking on the employees' innovation capability	01	04
Comments			
Analyse how design thinking training affects how teams innovate. Possible indicators might be the ability of the employees to generate and implement new ideas.			

In summary, Table 24 provides a description of the practices that need to be improved in order to enable Team D.1 to achieve their desired capability profile, which is to move to capability level 02. In order to move to capability level 02, the team must perform all practices related to capability level 01 and 02 on an evolution level of at least 04 out 05. All practices that did not meet this requirement were illustrated in the table. Since the practices related to capability level 03 are not required for the team to reach capability level 02, they were not included in the table. In total, 25 practices were identified. Descriptions and comments for suggestions for each practices were provided. From the 25 practices, almost 70% of the practices are related to Strategy and Skill Development, which indicates that Team D-1 had more deficiencies in these two dimensions as discussed in the previous section. In order to facilitate the visualisation of the suggestions for improvement, the DTCM Dashboard was also presented to Company D. DTCM Dashboard presents the respondents' answers for all the 52 practices. In addition, it points out practices that are critical, which means that more efforts should be concentrated on these practices if the team wants to move to capability level 02. For instance, in the dimension Strategy, practices related to monitor and control are critical for this project. In terms of Implementation, the Dashboard indicates that design thinking was not very well integrated to the NPD and related process. In addition, practices related to monitor and control are also critical for Implementation. No critical practices were identified in the dimension Culture. Finally, in terms of Skill Development, practices related to monitor and control were also identified as being critical.

7.3.3 Team D.2 - Design thinking capability profile

In this section, a broad overview of the capability profile of team D.2 is discussed. Team D.2's project aimed to improve customer retention. The duration of the project was eight weeks where the teams would meet 2-3 days per week. The design thinking team was composed of three employees with less than five years of experience implementing design thinking. In order to define the capability profile of the teams, the DTCM scorecard was used as a mechanism to capture data and the respondents were required to assess their current situation (AS IS).

Based on the analysis of the DTCM Scorecard results, Team D.2 was capability level 01, which means that all practices from capability level 01 were implemented by the team on an evolution level of at least 03. Figure 15 summarises the results of the survey through the Design Thinking Capability Radar. The line inside the radar represents which design thinking practices were applied and at which evolution level.

The analysis of the Design Thinking Capability Radar for Team D.2 provides evidence on the application of not many design thinking practices with high evolution levels. There are no practices applied at evolution level 05 and only 13.5% of the practices were at evolution level 4.

Strategy. From the 13 practices under the dimension Strategy, there is only one practice with evolution level 04. All the other 12 practices are either evolution 03 or 02. The only practice that scored an evolution level 04 was "S12 Customise metrics based on lessons learnt". Although respondents indicated that the metrics they have are customised, all practices related to having metrics (S06 - S10) scored low evolution level. This might indicate that the team has developed their own repository of indicators (based on the current project needs), which are not covered by the Design Thinking Capability Model. In this way, further analysis would have to be conducted in order to understand how to evaluate the team's current set of metrics. Thus, the design thinking capability profile of Team D.2 shows that there was a lack of deployment of the strategic design thinking issues into the project. More specifically, deficiencies in adequate funding, the creation of a strategic plan, guidelines for design thinking implementation and adequate metrics are clear from the data.

Culture. From the 13 practices under the dimension Culture, there are only four practices with evolution level 04. More specifically, the team scored high in practices related to collaboration, diversity, empathy and ambiguity. Under the umbrella of collaboration, the data shows that the highest scored practice was C05-Establish collaborative initiatives

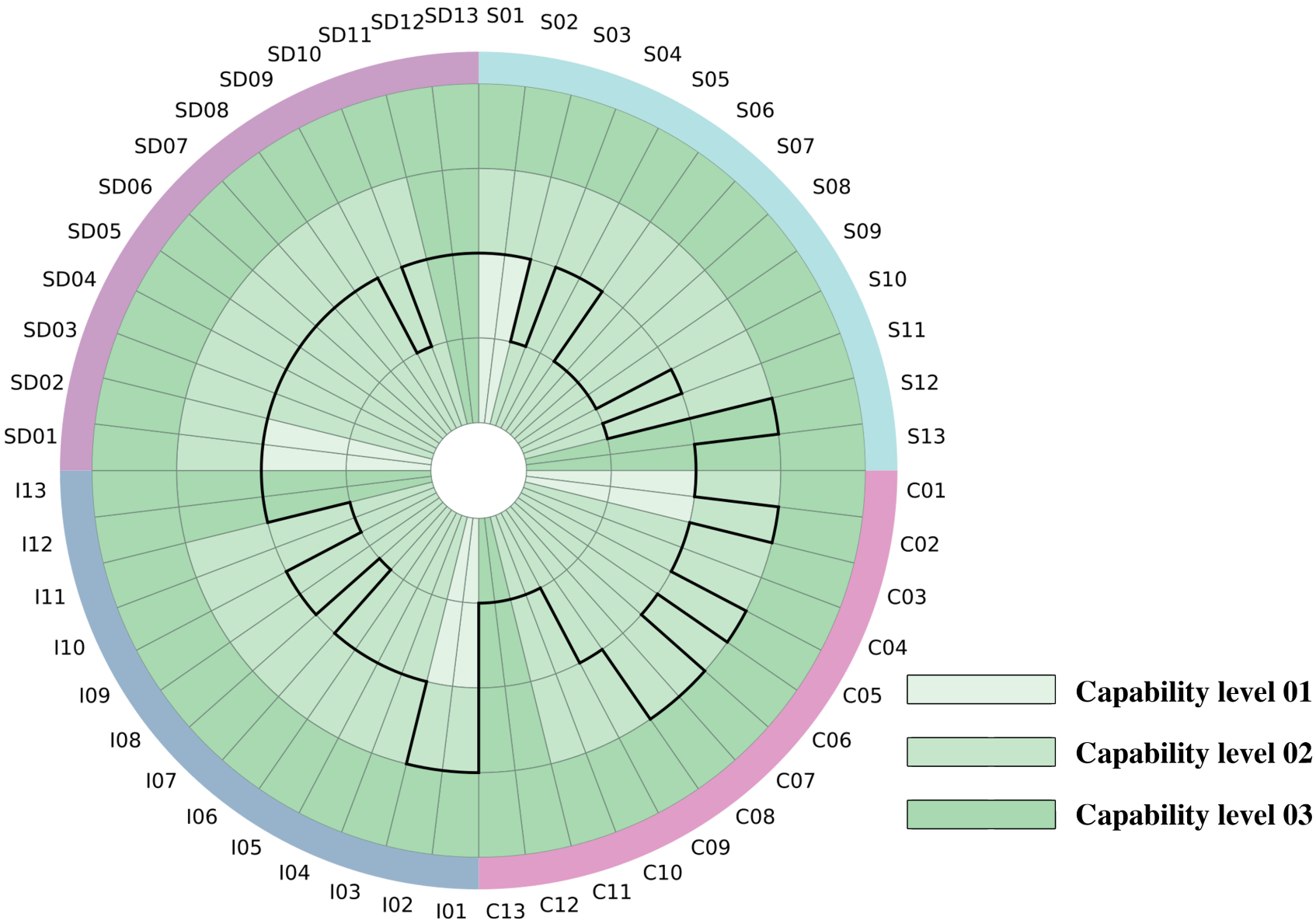

Figure 15: The Design Thinking Capability Radar - Team D.2

with key partners, whereas all the other practices (C01 and C08) related to collaboration had a lower score. In this way, employees should be more encouraged to work cross functionally and to collaborate more. Under the umbrella of empathy, the practice related to empathy for the user (S07) scored higher than the practice related to empathy for the co-worker's needs (S06). In this way, actions should be taken in order to make employees feel more heard and comfortable when sharing their thoughts and needs. The lowest scored practices (C10 - C13) are related to measure and learn the practices in order to establish a work environment that promotes design thinking principles and is also fully adapted to the company's needs. To sum up, the design thinking capability profile of Team D.2 shows that the team implemented the design thinking practices related to Culture in a higher evolution level when compared to Strategy. In order to reach capability level 02, improvements should be made in terms of how to monitor and control how the organisational culture changes over time due to the DT initiatives.

Implementation. From the 13 practices under the dimension Implementation, there are only two practices with evolution level 04. All the other practices are either evolution level 03 or 02. The team scored the highest evolution level in the practices related to: having access to materials to conduct design thinking practices (I1) and perform specific design thinking practices (I2). And the lowest evolution level were the practices related to how to integrate design thinking with other approaches (I07), and also how to measure and review the design thinking process. In this sense, the design thinking capability profile of Team D.2 shows that it is necessary to disseminate more knowledge to promote design thinking development in the company in terms of integrating it to existing processes. To sum up, the design thinking capability profile of Team D.2 shows that the team implemented the design thinking practices related to implementation in a higher evolution level when compared to Strategy, but lower when compared to Culture. In order to reach the next capability level, improvements should be made in terms of informing employees how to better embed design thinking in the project, how to monitor and control how the design thinking implementation changes over time due to the DT initiatives.

Skill Development. From the 13 practices under the dimension Skill Development, 12 practices are evolution level 03 and one practice is evolution level 02. The team scored evolution level 02 in the practices related to: evaluate the impact of the training on the team's performance (SD10). Interestingly, this dimension has the most consistent answers (when compared to the other three dimensions) with most practices being scored at evolution level 03. In this sense, the design thinking capability profile of Team D.2 shows that the team's perceptions of knowledge creation on design thinking and how their work environment supported that are well aligned. To sum up, the design thinking capability profile of Team D.2 shows that the team implemented the design thinking practices

related to Skill Development in a lower evolution level, when compared to Culture and Implementation, but had a higher evolution level when compared to strategy. In order to reach capability level 02, improvements should be made in terms of informing employees of different ways to acquire more design thinking traits and also how to monitor and control how design thinking impact on team performance.

7.3.4 Team D.2 - Roadmap for improvement

Once the current design thinking capability profile of Team D.2 was determined, all practices that did not have the ideal evolution level to reach the next capability level were identified in order to develop a roadmap for improvement. In order to reach capability level 02, the team would have to perform all the identified practices on an evolution level of at least 04 out of 05. Since Team D-2 had the same capability and similar weaknesses and strengths in their design thinking implementation as Team D-1, a table with details and suggestions (similar to Table 7.3.2) of how to improve the practices was omitted in this thesis. However, the report shared with Company D had all the details for all the three teams.

In order to facilitate the visualisation of the road map for improvement, the DTCM Dashboard was also presented. Figure 16 illustrates the DTCM Dashboard for Team D.2. The dashboard is an information management tool that summarises the proposed practices organised by the critical success factors and dimensions they represent. The circles presented in the dashboard represent the current status of each dimension and success factor. The colours follow a traffic light system. The red circle (or the darkest colour) represents critical practices that are "in need of action", the yellow circle (or mid colour) represents "to be improved", and the green circles (or lightest colour) represents "no action required". DTCM Dashboard presents the respondents' answers for all the 52 practices. In addition, it points out practices that are critical, which means that more efforts should be concentrated on these practices if the team wants to move to capability level 02. An analysis of the Dashboard for Team D.2 indicates that no practices were identified as being critical. Most of the practices have the status "to be improved" but are not critical. Two practices were identified as being an evolution level of 04, which means that they meet the necessary requirement to enable D.2 to move to capability level 02. Under the dimension Implementation, the practice related to material scored evolution level 04. Under the dimension Culture, the practice related to the success factor diversity was also scored as being evolution level 04. In summary, the DTCM Dashboard for Team D.2 illustrates a roadmap of improvement for Team D.2 to understand how they could reach capability level 02.

Strategy

Secure management support
- ⇒ S01 Secure management support for design thinking initiatives

Have design thinking guidelines
- ⇒ S03 Assign responsibility for defining a strategic plan for design thinking initiatives
- ⇒ S04 Inform employees about fundamental guidelines for effective design thinking implementation
- ⇒ S05 Ensure that the organisational culture nurtures the design thinking initiatives

Ensure funding
- ⇒ S06 Ensure design thinking initiatives are well-funded

Have clear metrics
- ⇒ S02 Share success stories about design thinking implementation
- ⇒ S07 Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)
- ⇒ S08 Establish indicators that measure design thinking's impact on development time
- ⇒ S09 Establish indicators that measure design thinking's impact on the product's time-to-market

Monitor and control
- ⇒ S10 Publish the performance metrics
- ⇒ S11 Analyse how the performance metrics change over time

Define
- ⇒ S12 Customise metrics based on lessons learnt
- ⇒ S13 Customise the guidelines for effective design thinking implementation based on lessons learnt

Culture

Encourage collaboration and cross-functional teams
- ⇒ C01 Encourage teams to collaborate (e.g. idea generation, discussions)
- ⇒ C03 Assign responsibility for promoting design thinking principles in the company
- ⇒ C04 Inform employees, from different unities, of design thinking principles
- ⇒ C05 Establish collaborative initiatives with key partners (e.g. universities)
- ⇒ C08 Enable cross-functional collaboration in the product development process

Promote diversity
- ⇒ C02 Ensure cultural diversity in teams

Foster empathy
- ⇒ C06 Establish an environment that fosters empathy for co-workers' needs
- ⇒ C07 Establish an environment that foster empathy for the user

Be able to handle ambiguous situations
- ⇒ C09 Establish a work environment where teams feel comfortable in working with ambiguity

Monitor and control
- ⇒ C10 Measure how the culture of the organisation changes (due to DT initiatives) over time
- ⇒ C11 Analyse how the culture of the organisation changes (due to DT initiatives) over time

Define
- ⇒ C12 Establish a dynamic work environment that can change to meet current needs
- ⇒ C13 Establish an organisational culture that effectively promotes design thinking principles (based on lessons learnt from past projects)

Implementation

Provide material
- ⇒ I01 Ensure teams have access to materials to conduct design thinking practices

Establish a flexible and responsive DT implementation
- ⇒ I02 Perform specific design thinking practices
- ⇒ I03 Assign responsibility for design thinking implementation
- ⇒ I04 Select appropriate design thinking practices that meet the project's needs
- ⇒ I05 Define a design thinking process
- ⇒ I06 Ensure design thinking's principles are embodied in the company

Integrate DT into NPD and related processes
- ⇒ I07 Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum)

Access to the user
- ⇒ I08 Ensure product attributes are aligned to the users' needs

Provide innovation spaces
- ⇒ I09 Enable employees to come together in innovation spaces to work on projects

Monitor and control
- ⇒ I10 Measure how the design thinking implementation changes over time
- ⇒ I11 Ensure the design thinking implementation is reviewed

Define
- ⇒ I12 Customise design thinking practices based on lessons learnt from past projects
- ⇒ I13 Customise resources for design thinking practices based on lessons learnt from past projects

Skill Development

Create DT awareness
- ⇒ SD01 Inform employees of opportunities to apply design thinking in their projects
- ⇒ SD03 Assign responsibility for spreading design thinking in the company
- ⇒ SD04 Disseminate knowledge on how to perform design thinking practices

Include DT principles into everyday work
- ⇒ SD02 Encourage employees to include design thinking practices in their daily work
- ⇒ SD06 Encourage employees to bring lessons learnt from the trainings to everyday work

Enable the optimal team skills
- ⇒ SD07 Encourage team members to help inexperienced co-workers with design thinking practices

Provide training on design thinking
- ⇒ SD05 Provide appropriate training on design thinking practices when needed
- ⇒ SD08 Enable employees to have access to mentoring on design thinking when needed

Establish collaboration with key partners
- ⇒ SD9 Engage practitioners and researchers aiming to foster the development of design thinking in the company

Monitor and control
- ⇒ SD10 Evaluate the impact of the training on the team's performance
- ⇒ SD11 Evaluate the impact of design thinking on the employees' innovation capability

Define
- ⇒ SD12 Establish a workplace that fosters the development of design thinking in the company
- ⇒ SD13 Establish a customised design thinking training program based on lessons learnt from past projects

Figure 16: DTCM Dashboard - Team D.2

7.3.5 Team D.3 - Design thinking capability profile

In this section, a broad overview of the capability profile of team D.3 is discussed Team D.3's project aimed to improve customer referral by identifying how to make insurance advisers recommend Company D to their clients. The duration of the project was 15 weeks where the teams would meet two days per week. The design thinking team was composed of three employees with less than five years of experience in implementing design thinking.

Based on the analysis of the survey results, Team D.3 was capability level 0, which means that not all practices from capability level 01 were implemented by the team on an evolution level of at least 03. Figure 17 summarises the results of the survey through the Design Thinking Capability Radar. The line inside the radar represents which design thinking practices were applied at which evolution level.

The analysis of the Design Thinking Capability Radar for Team D.3 provides evidence on the application of not many design thinking practices with high evolution levels. There are no practices at evolution level 05 and only 7% of the practices were at evolution level 4.

Strategy. From the 13 practices under the dimension Strategy, there are only two practices with evolution level 04. All the other 11 practices are either evolution level 03 or 02. The two practices that scored an evolution level 04 was "S01 Secure management support for design thinking initiatives" and "S02 Share success stories about design thinking implementation", which are the first two practices of this dimension. In this sense, the design thinking capability profile of Team D.2 shows that the practices related to assign and inform were well implemented, whereas provide, measure and learn need more attention. Thus, the design thinking capability profile of Team D.3 shows that there was a lack of deployment of the strategic design thinking issues into the project. More specifically, deficiencies in adequate funding and metrics are clear from the data.

Culture. From the 13 practices under the dimension Culture, there are three practices with evolution level 04. All the other nine practices are either evolution level 03 or 02. More specifically, the team scored high in the practices related to diversity and collaboration. In addition, the team scored satisfactory in the practices related to empathy for the user and co-workers, and also in term of the responsibility for creating awareness of design thinking. The first lowest scored (C09) is related to the ability to handle ambiguous situations, where the other lowest scored practices (C10 - C13) are related to measure the organisational culture in order to establish a work environment that promotes design

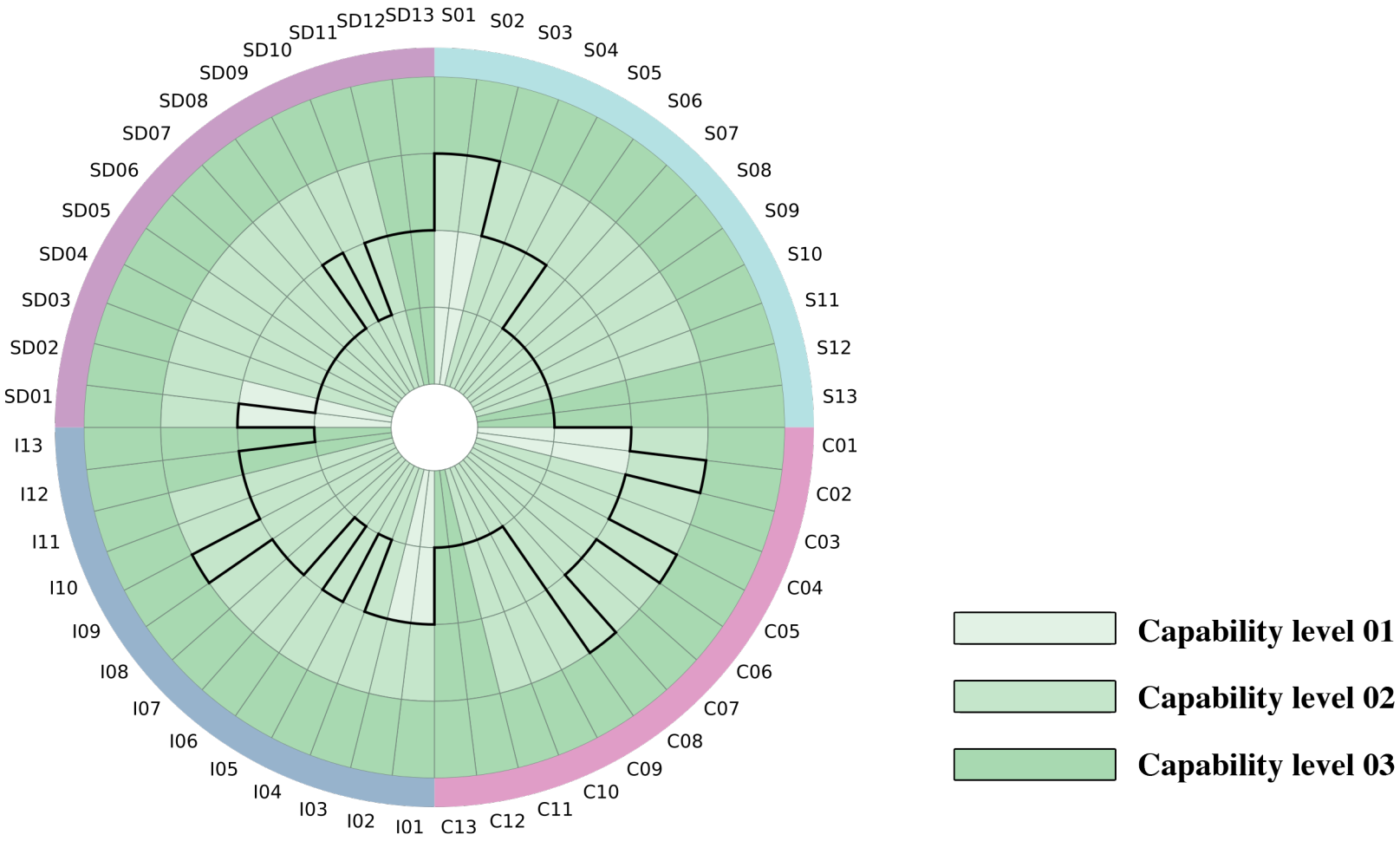

Figure 17: The Design Thinking Capability Radar - Team D.3

thinking principles and that is also fully adapted to the company's needs. To sum up, the design thinking capability profile of Team D.3 shows that the team implemented the design thinking practices related to Culture in a lower evolution level when compared to Strategy. In order to reach the next capability level, improvement should be made in terms of how to monitor and control how the organisational culture changes over time due to the DT initiatives.

Implementation. From the 13 practices under the dimension Implementation, one practice is evolution level 04. All the other twelve practices are either evolution level 03 or 02. The team scored highest evolution level in the practice related to gathering together in innovation spaces to work on projects, whereas the lowest scored practices are related to selecting appropriate design thinking techniques, how to embed design thinking in the project and also how to customise resources for design thinking implementation. To sum up, the design thinking capability profile of Team D.3 shows that the team implemented the design thinking practices related to Implementation in a lower evolution level when compared to Strategy and Culture. For Implementation, all practices necessary to reach the next capability level were implemented with an evolution level of 03. In this way, no improvements are needed in this dimension to help the team move to capability level 01.

Skill Development. From the 13 practices under the dimension Skill Development, four practices are at evolution level 03. All the other nine practices are evolution level 02. The team scored evolution level 03 in the practices related to collaboration between researchers and practitioners, measuring the employees' innovation capability, establishing a workplace that fosters the development of design thinking, and establishing a customised design thinking training program. Interestingly, this dimension is the only one that has no practices with evolution level 04. In this sense, Skill Development scored a lower evolution level when compared to Strategy and Culture, but the same evolution level when compared to Implementation. In order to reach the next capability level, improvement should be made in terms of encouraging employees to include design thinking practices in their daily work.

In the next section, a more detailed overview of the capability profile of team D.3 is discussed. In particular, what practices need be improved in order to reach capability level 01 are discussed. In addition, suggestions on how to improve the practices are also proposed.

7.3.6 Team D.3 - Roadmap for improvement

Once the current design thinking capability profile of Team D.2 was determined, all practices that did not have the ideal evolution level to reach the next capability level were

identified in order to develop a roadmap for improvement. In order to reach capability level 01, the team would have to perform all the identified practices on an evolution level of at least 03 out of 04. Furthermore, the table also provides comments about how to perform each practice. It is important to point out that the purpose of the Design Thinking Capability Model is to describe what (not how) activities should be implemented in order to reach the next capability level. Therefore, these comments are only suggestions and a more detailed analysis of the company would need to be undertaken in order to propose more tailored suggestions

In order to facilitate the visualisation of the road map for improvement, the DTCM Dashboard was also presented. Figure 16 illustrates the DTCM Dashboard for Team D.3. An analysis of the Dashboard for Team D.3 indicates that no practices were identified as being critical. Most of the practices have the status "to be improved" , but are not critical. Four practices were identified as being an evolution level of 04, which means that they meet the necessary requirement to enable D.2 to move to capability level 02. Under the dimension Implementation, the practice related to material scored at evolution level 04. Under the dimension Culture, the practice related to the success factor diversity and was also scored as being evolution level 04. In summary, the DTCM Dashboard for Team D.2 illustrates a roadmap of improvement for Team D.3 to understand how they could reach capability level 01.

Figure 18 illustrates the DTCM Dashboard for Team D.3. This dashboard illustrates a roadmap of improvement for Team D.3 to understand how they could reach capability level 01.

A more detailed analysis of the design thinking management practices from the DTCM Dashboard is presented in Table 25, which also includes the current and the future evolution levels to be achieved in order to reach capability level 01.

Strategy

Secure management support
- ⇒ S01 Secure management support for design thinking initiatives

Have design thinking guidelines
- ⇒ S03 Assign responsibility for defining a strategic plan for design thinking initiatives
- ⇒ S04 Inform employees about fundamental guidelines for effective design thinking implementation
- ⇒ S05 Ensure that the organisational culture nurtures the design thinking initiatives

Ensure funding
- ⇒ S06 Ensure design thinking initiatives are well-funded

Have clear metrics
- ⇒ S02 Share success stories about design thinking implementation
- ⇒ S07 Establish indicators that measure design thinking's impact on team morale (e.g. happy workforce, motivation, engagement, encouragement)
- ⇒ S08 Establish indicators that measure design thinking's impact on development time
- ⇒ S09 Establish indicators that measure design thinking's impact on the product's time-to-market

Monitor and control
- ⇒ S10 Publish the performance metrics
- ⇒ S11 Analyse how the performance metrics change over time

Define
- ⇒ S12 Customise metrics based on lessons learnt
- ⇒ S13 Customise the guidelines for effective design thinking implementation based on lessons learnt

Culture

Encourage collaboration and cross-functional teams
- ⇒ C01 Encourage teams to collaborate (e.g. idea generation, discussions)
- ⇒ C03 Assign responsibility for promoting design thinking principles in the company
- ⇒ C04 Inform employees, from different unities, of design thinking principles
- ⇒ C05 Establish collaborative initiatives with key partners (e.g. universities)
- ⇒ C08 Enable cross-functional collaboration in the product development process

Promote diversity
- ⇒ C02 Ensure cultural diversity in teams

Foster empathy
- ⇒ C06 Establish an environment that fosters empathy for co-workers' needs
- ⇒ C07 Establish an environment that foster empathy for the user

Be able to handle ambiguous situations
- ⇒ C09 Establish a work environment where teams feel comfortable in working with ambiguity

Monitor and control
- ⇒ C10 Measure how the culture of the organisation changes (due to DT initiatives) over time
- ⇒ C11 Analyse how the culture of the organisation changes (due to DT initiatives) over time

Define
- ⇒ C12 Establish a dynamic work environment that can change to meet current needs
- ⇒ C13 Establish an organisational culture that effectively promotes design thinking principles (based on lessons learnt from past projects)

Implementation

Provide material
- ⇒ I01 Ensure teams have access to materials to conduct design thinking practices

Establish a flexible and responsive DT implementation
- ⇒ I02 Perform specific design thinking practices
- ⇒ I03 Assign responsibility for design thinking implementation
- ⇒ I04 Select appropriate design thinking practices that meet the project's needs
- ⇒ I05 Define a design thinking process
- ⇒ I06 Ensure design thinking's principles are embodied in the company

Integrate DT into NPD and related processes
- ⇒ I07 Define a design thinking process that is effectively integrated with other approaches (e.g. Lean, Scrum)

Access to the user
- ⇒ I08 Ensure product attributes are aligned to the users' needs

Provide innovation spaces
- ⇒ I09 Enable employees to come together in innovation spaces to work on projects

Monitor and control
- ⇒ I10 Measure how the design thinking implementation changes over time
- ⇒ I11 Ensure the design thinking implementation is reviewed

Define
- ⇒ I12 Customise design thinking practices based on lessons learnt from past projects
- ⇒ I13 Customise resources for design thinking practices based on lessons learnt from past projects

Skill Development

Create DT awareness
- ⇒ SD01 Inform employees of opportunities to apply design thinking in their projects
- ⇒ SD03 Assign responsibility for spreading design thinking in the company
- ⇒ SD04 Disseminate knowledge on how to perform design thinking practices

Include DT principles into everyday work
- ⇒ SD02 Encourage employees to include design thinking practices in their daily work
- ⇒ SD06 Encourage employees to bring lessons learnt from the trainings to everyday work

Enable the optimal team skills
- ⇒ SD07 Encourage team members to help inexperienced co-workers with design thinking practices

Provide training on design thinking
- ⇒ SD05 Provide appropriate training on design thinking practices when needed
- ⇒ SD08 Enable employees to have access to mentoring on design thinking when needed

Establish collaboration with key partners
- ⇒ SD9 Engage practitioners and researchers aiming to foster the development of design thinking in the company

Monitor and control
- ⇒ SD10 Evaluate the impact of the training on the team's performance
- ⇒ SD11 Evaluate the impact of design thinking on the employees' innovation capability

Define
- ⇒ SD12 Establish a workplace that fosters the development of design thinking in the company
- ⇒ SD13 Establish a customised design thinking training program based on lessons learnt from past projects

Figure 18: DTCM Dashboard - Team D.3

Table 25: Proposed Design Thinking Practices - Team D.3

ID	Practice	Evolution Level	
		Current	Goal
SD02	Encourage employees to include design thinking practices in their daily work	02	03
Comments			
When having specific knowledge about how to implement specific practices related to design thinking, employees should be encouraged to perform these practices. Identify early adopters to act as supporters of developing this practice. Create small experiments that allow the teams to practice gathering data, testing frequently, and iterating quickly. Perhaps suggest a time each week for teams to work on these skills or start with a small part of your business and grow over time.			

In summary, Table 25 provides a description of the practice that need to be improved in order to enable Team D.3 to achieve their desired capability profile, which is to move to capability level 01. In order to move to capability level 01, the team must perform all practices related to capability level 01 on an evolution level of at least 03 out 05. All practices that did not meet this requirement were illustrated in the table. Since the practices related to capability level 02 and 03 are not required for the team to reach capability level 01, they were not included in the table. In total, one practice was identified. A description and comment for suggestions for the practices were provided. The only practice identified as being in need of improvement is related to encouraging employees to include design thinking practices in their daily work, which is a practice under the dimension Skill Development. Furthermore, the DTCM Dashboard presents the respondents' answers for all 52 practices. Since no critical practices were identified, the dashboard only points out practices that have the status "needs improvement" and also practices in which no actions are required.

7.4 DTCM application assessment

The methodology employed and the results of the DTCM application method were presented at Company D in a detailed presentation. The presentation was divided into two main parts. First, the main components of DTCM and the relationship among them were explained to key representatives from each team. Then, the specific results for each team was presented. A report with all the results was also provided at the meeting. A week before the meeting, a document explaining the concepts and components of the DTCM was shared with all respondents. After the presentation, the attendees were asked to answer the evaluation questionnaire (Appendix C) in order to capture their feelings

and perceptions about the DTCM model. After answering the evaluation questionnaire, a group discussion was held. The purpose of the group discussion was to capture more in-depth information about the attendees' opinions on the relevance and precision of the results. In particular, they were asked whether the model presented an accurate description of the capability profile for each team. Figure 19 illustrates the results of the evaluation survey.

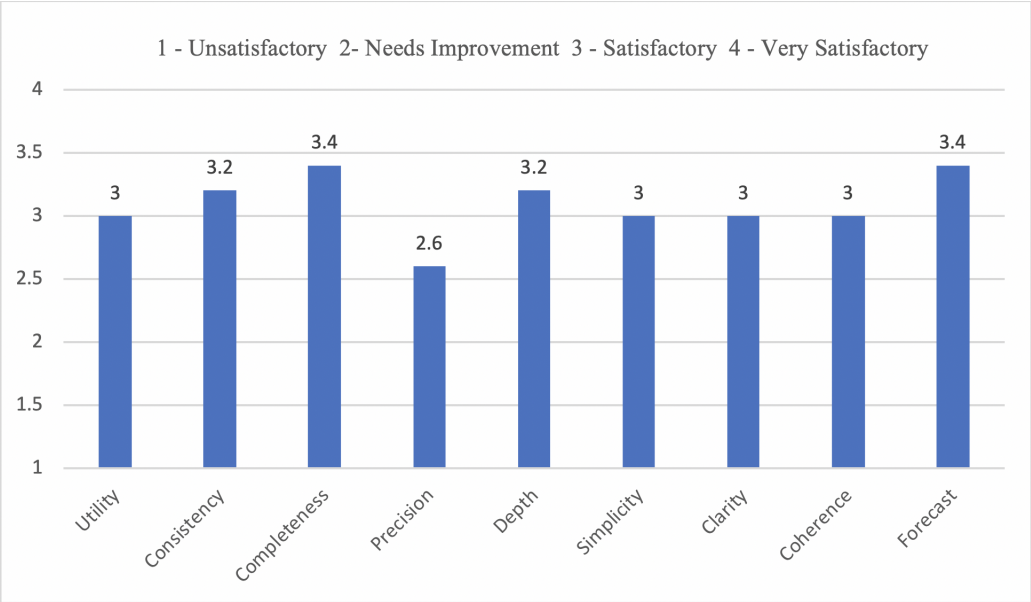

Figure 19: Evaluation of the DTCM by Company D

The evaluation questionnaire was developed following the criteria proposed by Vernadat (1996) and adapted by Pigosso, Rozenfeld and McAloone (2013). In total, nine criteria were used to evaluate the application of the model at Company D. Company D was satisfied with the results obtained with the DTCM application, rating eight out of nine criteria as "satisfactory". The only criterion classified as "needs improvement" was precision, with all the other eight criteria classified as "satisfactory". Precision aims to identify whether DTCM could provide a correct description of the capability profile for each team.

Utility and forecast. Utility aims to investigate whether the model is relevant for the teams to understand how to identify design thinking practices that should be applied. The criterion forecast aims to investigate whether the model provides a correct and clear definition of the next steps to be taken to improve the design thinking implementation in the company. In terms of utility and forecast, respondent D.1-A said, *"It is really interesting, because there is always the question (...) at least in large corporations (...) Does it [design thinking] bring something? Does it change something? Why should I do it?*

Before, the answers were just a feeling. Sometimes, you feel it (DT implementation) is OK. Sometimes, it was not so good. But you don't know what was the problem".

Completeness. This criterion aims to investigate whether the model provides a complete roadmap for improvements. This criterion was identified as being satisfactory and respondent D.1-B said *"It will give more understanding and visibility to design thinking. I am impressed".*

Precision. It aims to analyse the accuracy of the definition of the design thinking capability profile of each team. This criterion was identified as "needs improvement and respondent D.1-A said, *"I would need more time to read the case study results, so I could be more confident when saying that the results really reflect the characteristics of the teams".*

Depth. This criterion aims to understand whether the model provides a thorough understanding of the diagnosis of the current capability profile of the teams and proposition of design thinking practices. This criterion was identified as being satisfactory and respondent D.2-A said, *"I like the approach to measure the team performance not based on the success of the MVP. Normally, it is how many prototypes, and here it is a different approach to measure team performance, despite the number of the prototypes".*

Consistency. Consistency aims to investigate whether the practices proposed are consistent with the needs of Company D. This criterion was identified as being satisfactory and respondent D.2-A suggested to apply the DTCM Scorecard to teams in two different moments in order to improve the consistency of the results. First, a few days after the end of the project, then, months after the end of the project. In this way, it would be possible to compare the answers to analyse if the feelings towards the project changed over time.

Clarity, simplicity, and coherence. Clarity and simplicity aims to investigate whether the results presented were clear and simple to understand, whereas coherence aims to investigate whether the design thinking practices proposed by the Design Thinking Capability Model are logical. Both criteria were identified as being satisfactory and all attendees confirmed that the practices are coherent and that they fully understood the results and the suggested improvements

When asked how the model could be improved, Respondent D.2-C pointed out how culture differences might have an effect in the scorecard results, *"I think here in [country's name omitted], we don't give ourselves a 5. I don't have the courage to give me a 5"*. Similarly, respondent D.1-A said, *"Most of the [nationality omitted] people want to be in the middle"*. The other attendees agreed and suggested that the DTCM should also be

applied in other countries in order to understand how cultural differences impact on the DTCM Scorecard results.

Finally, the difficulties the attendees had when answering the survey was asked. Respondent D.2-B said, *"It's too difficult to say what's 2 or 3"*. Respondent D.2-C said *"if I had the explanation about the model the way you did today before I answered the survey [scorecard], then I would have answered it differently"*.

In summary, it seems that the main problem in the application of the DTCM model was related to the precision of the answers. Culture differences and/or lack of understanding of 1-5 scale in the Scorecard were pointed out as possible causes for that problem. In the next chapter, these problems are discussed in more detail and recommendations for improving the model are suggested.

8 Discussion and Conclusions

This research used a mixed methods design approach to develop a Design Thinking Capability Model. It draws on existing theoretical and empirical studies on design thinking in the product development process.

Chapter 02 presented a review of the literature on the theories and concepts related to design thinking. In Chapter 03, how design thinking research for product development has evolved over the years was investigated, as were the current challenges and aspirations for future research. As a result, the pressing need to understand the underlying factors for an effective implementation of design thinking was identified. In order to investigate that, Chapter 04 presented a mixed methods approach, which allowed best practices from qualitative and quantitative methods to be employed in order to develop a comprehensive model to measure the design thinking capability of business organisations. The Design Thinking Capability Model aims to support companies in the selection of the most suitable design thinking practices to be implemented into the product development process, according to companies' strategic and objectives drivers. Then, Chapter 05 presented the findings from the qualitative methods that were employed in order to identify the critical success factors and practices involved in the design thinking implementation for product development. The chapter also presents how quantitative methods supported the creation of a scorecard aimed at operationalising DTCM. From the qualitative and quantitative analysis, the Design Thinking Capability Model was created and its main components were established. Chapter 6 then described the main components of DTCM, explaining how the model provides an assessment of a company's current design thinking capability profile, the understanding of improvement opportunities, the selection and prioritisation of design thinking practices, and the deployment of roadmaps for implementation considering companies' strategic objectives and drivers. An application method that explains how to implement the model is also presented. Based on the application method, the final version of the Design Thinking Capability model was tested as a case study in a large company that have been implementing design thinking for years. The results of the case study were presented in Chapter 7.

Chapter 8, here, presents the study's major empirical findings and it explains the meaning and importance of the study's results to the reader. Moreover, it relates the findings to previous research and helps address pressing issues in those fields. Then, it outlines the study's contributions from a theoretical and practical perspective. Finally, the chapter acknowledges the study's limitations and concludes by making suggestions for

future research.

8.1 Summary of findings

Design thinking has emerged as a promising approach to enhance innovation in the product development process and the likelihood of product success. Despite the recognition of the benefits related to design thinking, its application has not reached companies worldwide. That happens due to the challenges related to design thinking implementation and management. In order to address these challenges, this thesis introduced the Design Thinking Capability Model (DTCM), a framework aimed at supporting companies in the design thinking implementation based on their strategic objectives and drivers.

The DTCM was developed using a mixed methods approach, combining best practices from qualitative and quantitative research. Initially, the theoretical version of the model was developed based on a literature review and interviews with key opinion leaders in the area of design thinking from academia and industry. The literature review provided the first step in aligning research based on design thinking and new product development through a systematic analysis of more than ten years of research in the most relevant journals in the design and management field. It addresses the call of Liedtka (2015) who emphasises the need for more systematic studies in order to understand how design thinking can contribute to product success, and also D'Ippolito (2014) who suggests that a combined perspective is needed to enable the next generation of research on product development, and Micheli et al. (2012) who point out that it is only through such comprehensive understanding that we can recognise design thinking' s specific contribution to product development. The findings from the literature review confirm the need to understand the variables associated with design thinking implementation and management for product development. The review also indicates that organisational culture often remains resistant to such change due to the lack of guidance for organisations in how to adopt and operate a more designerly approach.

The interviews with key opinion leaders led to the identification of relevant dimensions of how design thinking adds value to business organisations: Strategy, Culture, Implementation, and Skill Development. This investigation answers the call of Rauth, Carlgren and Elmquist (2014) who point out that it is necessary to understand how design thinking is implemented in practice to assess its impacts and facilitate its integration within the company. The interview findings together with findings from the literature review resulted in the identification of four dimensions and 20 critical success factors for design thinking implementation for product development; over the past years, these critical success factors were presented in the literature in a fragmented way. Then, this

study summarised years of research on DT in the NPD, and then combined it with what established companies in the area of design thinking are doing. In this way, this research not only proposes the first attempt to consolidate critical success factors for design thinking implementation for product development, but also bridges the gap between academia and industry by combining evidence from both.

Each success factor contains at least one design thinking management practice aimed at helping companies understand what activities should be implemented in order to address each success factor. In total, 52 practices are proposed in this study as a way to implement the 20 criticalsuccess factors. In this research, these practices were systematised to offer a progression and organised into an instrument (a scorecard) in order to operationalise the success factors. Before that, no study has ever proposed a list of practices indicating when and how they should be applied. In this research, the practices were not only systematised but also relationships among them were established in order to facilitate their selection and implementation. Moreover, these practices were organised into capability levels and the DTCM application method was developed. As a result, the first capability model for design thinking was created.

The DTCM dimensions combines new evidence from the literature in terms of relevant factors and new perspectives that should be considered when addressing innovation challenges. In the same vein, the theoretical lenses of knowledge management capability provided the base for the creation of the DTCM goals. The basic components of knowledge management capability theory were further developed to become Inform-Assign-Provide-Learn-Measure (See section 5.2.2). In this way, this study extends the knowledge of the field of organisational capability by providing evidence of new dimensions and factors that should be considered when developing and managing capabilities for product development in business organisations.

The theoretical version of the DTCM was then further developed by means of a case study at large company (Company D), which brought richness to the understanding of how the application of DTCM is done in practice in companies add what are the results that can be expected from its application. As a result, most of the criteria defined for the DTCM application evaluation were evaluated as "satisfactory" - only the criterion precision was rated as "needs improvement" (see section 7). The conclusion is that the DTCM achieved the goal of the research, which was to support companies in the selection of the most suitable design thinking practices to be implemented into the product development process.

In summary, the results obtained from this study provide more evidence to sustain

the argument of design thinking as a management capability. Besides enabling a broad understanding of the current situation of the company on design thinking implementation, the results provide first evidence to show that design thinking capability is a measurable variable. The detailed explanation of all the components of the DTCM may be of interest to future researchers who want to understand how design thinking can be managed and what the underlying factors for its implementation are. It is important to note that this study is exploratory and therefore further studies need to be conducted in order to provide more evidence to strengthen the findings and establish generalisations of the application of the Design Thinking capability Model. In the next sections, the contributions, limitations, and future capacity of this study are discussed.

8.2 Contributions

This study is among the first efforts to investigate the changing patterns of design thinking, from being only a process, to how design thinking can be used as a management capability to promote innovation. The main contribution of this research is the development of a framework that can support companies in the selection of the most suitable design thinking practices to be implemented into the product development process according to companies' strategic and objectives drivers.

More specifically, The Design Thinking Capability Model enables the assessment of a company's current design thinking capability profile, the understanding of improvement opportunities, the selection and prioritisation of design thinking practices and the deployment of roadmaps for implementation. Moreover, the model provides a guide and common language for a strategic deployment of design thinking for product development.

Contributions to theory. First, it proposes a detailed synthesis of the literature in relation to design thinking theories and models. It explains how the understanding of the term "design thinking" has evolved over the years. It also provides an understanding of how design thinking research is influencing research in other fields.

Second, it proposes an integrated perspective of research based on design thinking and new product development. In particular, the evolution, challenges, and benefits of the discourse of design thinking literature in relation to the new product development domain are discussed and synthesised.

Third, it proposes a consolidated list of 20 critical success factors for a successful design thinking implementation for product development were identified, based on an extensive literature review and also on what established companies in the design

thinking domain have been doing. Through the consolidation of these critical success factors, researchers can better understand what indicators are relevant to design thinking implementation and management, which can enable them to redirect efforts to further investigate the underlying factors for the effective implementation of design thinking for product development.

Fourth, it proposes an instrument to operationalise the critical success factors based on scale development research. Practices were derived from the critical success factors and classified into capability levels in order to build the instrument. The instrument is a scorecard based on well established capability maturity models and also on knowledge management theory. The instrument is composed of 52 practices that are considered fundamental to address each success factor.

Finally, it provides the first attempt to create a Design Thinking Capability Model that can support companies in the strategic deployment of design thinking for product development. In particular, the model provides a common language and guide for companies that wish to develop a design thinking capability. It also provides a detailed application method explaining how to operationalise the model. In this way, researchers who want to build new capability models for other fields might use this thesis to repeat the procedures described in Chapter 5.

Contributions to practice. First, the Design Thinking Capability Model helps the establishment of a common language and a shared vision across the organisation for design thinking implementation.

Second, DTCM provides a guide on how to embed design thinking into a company's strategy, process, and corporate culture. The guide contains the description of the practices and description of the goals they aim to achieve in order to achieve their desired design thinking capability.

Third, it provides two information management tools - DTCM Capability Radar and DTCM Dashboard - that can analyse and display a company's current capability profile in design thinking in order to show strengths and weaknesses and identifying gaps for improvement in design thinking implementation.

Fourth, the DTCM Application Method provides guidance on how to use the Design Thinking Capability Model to measure a company's current design thinking profile. The main components of the DTCM Application Method are (ii) analysis of context and purpose, (ii) diagnosis of a company's current capability profile, and (iii) actionable

plan. The diagnosis of a company's current capability profile enables the identification of strengths and weaknesses in a company's design thinking implementation for product development. Once the current capability profile of a company is defined in the diagnosis step, a guide is proposed to help companies improve their design thinking implementation. Moreover, the DTCM Application method provides a comprehensive Actionable Plan, which contains the general activities to be performed in order to reach higher capability levels in design thinking implementation.

Finally, the DTCM Application method also provides guidance on how to acquire the necessary skills to implement design thinking. In this way, DTCM promotes the creation of a design capability in the organisation. By doing so, it can enable companies to apply and adapt design thinking according to a specific problem, which has the potential to enhance the likelihood of a product's success.

8.3 Limitations

The main limitation of this study is related to the consequences of the implementation of the design thinking practices after they have been proposed to the company. In particular, this study does not monitor the impact of the model on the company after the improvements are proposed. Figure 7 illustrates the necessary steps for the DTCM application guide. In other words, it was not possible to monitor the application of the DT practices and verify the improvements proposed by the model being implemented in the company. In this way, the application of the framework relies on the subjects' perception of whether the proposed practices (if implemented) have the potential to improve their design thinking implementation.

In addition, the DTCM application method does not provide guidance to companies on how to plan improvement projects for design thinking implementation. More specifically, the model explains *what* practices should be implemented, but it does not explain *how* the practices should be implemented. Thus, it is important to emphasise that the purpose of capability models is to indicate a road map for improvements that companies can decide on how to implement the practices based on their specific scenario. Thus, providing the *how* was not in the scope of this study.

It is important to reiterate that the model was validated only with teams that were using design thinking for software development. Thus, not all possible applications of the model for different products have been tested. Since all its links have not been empirically verified, the conceptual framework is not ready to be used by different industries. In this way, for now, it merely provides a guide for future research.

8.4 Future research

The findings from this exploratory study provide an initial step to afford insight into how to support companies in implementing design thinking by proposing practices to be implemented based on their current design thinking profile. Hence, more research is required to further improve the model.

A natural progression of this work is to analyse how to monitor and evaluate the performance of the DTCM projects. A DTCM project is a project that was influenced by the DTCM assessment. More specifically, it is a project that followed the proposed design thinking projects. By monitoring the DTCM practices, it would be possible to evaluate the impact of the model on the company, and consequently further identify its specific benefits and areas for improvement.

Additionally, a further study could investigate how to adapt DTCM for different products - or even how to adapt it to services. Since the Design Thinking Capability Model was only tested in a software scenario, it would be interesting to analyse if the current state of the model would also support companies in the selection of the most suitable design thinking practices to be integrated into the process of developing other products. If not, more work would need to be done in order to adapt the model to suit different products needs.

What adjustments would need to be done to the DTCM in order to verify how it could be adapted to different company sizes would be a fruitful area for further research. In this study, the model was implemented in a large organisation. In order to understand whether the model can be implemented in smaller companies, it is recommended to perform further studies.

Finally, research is also needed to investigate how to keep the model up to date. Considering that products and projects change over time, it is thus important to understand how the model can integrate new needs and still be relevant to companies.

Bibliography

ACKLIN, C. Design-driven innovation process model. **Design Management Journal**, Wiley Online Library, v. 5, n. 1, p. 50–60, 2010. Cited in page 38.

ACKLIN, C. Design management absorption model: A framework to describe and measure the absorption process of design knowledge by smes with little or no prior design experience. **Creativity and Innovation management**, Wiley Online Library, v. 22, n. 2, p. 147–160, 2013. Cited in page 12.

ANASTASI, A. Psychological testing. Macmillan Co., 1954. Cited 2 times in pages 59 and 60.

AWAN, U.; SROUFE, R.; KRASLAWSKI, A. Creativity enables sustainable development: Supplier engagement as a boundary condition for the positive effect on green innovation. **Journal of Cleaner Production**, Elsevier, v. 226, p. 172–185, 2019. Cited in page 44.

BAGNO, R. B.; SALERNO, M. S.; SILVA, D. O. da. Models with graphical representation for innovation management: a literature review. **R&D Management**, Wiley Online Library, v. 47, n. 4, p. 637–653, 2017. Cited in page 45.

BAILEY, S. G. Embedding service design: the long and the short of it. In: LINKÖPING UNIVERSITY ELECTRONIC PRESS, LINKÖPINGS UNIVERSITET. **ServDes. 2012 Conference Proceedings Co-Creating Services; The 3rd Service Design and Service Innovation Conference; 8-10 February; Espoo; Finland**. [S.l.], 2012. p. 31–41. Cited in page 14.

BECKMAN, S. L.; BARRY, M. Innovation as a learning process: Embedding design thinking. **California management review**, SAGE Publications Sage CA: Los Angeles, CA, v. 50, n. 1, p. 25–56, 2007. Cited in page 30.

BELL, E.; BRYMAN, A.; HARLEY, B. **Business research methods**. [S.l.]: Oxford university press, 2018. Cited in page 51.

BELTAGUI, A. A design-thinking perspective on capability development: The case of new product development for a service business model. **International Journal of Operations & Production Management**, Emerald Publishing Limited, v. 38, n. 4, p. 1041–1060, 2018. Cited in page 44.

BEST, K. **Design management: managing design strategy, process and implementation**. [S.l.]: AVA publishing, 2006. Cited 2 times in pages 38 and 83.

BHATT, G. D. Knowledge management in organizations: examining the interaction between technologies, techniques, and people. **Journal of knowledge management**, MCB UP Ltd, v. 5, n. 1, p. 68–75, 2001. Cited in page 89.

BLOCH, P. H. Product design and marketing: reflections after fifteen years. **Journal of Product Innovation Management**, Wiley Online Library, v. 28, n. 3, p. 378–380, 2011. Cited in page 23.

BOHLMANN, J. D. et al. The interplay of customer and product innovation dynamics: an exploratory study. **Journal of Product Innovation Management**, Wiley Online Library, v. 30, n. 2, p. 228–244, 2013. Cited 3 times in pages 55, 57, and 70.

BOLAND, R. J.; COLLOPY, F. **Design matters for management**. [S.l.]: na, 2004. Cited in page 82.

BONT, C. de; LIU, S. X. Breakthrough innovation through design education: Perspectives of design-led innovators. **Design Issues**, MIT Press, v. 33, n. 2, p. 18–30, 2017. Cited in page 46.

BRAUN, V.; CLARKE, V. Using thematic analysis in psychology. **Qualitative research in psychology**, Taylor & Francis, v. 3, n. 2, p. 77–101, 2006. Cited in page 40.

BRENNER, W.; UEBERNICKEL, F.; ABRELL, T. Design thinking as mindset, process, and toolbox. In: **Design Thinking for Innovation**. [S.l.]: Springer, 2016. p. 3–21. Cited 6 times in pages 25, 26, 27, 28, 83, and 84.

BROWN, T. Change by design. Harper Collins, 2009. Cited 5 times in pages 12, 13, 25, 82, and 84.

BROWN, T. Design thinking. Harvard Business Review, 2009. Cited 8 times in pages 11, 25, 28, 29, 80, 81, 82, and 84.

BRUCE, M.; VAZQUEZ, D. Defining a design manager's role in food retail. **International Journal of New Product Development and Innovation Management**, v. 1, n. 2, p. 167–178, 1999. Cited in page 23.

BUCHANAN, R. Wicked problems in design thinking. **Design issues**, JSTOR, v. 8, n. 2, p. 5–21, 1992. Cited 2 times in pages 12 and 23.

BURDICK, A.; WILLIS, H. Digital learning, digital scholarship and design thinking. **Design Studies**, Elsevier, v. 32, n. 6, p. 546–556, 2011. Cited 2 times in pages 11 and 38.

CALLAGHAN, E. Personalities of design thinking. **Design Management Journal**, Wiley Online Library, v. 4, n. 1, p. 20–32, 2009. Cited in page 45.

CARLGREN, L.; ELMQUIST, M.; RAUTH, I. Implementing design thinking in large organizations. In: **Proceedings of the IPDM Conference 2012, Manchaster.** [S.l.: s.n.], 2012. Cited in page 14.

CARLGREN, L.; ELMQUIST, M.; RAUTH, I. Exploring the use of design thinking in large organizations: Towards a research agenda. **Swedish design research journal**, v. 11, p. 55–63, 2014A. Cited 2 times in pages 11 and 13.

CARLGREN, L.; ELMQUIST, M.; RAUTH, I. Design thinking: Exploring values and effects from an innovation capability perspective. **The Design Journal**, Taylor & Francis, v. 17, n. 3, p. 403–423, 2014B. Cited 6 times in pages 11, 25, 29, 30, 74, and 84.

CARLGREN, L.; ELMQUIST, M.; RAUTH, I. The challenges of using design thinking in industry–experiences from five large firms. **Creativity and Innovation Management**, Wiley Online Library, v. 25, n. 3, p. 344–362, 2016B. Cited 8 times in pages 12, 13, 14, 26, 29, 45, 61, and 73.

CARLGREN, L.; ELMQVIST, M.; RAUTH, I. Exploring the use of design thinking in large organizations: Towards a research agenda. **Swedish design research journal**, v. 11, n. 1, p. 55–63, 2016A. Cited 2 times in pages 25 and 27.

CARLGREN, L.; RAUTH, I.; ELMQUIST, M. Framing design thinking: The concept in idea and enactment. **Creativity and Innovation Management**, Wiley Online Library, v. 25, n. 1, p. 38–57, 2016C. Cited 3 times in pages 80, 81, and 82.

CARRILLO, J. E.; DRUEHL, C.; HSUAN, J. Introduction to innovation within and across borders: A review and future directions. **Decision Sciences**, Wiley Online Library, v. 46, n. 2, p. 225–265, 2015. Cited in page 38.

CHANG, Y.; KIM, J.; JOO, J. An exploratory study on the evolution of design thinking: Comparison of apple and samsung. **Design Management Journal**, Wiley Online Library, v. 8, n. 1, p. 22–34, 2013. Cited 5 times in pages 11, 12, 13, 38, and 39.

CHARMAZ, K. **Constructing grounded theory**. [S.l.]: Sage, 2014. Cited 4 times in pages 55, 57, 61, and 62.

CHEN, S. et al. Teaching design thinking in marketing: Linking product design and marketing strategy in a product development class. **Journal of Marketing Education**, SAGE Publications Sage CA: Los Angeles, CA, v. 40, n. 3, p. 176–187, 2018. Cited in page 46.

CHRISSIS, M. B.; KONRAD, M.; SHRUM, S. **CMMI for development: guidelines for process integration and product improvement**. [S.l.]: Pearson Education, 2011. Cited in page 58.

CIPOLLA, C.; MOURA, H. Social innovation in brazil through design strategy. **Design Management Journal**, Wiley Online Library, v. 6, n. 1, p. 40–51, 2011. Cited 3 times in pages 11, 12, and 38.

CLARK, K.; SMITH, R. Unleashing the power of design thinking. **Design Management Review**, Wiley Online Library, v. 19, n. 3, p. 8–15, 2008. Cited 5 times in pages 29, 30, 81, 82, and 84.

CLARK, L. A.; WATSON, D. Constructing validity: Basic issues in objective scale development. **Psychological assessment**, American Psychological Association, v. 7, n. 3, p. 309, 1995. Cited 2 times in pages 59 and 60.

CONDORI-FERNANDEZ, N. et al. A systematic mapping study on empirical evaluation of software requirements specifications techniques. In: IEEE. **Empirical Software Engineering and Measurement, 2009. ESEM 2009. 3rd International Symposium on**. [S.l.], 2009. p. 502–505. Cited in page 31.

COOPER, R.; JUNGINGER, S.; LOCKWOOD, T. Design thinking and design management: A research and practice perspective. **Design Management Review**, Wiley Online Library, v. 20, n. 2, p. 46–55, 2009. Cited 3 times in pages 13, 29, and 83.

CORBIN, J.; STRAUSS, A. et al. Basics of qualitative research: Techniques and procedures for developing grounded theory. Thousand Oaks, CA: Sage, 2008. Cited 2 times in pages 61 and 62.

CRESWELL, J. et al. An expanded typology for classifying mixed methods research info design. **Handbook of Mixed Methods in Social and Behavioural Research**, 2003. Cited in page 51.

CRESWELL, J. W.; CLARK, V. L. P. **Designing and conducting mixed methods research**. [S.l.]: Sage publications, 2017. Cited in page 50.

CRESWELL, J. W.; FETTERS, M. D.; IVANKOVA, N. V. Designing a mixed methods study in primary care. **The Annals of Family Medicine**, Annals Family Med, v. 2, n. 1, p. 7–12, 2004. Cited in page 51.

CRESWELL, J. W. et al. Best practices for mixed methods research in the health sciences. **Bethesda (Maryland): National Institutes of Health**, v. 2013, p. 541–545, 2011. Cited 2 times in pages 53 and 56.

CRESWELL, J. W.; MILLER, D. L. Determining validity in qualitative inquiry. **Theory into practice**, Taylor & Francis, v. 39, n. 3, p. 124–130, 2000. Cited in page 62.

CROSBY, P. B. **Quality is Free**. [S.l.]: McGraw-Hill Companies, 1979. Cited in page 86.

CROSS, N. **Designerly ways of knowing**. [S.l.]: Elsevier, 1982. Cited 3 times in pages 11, 13, and 22.

DAWIS, R. V. Scale construction. **Journal of Counseling Psychology**, American Psychological Association, v. 34, n. 4, p. 481, 1987. Cited in page 60.

DEVELLIS, R. F. **Scale development: Theory and applications**. [S.l.]: Sage publications, 2016. Cited 3 times in pages 58, 59, and 60.

DEVON, H. A. et al. A psychometric toolbox for testing validity and reliability. **Journal of Nursing scholarship**, Wiley Online Library, v. 39, n. 2, p. 155–164, 2007. Cited in page 61.

D'IPPOLITO, B. The importance of design for firms' competitiveness: a review of the literature. **Technovation**, p. forhcoming, 2014. Cited 8 times in pages 11, 14, 26, 29, 39, 46, 48, and 143.

DORST, K. The core of 'design thinking'and its application. **Design studies**, Elsevier, v. 32, n. 6, p. 521–532, 2011. Cited 2 times in pages 30 and 39.

DREWS, C. Unleashing the full potential of design thinking as a business method. **Design Management Review**, Wiley Online Library, v. 20, n. 3, p. 38–44, 2009. Cited in page 83.

DUNNE, D.; MARTIN, R. Design thinking and how it will change management education: An interview and discussion. **Academy of Management Learning & Education**, Academy of Management Briarcliff Manor, NY 10510, v. 5, n. 4, p. 512–523, 2006. Cited 3 times in pages 25, 39, and 82.

ERICHSEN, P. G.; CHRISTENSEN, P. R. The evolution of the design management field: a journal perspective. **Creativity and Innovation Management**, Wiley Online Library, v. 22, n. 2, p. 107–120, 2013. Cited in page 43.

FERNANDES, A. A. et al. Structured methods of new product development and creativity management: A teaching experience. **Creativity and Innovation Management**, Wiley Online Library, v. 18, n. 3, p. 160–175, 2009. Cited 2 times in pages 46 and 48.

FETTERS, M. D.; CURRY, L. A.; CRESWELL, J. W. Achieving integration in mixed methods designs—principles and practices. **Health services research**, Wiley Online Library, v. 48, n. 6pt2, p. 2134–2156, 2013. Cited in page 53.

FORD, P.; TERRIS, D. An intimate approach to the management and integration of design knowledge for small firms. **Design Management Journal**, Wiley Online Library, v. 12, n. 1, p. 58–70, 2017. Cited in page 43.

FRASER, P.; MOULTRIE, J.; GREGORY, M. The use of maturity models/grids as a tool in assessing product development capability. In: IEEE. **IEEE international engineering management conference**. [S.l.], 2002. v. 1, p. 244–249. Cited 2 times in pages 93 and 94.

GARCÍA, L. M.; DESERTI, A.; TEIXEIRA, C. Entrepreneurial design: the role of design as driver of entrepreneurial opportunity generation and assessment. **International Journal of Entrepreneurship and Innovation Management**, Inderscience Publishers (IEL), v. 21, n. 1-2, p. 64–85, 2017. Cited in page 45.

GARFIELD, E. Keywords plus-isi's breakthrough retrieval method. 1. expanding your searching power on current-contents on diskette. **Current Contents**, INST SCI INFORM INC 3501 MARKET ST, PHILADELPHIA, PA 19104 USA, v. 32, p. 5–9, 1990. Cited 3 times in pages 32, 33, and 41.

GERBING, D. W.; ANDERSON, J. C. An updated paradigm for scale development incorporating unidimensionality and its assessment. **Journal of marketing research**, JSTOR, p. 186–192, 1988. Cited in page 59.

GLASER, B. G.; STRAUSS, A. L.; STRUTZEL, E. The discovery of grounded theory; strategies for qualitative research. **Nursing research**, LWW, v. 17, n. 4, p. 364, 1968. Cited in page 55.

GLOPPEN, J. Perspectives on design leadership and design thinking and how they relate to european service industries. **Design Management Journal**, Wiley Online Library, v. 4, n. 1, p. 33–47, 2009. Cited 3 times in pages 80, 82, and 84.

GREENE, J. C.; CARACELLI, V. J.; GRAHAM, W. F. Toward a conceptual framework for mixed-method evaluation designs. **Educational evaluation and policy analysis**, Sage Publications Sage CA: Los Angeles, CA, v. 11, n. 3, p. 255–274, 1989. Cited in page 51.

GRIFFIN, A.; HAUSER, J. R. Integrating r&d and marketing: a review and analysis of the literature. **Journal of Product Innovation Management: AN INTERNATIONAL PUBLICATION OF THE PRODUCT DEVELOPMENT & MANAGEMENT ASSOCIATION**, Wiley Online Library, v. 13, n. 3, p. 191–215, 1996. Cited in page 23.

GRUNER, K. E.; HOMBURG, C. Does customer interaction enhance new product success? **Journal of business research**, Elsevier, v. 49, n. 1, p. 1–14, 2000. Cited in page 23.

GUNES, S. Design entrepreneurship in product design education. **Procedia-Social and Behavioral Sciences**, Elsevier, v. 51, p. 64–68, 2012. Cited in page 46.

HALADYNA, T. M.; RODRIGUEZ, M. C. **Developing and validating test items**. [S.l.]: Routledge, 2013. Cited in page 61.

HARDING, J. **Qualitative data analysis from start to finish**. [S.l.]: Sage, 2013. Cited 2 times in pages 55 and 72.

HART, S.; TZOKAS, N.; SAREN, M. The effectiveness of market information in enhancing new product success rates. **European Journal of Innovation Management**, MCB UP Ltd, v. 2, n. 1, p. 20–35, 1999. Cited in page 23.

HASSI, L.; LAAKSO, M. Conceptions of design thinking in the design and management discourses. In: **Proceedings of IASDR2011, the 4th world conference on design research, Delft**. [S.l.: s.n.], 2011. p. 1–10. Cited 5 times in pages 13, 25, 26, 28, and 83.

HASSI, L.; LAAKSO, M. Design thinking in the management discourse: Defining the elements of the concept. In: **18th International Product Development Management Conference, IPDMC**. [S.l.: s.n.], 2011. p. 1–14. Cited 2 times in pages 13 and 14.

HINKIN, T. R. A brief tutorial on the development of measures for use in survey questionnaires. **Organizational research methods**, Sage Publications Sage CA: Thousand Oaks, CA, v. 1, n. 1, p. 104–121, 1998. Cited 2 times in pages 58 and 60.

HOBDAY, M.; BODDINGTON, A.; GRANTHAM, A. An innovation perspective on design: Part 1. **Design Issues**, MIT Press, v. 27, n. 4, p. 5–15, 2011. Cited in page 47.

HOBDAY, M.; BODDINGTON, A.; GRANTHAM, A. An innovation perspective on design: Part 2. **Design issues**, MIT Press, v. 28, n. 1, p. 18–29, 2012. Cited in page 12.

HOLLOWAY, M. How tangible is your strategy? how design thinking can turn your strategy into reality. **Journal of Business Strategy**, Emerald Group Publishing Limited, v. 30, n. 2/3, p. 50–56, 2009. Cited 2 times in pages 25 and 82.

JERRARD, B.; MARTIN, L.; WRIGHT, L. Gut feeling in small design consultancies. **The Design Journal**, Taylor & Francis, v. 20, n. 5, p. 577–594, 2017. Cited in page 44.

JOHANSSON-SKÖLDBERG, U.; WOODILLA, J.; ÇETINKAYA, M. Design thinking: past, present and possible futures. **Creativity and innovation management**, Wiley Online Library, v. 22, n. 2, p. 121–146, 2013. Cited 2 times in pages 25 and 28.

JOHANSSON, U.; WOODILLA, J. Looking at design thinking interventions as artistic interventions. **LEADING THROUGH DESIGN**, University of Virginia, p. 871, 2012. Cited in page 25.

JUNGINGER, S. Product development as a vehicle for organizational change. **Design Issues**, MIT Press, v. 24, n. 1, p. 26–35, 2008. Cited in page 45.

KAHN, K. B. Interdepartmental integration: a definition with implications for product development performance. **Journal of Product Innovation Management: AN INTERNATIONAL PUBLICATION OF THE PRODUCT DEVELOPMENT & MANAGEMENT ASSOCIATION**, Wiley Online Library, v. 13, n. 2, p. 137–151, 1996. Cited in page 23.

KALLMANN, R. Inclusive design: excluding users in a conscious way. In: SAGE PUBLICATIONS SAGE CA: LOS ANGELES, CA. **Proceedings of the Human Factors and Ergonomics Society Annual Meeting**. [S.l.], 2000. v. 44, n. 38, p. 901–904. Cited in page 74.

KELLEY, T.; KELLEY, D. **Creative confidence: Unleashing the creative potential within us all**. [S.l.]: Currency, 2013. Cited 2 times in pages 24 and 25.

KIM, B. Y.; BAEK, J. H. Leading the market with design thinking and sensibility. **Design Management Review**, Wiley Online Library, v. 22, n. 3, p. 80–89, 2011. Cited 2 times in pages 46 and 74.

KIMBELL, L. Rethinking design thinking: Part i. **Design and Culture**, Routledge, v. 3, n. 3, p. 285–306, 2011. Cited 3 times in pages 13, 22, and 25.

KIMBELL, L.; STREET, P. E. Beyond design thinking: Design-as-practice and designs-in-practice. In: **CRESC Conference, Manchester**. [S.l.: s.n.], 2009. p. 1–15. Cited 2 times in pages 13 and 29.

KITCHENHAM, B. What's up with software metrics?–a preliminary mapping study. **Journal of systems and software**, Elsevier, v. 83, n. 1, p. 37–51, 2010. Cited in page 31.

KOEN, P. et al. Providing clarity and a common language to the "fuzzy front end". **Research-Technology Management**, Taylor & Francis, v. 44, n. 2, p. 46–55, 2001. Cited in page 75.

KULKARNI, U.; FREEZE, R. Development and validation of a knowledge management capability assessment model. **ICIS 2004 Proceedings**, p. 54, 2004. Cited in page 89.

LEE, Y.; EVANS, D. M. What drives organizations to employ design-driven approaches? a study of fast-moving consumer goods brand development. **Design Management Journal**, Wiley Online Library, v. 7, n. 1, p. 74–88, 2012. Cited 3 times in pages 45, 48, and 49.

LEONARD-BARTON, D. Core capabilities and core rigidities: A paradox in managing new product development. **Strategic management journal**, Wiley Online Library, v. 13, n. S1, p. 111–125, 1992. Cited in page 58.

LEUNG, L. Validity, reliability, and generalizability in qualitative research. **Journal of family medicine and primary care**, Wolters Kluwer–Medknow Publications, v. 4, n. 3, p. 324, 2015. Cited in page 61.

LIEDTKA, J. Learning to use design thinking tools for successful innovation. **Strategy & Leadership**, Emerald Group Publishing Limited, v. 39, n. 5, p. 13–19, 2011. Cited 5 times in pages 11, 25, 39, 61, and 80.

LIEDTKA, J. Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction. **Journal of Product Innovation Management**, Wiley Online Library, v. 32, n. 6, p. 925–938, 2015. Cited 11 times in pages 12, 13, 14, 23, 24, 29, 39, 43, 73, 82, and 143.

LIEDTKA, J. Evaluating the impact of design thinking in action. In: ACADEMY OF MANAGEMENT BRIARCLIFF MANOR, NY 10510. **Academy of Management Proceedings**. [S.l.], 2017. v. 2017, n. 1, p. 10264. Cited in page 13.

LIEDTKA, J.; KING, A.; BENNETT, K. **Solving problems with design thinking: Ten stories of what works**. [S.l.]: Columbia University Press, 2013. Cited 3 times in pages 29, 30, and 84.

LINDBERG, T. et al. On the perception, adoption and implementation of design thinking in the it industry. In: **Design thinking research**. [S.l.]: Springer, 2012. p. 229–240. Cited in page 27.

LINDBERG, T.; MEINEL, C.; WAGNER, R. Design thinking: A fruitful concept for it development? In: **Design thinking**. [S.l.]: Springer, 2011. p. 3–18. Cited in page 12.

LOCKWOOD, T. Transition: How to become a more design-minded organization. **Design Management Review**, Wiley Online Library, v. 20, n. 3, p. 28–37, 2009. Cited in page 82.

LOCKWOOD, T. **Design thinking: Integrating innovation, customer experience, and brand value**. [S.l.]: Skyhorse Publishing, Inc., 2010. Cited in page 24.

LYNN, M. R. Determination and quantification of content validity. **Nursing research**, Lippincott Williams & Wilkins, 1986. Cited 2 times in pages 60 and 61.

MAHMOUD-JOUINI, S. B.; MIDLER, C.; SILBERZAHN, P. Contributions of design thinking to project management in an innovation context. **Project Management Journal**, Wiley Online Library, v. 47, n. 2, p. 144–156, 2016. Cited 6 times in pages 11, 12, 14, 29, 38, and 83.

MARKHAM, S. K. The impact of front-end innovation activities on product performance. **Journal of Product Innovation Management**, Wiley Online Library, v. 30, p. 77–92, 2013. Cited in page 75.

MARTIN, R. L. **The design of business: Why design thinking is the next competitive advantage**. [S.l.]: Harvard Business Press, 2009. Cited 4 times in pages 25, 30, 80, and 83.

MICHELI, P. et al. Perceptions of industrial design: The "means" and the "ends". **Journal of Product Innovation Management**, Wiley Online Library, v. 29, n. 5, p. 687–704, 2012. Cited 8 times in pages 12, 14, 23, 29, 30, 39, 44, and 143.

MICHELI, P.; PERKS, H.; BEVERLAND, M. B. Elevating design in the organization. **Journal of Product Innovation Management**, Wiley Online Library, v. 35, n. 4, p. 629–651, 2018. Cited in page 43.

MOODY, D. L. Theoretical and practical issues in evaluating the quality of conceptual models: current state and future directions. **Data & Knowledge Engineering**, Elsevier, v. 55, n. 3, p. 243–276, 2005. Cited in page 56.

MORGAN, D. L. Practical strategies for combining qualitative and quantitative methods: Applications to health research. **Qualitative health research**, Sage Publications Sage CA: Thousand Oaks, CA, v. 8, n. 3, p. 362–376, 1998. Cited in page 51.

MORSE, J. M. Approaches to qualitative-quantitative methodological triangulation. **Nursing research**, LWW, v. 40, n. 2, p. 120–123, 1991. Cited in page 51.

MOULTRIE, J.; CLARKSON, P. J.; PROBERT, D. Development of a design audit tool for smes. **Journal of Product Innovation Management**, Wiley Online Library, v. 24, n. 4, p. 335–368, 2007. Cited 3 times in pages 14, 44, and 47.

MOZOTA, B. B. de. A theoretical model for design in management science: The paradigm shift in the design profession, from management as a constraint to management science as an opportunity. **Design Management Journal**, Wiley Online Library, v. 3, n. 1, p. 30–37, 2008. Cited in page 47.

PAULA, D. de; DOBRIGKEIT, F.; CORMICAN, K. Design thinking capability model (dtcm): A framework to map out design thinking capacity in business organisations. In: **DS92: Proceedings of the DESIGN 2018 15th International Design Conference**. [S.l.: s.n.], 2018. p. 557–566. Cited in page 25.

PAULK, M. C. et al. Capability maturity modelfor software, version 1.1. **Tech ReportCMUSEI-93TR-24, Software Engineeringlnstitute**, 1993. Cited in page 86.

PAULK, M. C. et al. Key practices of the capability maturity model for software, version 1.1. **Pittsburgh, PA: Software Engineering Institute (SEI)**, 1993. Cited in page 86.

PEDERSEN, T. Ø. Ux toolbox for software developers. 2016. Cited in page 26.

PETERSEN, K. et al. Systematic mapping studies in software engineering. In: **EASE**. [S.l.: s.n.], 2008. v. 8, p. 68–77. Cited 2 times in pages 31 and 40.

PETTICREW; ROBERTS. Systematic reviews in the social sciences: A practical guide. **Counselling and Psychotherapy Research**, v. 6, p. 304–305, 2006. Cited in page 31.

PIGOSSO, D. C.; ROZENFELD, H.; MCALOONE, T. C. Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. **Journal of Cleaner Production**, Elsevier, v. 59, p. 160–173, 2013. Cited 8 times in pages 17, 58, 62, 63, 65, 67, 86, and 139.

PLATTNER, H.; MEINEL, C.; LEIFER, L. **Design thinking: understand–improve–apply**. [S.l.]: Springer Science & Business Media, 2010. Cited in page 24.

PORCINI, M. Your new design process is not enough—hire design thinkers! **Design Management Review**, Wiley Online Library, v. 20, n. 3, p. 6–18, 2009. Cited in page 81.

RAUTH, I.; CARLGREN, L.; ELMQUIST, M. Making it happen: Legitimizing design thinking in large organizations. **Design Management Journal**, Wiley Online Library, v. 9, n. 1, p. 47–60, 2014. Cited 4 times in pages 12, 39, 61, and 143.

ROBINSON, A.; STERN, S. **Corporate creativity: How innovation and improvement actually happen**. [S.l.]: Berrett-Koehler Publishers, Inc, 1998. Cited in page 81.

ROSENSWEIG, R. R. More than heroics: building design as a dynamic capability. **Design Management Journal**, Wiley Online Library, v. 6, n. 1, p. 16–26, 2011. Cited 7 times in pages 12, 23, 27, 29, 39, 75, and 85.

ROWE, P. G. **Design thinking**. [S.l.]: MIT press, 1987. Cited 2 times in pages 12 and 22.

RYLANDER, A. Design thinking as knowledge work: Epistemological foundations and practical implications. **Design Management Journal**, Wiley Online Library, v. 4, n. 1, p. 7–19, 2009. Cited in page 83.

SCHEIN, E. H. Coming to a new awareness of organizational culture. **Sloan management review**, Cambridge, v. 25, n. 2, p. 3–16, 1984. Cited in page 81.

SCHÖN, D. A. **The reflective practitioner: How professionals think in action**. [S.l.]: Routledge, 2017. Cited in page 22.

SEIDEL, V. P.; FIXSON, S. K. Adopting design thinking in novice multidisciplinary teams: The application and limits of design methods and reflexive practices. **Journal of Product Innovation Management**, Wiley Online Library, v. 30, p. 19–33, 2013. Cited 4 times in pages 14, 30, 75, and 85.

SIMON, H. A. **The sciences of the artificial**. [S.l.]: MIT press, 1996. Cited 2 times in pages 12 and 23.

SIMONS, T.; GUPTA, A.; BUCHANAN, M. Innovation in r&d: Using design thinking to develop new models of inventiveness, productivity and collaboration. **Journal of Commercial Biotechnology**, Springer, v. 17, n. 4, p. 301–307, 2011. Cited in page 74.

SLAVEC, A.; DRNOVŠEK, M. A perspective on scale development in entrepreneurship research. **Economic & Business Review**, v. 14, n. 1, 2012. Cited in page 59.

STICKDORN, M. et al. **This is service design thinking: Basics, tools, cases**. [S.l.]: Wiley Hoboken, NJ, 2011. Cited 4 times in pages 25, 26, 28, and 83.

STORVANG, P.; JENSEN, S.; CHRISTENSEN, P. R. Innovation through design: A framework for design capacity in a danish context. **Design Management Journal**, Wiley Online Library, v. 9, n. 1, p. 9–22, 2014. Cited 4 times in pages 13, 39, 74, and 75.

TASHAKKORI, A.; CRESWELL, J. W. **The new era of mixed methods**. [S.l.]: Sage Publications, 2007. Cited 2 times in pages 50 and 67.

TASHAKKORI, A.; TEDDLIE, C.; TEDDLIE, C. B. **Mixed methodology: Combining qualitative and quantitative approaches**. [S.l.]: Sage, 1998. Cited in page 50.

TEAM, C. et al. Cmmi® for development version 1.3 cmmi-dev v1. 3. **Tech. Rep**, 2010. Cited 4 times in pages 58, 86, 87, and 99.

THORPE, R. et al. Using knowledge within small and medium-sized firms: a systematic review of the evidence. **International Journal of Management Reviews**, Wiley Online Library, v. 7, n. 4, p. 257–281, 2005. Cited in page 41.

TORRACO, R. J. A theory of knowledge management. **Advances in developing human resources**, Sage Publications Sage CA: Thousand Oaks, CA, v. 2, n. 1, p. 38–62, 2000. Cited 2 times in pages 81 and 89.

VALENCIA, A.; PERSON, O.; SNELDERS, D. An in-depth case study on the role of industrial design in a business-to-business company. **Journal of Engineering and Technology Management**, Elsevier, v. 30, n. 4, p. 363–383, 2013. Cited 2 times in pages 44 and 75.

VERNADAT, F. **Enterprise modeling and integration**. [S.l.]: Boom Koninklijke Uitgevers, 1996. Cited 3 times in pages 17, 67, and 139.

VERVAEKE, M. From watching the markets to making trends: the role of industrial designers in competitive strategies. In: **Working on innovation**. [S.l.]: Routledge, 2009. p. 56–85. Cited in page 12.

VERYZER, R. W.; MOZOTA, B. Borja de. The impact of user-oriented design on new product development: An examination of fundamental relationships. **Journal of product innovation management**, Wiley Online Library, v. 22, n. 2, p. 128–143, 2005. Cited in page 12.

VETTERLI, C. Embedded design thinking in organizations: A literature review. 2015. Cited in page 14.

WARD, A.; RUNCIE, E.; MORRIS, L. Embedding innovation: design thinking for small enterprises. **Journal of Business Strategy**, Emerald Group Publishing Limited, v. 30, n. 2/3, p. 78–84, 2009. Cited in page 81.

WENNGREN, J.; ERICSON, Å.; PARIDA, V. Improving team activities in the concept development stages: Addressing radical development and open-ended problems. **Journal of Promotion Management**, Taylor & Francis, v. 22, n. 4, p. 496–510, 2016. Cited in page 44.

WILKINSON, C. R.; ANGELI, A. D. Applying user centred and participatory design approaches to commercial product development. **Design Studies**, Elsevier, v. 35, n. 6, p. 614–631, 2014. Cited in page 74.

WÖLBLING, A. et al. Design thinking: An innovative concept for developing user-centered software. In: **Software for People**. [S.l.]: Springer, 2012. p. 121–136. Cited 3 times in pages 25, 26, and 83.

WONG, V. How business is adopting design thinking. **Business Week**, 2009. Cited 2 times in pages 12 and 39.

WORTHINGTON, R. L.; WHITTAKER, T. A. Scale development research: A content analysis and recommendations for best practices. **The Counseling Psychologist**, Sage Publications Sage CA: Thousand Oaks, CA, v. 34, n. 6, p. 806–838, 2006. Cited 2 times in pages 59 and 60.

Appendix

APPENDIX A – Survey questions (2nd round of interviews)

Design thinking implementation

Q1. In what stage of the development process is design thinking normally implemented and how?

DT collaboration

Q2. Do you believe having a cross-functional team would decrease costs with handover (e.g. time to explain the product concept to the next team) and rework (e.g. errors committed due to the lack of team collaboration)? If yes, why? If not, why not?

Users' involvement

Q3. How does the concept development team learn about the users? Q4. Do the users participate in the process in the company? Q5. Does the team learn about the users through other methods such as surveys, observations, and focus groups? Q6. How often does the team meet with the users?

The front-end phase

Q7. What is the role of design thinking to generate and select ideas?

DT Strategy

Q8. What drives your company to use design thinking? Q9. If you were asked to develop metrics to prove the usefulness of design thinking in terms of its benefits and cost? What would you do?

General

Q10. Do you have any other comments?

APPENDIX B – DTCM case study proposal

Measuring design thinking capability in business organisations: a case study proposal.

Danielly de Paula

Re: Companies wanted as industry partners to run a case study aimed at measuring their design thinking capability through the Design Thinking Capability Model.

Background

The Design Thinking Capability Model (DTCM) is a management framework aiming to support companies in implementing design thinking for software development. The purpose of the model is to diagnose the current design thinking capability profile of a company, identify improvement opportunities and develop a roadmap for the company to achieve their desired design thinking capability.

Case Study Agenda

The agenda for the case study is as follows :

1. Analysis of context and purpose: Meeting (1h)
2. Diagnosis of the current capability profile (survey): 20min
3. Actionable plan for improving design thinking capabilities (presentation + documentation) and assessment of results (survey): 1h - 2h

Benefits for the company

In this way, companies would benefit from:

(I) an assessment of strengths and weaknesses in their design thinking implementation; and
(II) a roadmap to achieve their desired design thinking capability

Interested? Simply email Danielly at: danielly.depaula@hpi.de

About Danielly de Paula

Danielly holds a Bachelor degree in Information Systems and a Masters in Computer Science from Brazil. During her masters studies, Danielly worked as the Innovation Manager for the BlackBerry Recife, which enabled her to lead design thinking initiatives for B2C mobile applications. Even though she is doing a PhD in Ireland, she is currently based in Potsdam (Germany) working as a research assistant for the Hasso-Plattner-Institut.

She has a passion for creating great experiences through a deep understanding of users, customers, and employees. Her main professional interest is to understand how design can lead to personal and organisational growth. At the moment, her biggest career challenge is to discover how to authentically measure the impact of design thinking on company's performance.

APPENDIX C – Questionnaire to evaluate DTCM

An Evaluation of the Design Thinking Capability Model (DTCM)

Thank you for participating in the case study. Please help us to evaluate the potential contribution of the Design Thinking Capability Model in supporting your company in the effective selection of design thinking practices to be integrated into the product development process. Please select your level of satisfaction with the Design Thinking Capability Model for the various areas of product development.

1. **Utility**: How do you evaluate the utility of the DTCM in supporting companies in the selection of the most suitable design thinking practices to be applied?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

2. **Consistency:** How do you evaluate the consistency of the design thinking practices proposed by the DTCM?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

3. **Completeness:** How do you evaluate the completeness of the suggested improvements for design thinking implementation proposed by the DTCM?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

4. **Precision:** How do you evaluate the precision in the definition of the design thinking capability profile of each team?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

5. **Depth:** How do you evaluate the Design Thinking Capability Model (DTCM) in relation to the depth of the diagnosis of the current capability profile and proposition of design thinking practices?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

6. **Simplicity:** How do you evaluate the Design Thinking Capability Model (DTCM) in relation to the simplicity of the results presented (e.g. the Design Thinking Capability Radar)?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

7. **Clarity:** How do you evaluate the Design Thinking Capability Model (DTCM) in relation to the clarity in which the results are presented?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

8. **Coherence:** How do you evaluate the coherence of the design thinking practices proposed by the Design Thinking Capability Model?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

9. **Forecast:** How do you evaluate the DTCM in relation to the definition of the next steps to be taken to improve the design thinking implementation?

( ) Very satisfactory
( ) Satisfactory
( ) Needs Improvement
( ) Unsatisfactory
Comments, suggestions, critics:

10. Would you be interested in using the Design Thinking Capability Model to identify the design thinking capability profile of other teams/projects?

o Yes

o No

o Maybe

If yes, please enter email details: _____

Do you have other general comments about the Design Thinking Capability Model (DTCM) and its application at the company?

APPENDIX D – List of publications

1. (2019) de Paula, D., Dobrigkeit F, Cormican, K. Doing it right - critical success factors for design thinking implementation. 22nd International Conference on Engineering Design (ICED19). Delft, The Netherlands, 5th - 8th August 2019.

2. (2018) de Paula, D., Dobrigkeit, F. and Cormican, K. From team collaboration to product success-the domino effect of design thinking. DS 91: Proceedings of NordDesign 2018, Linköping, Sweden, 14th-17th August 2018.

3. (2018) de Paula, D., Dobrigkeit F, Cormican, K. Design thinking capability model (DTCM): a framework to map out design thinking capacity in business organisations. In Proceedings of 15th International Design Conference, Vol. II, pp. 557-566.

4. (2017) de Paula, D., Menning, A., Ewald, B., Cormican, K. “The beginning of a new era: using design thinking to identify dimensions for product assessment”. In Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol.7: Design Theory and Research Methodology, Vancouver, Canada, 21st - 25th August 2017, pp. 131 - 140.

5. (2016) Paula, D., and K. Cormican. "Understanding design thinking in design studies (2006-2015): a systematic mapping study." DS 84: Proceedings of the DESIGN 2016 14th International Design Conference. 2016.