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Entrepreneurial Teams and Design Thinking:

A Longitudinal Evaluation of Success Factors

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Abstract

Design continuously re-defines its meaning. Over the last years, the way designers interpret information, solve problems as well as prototype and express ideas has received increased attention from domains outside of traditional design, especially from the business world. However, much of the design thinking discourse outside of traditional design centres around a few widely-read practitioner books and only builds on a rudimentary understanding of its principles. Likewise, the academic literature only offers a few rigorous investigations of the application of design thinking in the management and innovation domain, especially when it comes to the development of novice multidisciplinary teams.

Therefore, this thesis provides an evaluation of the influence of the following five key themes discussed in the design thinking literature: Team diversity, iteration, learning styles, creative confidence, and team communication. These themes were explored during a quantitative quasi-experimental research study, which was built on a novel research framework. Data was collected from 42 German research participants over a period of 10 month. The longitudinal perspective enabled the researcher to illustrate how novices develop design thinking competencies in projects over time.

While investigating team diversity, multidisciplinary teams were found to produce significantly better project outcomes than single-discipline teams. On the other hand, diversity of personality traits was not found to have a significant effect on the final performance of teams. The exploration of iteration behaviour revealed that multidisciplinary teams did not iterate significantly more than single-discipline teams. In addition, more experienced participants approached design thinking projects slightly less iteratively than novices. Overall, the degree of iteration was not found to have a significant effect on the final team performance. Regarding the use of different learning styles, it was discovered that, teams with a balance of learning styles achieved significantly better project outcomes than less-balanced teams. In terms of learning styles, participants approached design thinking tasks mainly

through rational conceptualisation rather than concrete experience. The analysis of individual and team confidence showed that creative confidence developed slowly and linearly over the course of a project, but only partly carried over to new project and team settings. Furthermore, no evidence was found that higher levels of creative confidence directly influenced the quality of the project outcomes. The investigation of team communication revealed that the importance of individuals in design thinking teams significantly changed over the course of a project. Contrary to previous assumptions, high degrees of internal team cohesion were found to have a significant negative effect on project outcomes.

While several of these findings clarify and reiterate existing design thinking theory, others call for an adjustment of theory and highlight the need for more rigorous research. Several recommendations are offered for practitioners, educators, and researchers on how to incorporate the presented findings into practice and future research.

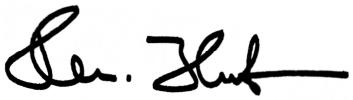
Declaration

I hereby declare that this thesis, submitted in partial fulfilment of the requirements of Edinburgh Napier University, for the degree of Doctor of Philosophy, represents my own work and has not been previously submitted to this or any other institution for any degree.

All verbatim quotes have been marked within the text. All sources have been acknowledged and are included in the list of references.

Some of the research related to this thesis has been presented at conferences and published in academic journals during the process of completing this thesis.

Edinburgh, April 2017



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Abbreviations

APE	Academic Program for Entrepreneurship
APE_n	APE novice sample (main sample 1)
APE_e	APE experienced sample (main sample 2)
BA	Business administration course 131b (student control sample)
CAT	Consensual Assessment Technique
ELT	Experiential Learning Theory
IPIP	International Personality Item Pool
LSI	Learning Style Inventory
MUAS	Munich University of Applied Sciences
NPD	New Product Development
SCE	Strascheg Center for Entrepreneurship
SPSS	Statistical Package for the Social Sciences

1. Introduction

1.1. Chapter Introduction

This introductory chapter situates this thesis in the wider context of innovation management. In this chapter, the author argues that due to the increasing complexity of current business environments, organisations seek to cultivate dynamic innovation capabilities to increase their competitive advantage. In this pursuit, several prominent organisations have turned towards utilising principles, frameworks, and tools from the discipline of design, a movement which is often summarised as *design thinking*. However, many organisations still struggle with fully grasping and implementing design thinking in ways which add value to their activities, especially when it's implementation is facilitated through multidisciplinary teams with little prior experience in this innovation methodology. Towards the end of this chapter, aims and objectives for an extensive research study are therefore laid out, before providing an overview of the thesis structure.

1.2. Increasing Business Complexity

> *"Let's face it: the evidence before us is that our world is not going to get any less complicated or volatile. As a result, organizations have to be more adaptable and more resilient than ever before. As today's leading companies have shown, the key components of adaption and resiliency are innovation, creativity, and design." (Brown, 2013, p. 165)*

Organisations are continuously faced with rapidly changing environments (Ireland & Webb, 2007). The complexity and volatility of the business world is likely to increase further in the future (Brown, 2009, 2013). In addition to this, product lifecycles have drastically declined over the last decades (Assink, 2006) and most of the existing products and services on the market are highly complex systems (Brown, 2009, 2013). Organisations therefore have to continuously strive to develop innovation capabilities which allow them to

dynamically react to changing market conditions and develop a sustainable competitive advantage.

1.3. Dynamic Innovation Capabilities as a Competitive Advantage

Innovation capabilities are considered to be the primary coping mechanism for organisations dealing with the increased complexity of products, processes, systems and markets (Francis & Bessant, 2005; Lawson & Samson, 2001; Lewrick et al., 2007; Teece et al., 1997). The capacity of an organisation to quickly produce, assimilate, and explore successful innovation is a major source of competitive advantage (Alves et al., 2006; Francis & Bessant, 2005). To foster innovation capabilities, firms need to adapt, integrate and reconfigure their organisational skills, resources, functional competencies, and business models on a continuous basis (Assink, 2006; O'Reilly & Tushman, 2008; O Reilly & Tushman, 2004; Teece, 2010). However, only a few organisations have figured out what it takes to continually and successfully innovate (Christensen, 1997; Christensen & Raynor, 2003; O'Connor, 2008; O'Reilly & Tushman, 2008).

Established organisations face the dilemma of having to engage in two contradictory modes of innovation simultaneously (Christensen, 1997; Christensen & Raynor, 2003; Smith & Tushman, 2005). On the one hand, firms need to exploit their available structural and cultural mechanisms to stay competitive in the short run (Ireland & Webb, 2007). Through such evolutionary development and incremental innovation, firms seek to maintain their existing competitive advantage and market position (Tushman & O'Reilly, 1996). On the other hand, firms need to explore new ways of positioning themselves and identify novel mechanisms to deal with continuous environmental change (Ireland & Webb, 2007). According to Tushman and O'Reilly (1996) as well as O'Connor (2008), this revolutionary and disruptive form of innovation allows organisations to reap high returns and ensures their relevance in the long run. These two different modes of “exploitation” and “exploration” require fundamentally different organisational architectures (Smith & Tushman, 2005). According to Martin (2005, 2009), younger firms, such as start-ups, are more often associated with the

“exploration” mode of innovation, whereas established organisations are more often associated with the “exploitation” mode of innovation. As both modes of innovation are needed for short-term and long-term success, organisations strive to develop organisational ambidexterity to allow them to operate both exploitation and exploration activities simultaneously (Francis & Bessant, 2005; O'Reilly & Tushman, 2008; O Reilly & Tushman, 2004; Tushman & O'Reilly, 1996).

However, many established organisations fail at creating disruptive innovation through exploration and therefore tend to focus on incremental innovation through exploitation (Assink, 2006; Christensen, 1997; Christensen & Raynor, 2003; Tushman & O'Reilly, 1996). This increases their risk of being overtaken by younger entrepreneurial companies (Christensen, 1997; Christensen & Raynor, 2003). According to Börjesson and Elmquist (2011) as well as O'Connor (2008), existing organisational structures of larger firms seldom provide good conditions for creating change. These firms have often developed structural and cultural inertia, which hinders exploration activities (Tushman & O'Reilly, 1996). These activities are also often inhibited by an inability to unlearn obsolete mental models, the fixation on dominant business concepts, a risk-averse climate, and the mismanagement of innovation processes (Assink, 2006). To successfully implement exploration activities within a larger firm, awareness for the need to change needs to exist on a systems-level (Börjesson & Elmquist, 2011).

1.4. Organisations Turn towards Design Thinking

Stewart (2011) illustrates that over the last two centuries, the focus of design has shifted from designing material things to more immaterial things such as systems and organisations. According to Cruickshank and Evans (2012) as well as Kolko (2015), this led to design being given a more global and strategic role. Several authors have therefore proposed that design should also play a more crucial role in business and management practice as well as education (Boland & Collopy, 2004; Fraser, 2010; Glen et al., 2015; Liedtka & Mintzberg, 2006; Liedtka & Ogilvie, 2011; Martin, 2004, 2009; Tynan et al., 2016 forthcoming). Through an effective integration of design practices,

companies can improve their innovation capabilities, open up new opportunities, and evolve their business models to better seize market opportunities (Carlgren et al., 2014; Cruickshank & Evans, 2012; Fraser, 2010; Gruber et al., 2015). Growth is increasingly driven by imagination and creativity, rather than scale-intensive activities (Kelley & Kelley, 2013; Martin, 2004). Fostering organisational creativity has thus become a priority for many established firms (Alves et al., 2006). As a result, Martin (2009) boldly declared organisational design capabilities to be “the next competitive advantage”.

Since its conception as a distinct methodology, design thinking has received increased attention, especially from the business world (Brown, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Martin, 2004, 2009; Rauth et al., 2015). Many authors agree that a universal definition of what design thinking is, does not exist (Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Rodgers, 2013; von Thienen et al., 2011). Design thinking rather has various context-specific meanings (Johansson-Sköldberg et al., 2013) and can be defined in several ways, as will be presented later in Section 2.2. In general, design thinking can be described as a multidisciplinary team-based approach to innovation, which includes various analytic and creative tools and principles from the “designer’s toolkit”. Its goal is to solve ill-defined and wicked problems. Specific attitudes and behaviours guide its practice and develop the creative confidence of its practitioners. Formalised process models of design thinking provide structure for the various connected activities of design thinking.

The way designers solve problems adds value to a wide range of organisational contexts (Kimbell, 2011). As a holistic approach, it helps organisations to encourage innovation and growth (Liedtka & Ogilvie, 2011). Much of the existing management theory focuses on stable and predictive situations where inferences are drawn from the past to make predictions and recommendations for the future (Martin, 2004, 2009). As markets and organisations become ever more complex, these approaches seem ill-equipped to handle the ambiguous, open-ended, ill-defined, and wicked

problems of today (Dorst, 2011; Glen et al., 2015; Hobday et al., 2012; Liedtka & Ogilvie, 2011; Liedtka & Parmar, 2012; Stewart, 2011). In contrast, the iterative nature of the design process, where problems and potential solutions are constantly framed and re-framed, offers an alternative path to developing solutions to such problems (Brown, 2008, 2009; Dorst, 2011; Gruber et al., 2015; Kolko, 2013). During this process, abductive logic provides a way to envision novel concepts beyond incremental improvements of existing solutions by focussing on the question of "What might be?" (Collins, 2013; Dorst, 2011; Leavy, 2010; Liedtka, 2000, 2015; Scott et al., 2016; Tynan et al., 2016 forthcoming). Analytic tools and frameworks are combined with intuition (Martin, 2009; Suri, 2008; Suri & Hendrix, 2010). In this regard, design thinking has proven itself useful for approaching ambiguous, open-ended and ill-defined problems, where strictly analytical approaches have failed (Collins, 2013).

Design thinking is human-centred (or customer-centred) in nature (Brown, 2008, 2009; Glen et al., 2015; Grots & Pratschke, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Liedtka & Ogilvie, 2011; Rodgers, 2013; Tynan et al., 2016 forthcoming; von Thienen et al., 2011). Its' clear focus on constantly uncovering latent user needs provides organisations with a way to increase their innovativeness around new products and services whilst also allowing them to differentiate themselves from their competitors (Wattanasupackoke, 2012); a factor, which is critical to superior market performance (Venkatesh et al., 2012). Design thinking also allows managers to improve their strategic decision making processes by mitigating common cognitive flaws such as projecting your own views onto others, reducing options early on and ignoring disconfirming data (Liedtka, 2015). Including this human-centred component into innovation strategies is not just applicable for consumer products. Keinz and Prügl (2010) have shown that such strategies also yield benefits for innovation through technology commercialisation.

In the literature, design thinking is often described as a multidisciplinary team-based approach to innovation. As West (2002, 2003) notes, the

importance of teams when it comes to creative work in organisations is increasing. Only rarely do creative processes result from individual effort (Alves et al., 2006). Including multiple perspectives from various disciplines in the problem-solving approach increases the likelihood of success (Alves et al., 2006; Brown, 2009; Fischer, 2000; Kelley & Kelley, 2013; Kelley & Littman, 2006; Lojacono & Zaccai, 2004; von Thienen et al., 2011). Allowing non-designers to participate in the design process allows organisations to solve more complex problems (Lloyd, 2012). For managers, this is a chance to more actively engage in the design process to create innovation and growth (Liedtka, 2011). Practicing this approach together allows teams to create learning spaces where ideas can be critically contested without stigmatising failure (Welsh & Dehler, 2012).

Design thinking also provides a way to create a mindset of innovation within a company. This includes fostering radical collaboration, finding inspiration from a broad variety of sources, sharing insights and knowledge across the organisation in an accessible way and exploring as well as testing options and ideas early on to clarify underlying assumptions (Simons et al., 2011). It adds experimentation to the activities of managers and better equips them to deal with uncertainty (Gerber & Carroll, 2012; Liedtka, 2010). Design thinking enables its practitioners to reframe problems, which are traditionally seen as constraints, into new opportunities for innovation (Boland & Collopy, 2004; Dunne & Martin, 2006). For managers, this provides a practical approach to become more hypothesis-driven and forward-looking (Liedtka & Parmar, 2012), which in turn improves strategic decision making and reduces cognitive biases (Liedtka, 2015).

Many leading companies have already implemented design thinking for various purposes within their organisation. For example, the multinational consumer goods company Proctor & Gamble uses design thinking to better align their individual products to different global markets and to tailor these products to current user needs (Carlgren et al., 2014; Carlgren et al., 2016; Martin, 2004). Indra Nooyi, the current CEO of PepsiCo, employs design thinking to drive the transformation of her organisation towards an innovation

culture focused on the customer. This allows PepsiCo to bring products to market faster and rely on iterations for small course-corrections (Nooyi & Ignatius, 2015). General Electric is using design thinking to facilitate their shift from focusing on physical products to becoming one of the largest software providers in the world (Kolko, 2015). At Panasonic, principles of design thinking are incorporated in the new product development practice to identify and evaluate far-distant innovation projects (Carlgren et al., 2014; Carlgren et al., 2016). With the goal of getting the 90 % of US residents who did not ride bicycles to do so, Shimano built several new product lines, based on their research and experience gained through design thinking projects (Brown, 2008). At the Bank of America, design thinking was used to develop a banking experience which helps customers save up small amounts of money in a way that is engaging and fun; attracting more than 2.5m new customers in the process (Brown, 2008). Kaiser Permanente, a global healthcare provider, applies design thinking to create and test a portfolio of new product, service and system innovations (Brown, 2008; Carlgren et al., 2014; Carlgren et al., 2016; McCreary, 2010). Similarly, Pfizer, the multinational pharmaceutical company, is experimenting with this approach to closely tailor several consumer health products to identified customer needs (Liedtka, 2011; Liedtka & Ogilvie, 2011).

With a new-found focus on design, IBM is using design thinking to overhaul their client centres and retrain their sales staff to be more client-focused (Clark & Smith, 2008; Kolko, 2015). AT SAP, the German multinational software corporation, design thinking forms part of the core philosophy and helps the SAP teams to develop rapid prototypes to better communicate product ideas and go-to-market strategies (Holloway, 2009). In cooperation with the University of St. Gallen, the IT department of Deutsche Bank is embracing design thinking to develop new B2B and B2C solutions in an effort to make banking more accessible (Carlgren et al., 2014; Carlgren et al., 2016; Vetterli et al., 2011; Vetterli et al., 2016). The company 3M, which is known for their track record of continuous innovation, is constantly trying to leverage their new and existing technologies as well as their brand towards new market offerings. Through a design thinking approach, they were better

able to build meaningful solutions which fulfil user expectations and further enable 3M's growth (Porcini, 2009). The professional services firm Deloitte has committed to implementing design thinking throughout their organisation to create better outcomes for internal and external stakeholders by making it part of their company culture (Howard, 2012). At Hewlett-Packard, a design thinking approach is being used to create a focus on the user experience within the organisation and modify their organisational change and development methods (Sato et al., 2010).

In the public sector, design thinking was leveraged by the UK Government to rethink its public services and create the internationally lauded gov.uk website (Gruber et al., 2015). Another interesting case is presented by the U.S. Department of Veteran Affairs. They have used a design thinking approach to better tailor their service to the needs of veterans and to clear up some preconceived notions about their services (U.S. Department of Veterans Affairs, 2014). As Brown and Wyatt (2010) argue, design thinking is also a great framework to foster social innovation and entrepreneurship. At the Bill & Melinda Gates foundation, the approach is actively used in several ongoing projects. For example, design thinking was used to create a better understanding of the current needs of women in developing countries so that initiatives could be created to give them a clear voice and enable them to shape their own future (Gates, 2015). In rural India, the approach was used to improve access to clean drinking water, which still is one of the biggest health concerns in rural areas of developing countries (Brown & Wyatt, 2010). Howlett (2014) even suggests design thinking as a fruitful strategy to tackle major public policy issues, as the approach has proven itself as a good way to bring together many different stakeholders.

1.5. Organisations Struggle to Implement Design Thinking

Despite the presented benefits of implementing design thinking within an organisation and the growing list of companies which report early successes in employing this methodology, design thinking still remains poorly understood and under-researched in the business context (Carlgren et al., 2014; Dinar et al., 2015; Hobday et al., 2011; Johansson-Sköldberg et al.,

2013; Kimbell, 2011; Liedtka, 2015). In this domain, rigorous scholarly contributions which could support the practical development of design thinking remain rare, as Razzouk and Shute (2012), Carlgren et al. (2014) as well as Dinar et al. (2015) point out.

Many organisations still struggle with the implementation of design thinking at various levels (Lindberg et al., 2011). Adding design orientation to an established organisation often conflicts with the process-oriented approaches they inherited from the industrial era (Conklin & Christensen, 2009). These linear decision-making processes are oftentimes a result of existing pyramid models of management which are common within larger organisations (Pacanowsky, 1996). As Golsby-Smith (2007, p. 22) describes, mature organisations tend to “exist at the delivery of the thinking life cycle, not at the discovery end”. The author further explains that for a mature organisation, efficiency becomes the overriding goal, whereas discovering alternative possibilities declines in importance. In contrast, innovation approaches such as design thinking focus on the ability to move beyond such “limited frameworks of business-as-usual” to find new opportunities and problems to solve (Conklin & Christensen, 2009, p. 20).

As Venkatesh et al. (2012) point out, for design orientation to add value to an organisation, it needs to be embraced throughout a company and cannot be left as a marginalised function. The more radical the design orientation is pursued, the more each member of an organisation needs to buy into such a new organisational setup (Choi & Moon, 2013). This continuous change process is a collective effort and requires the participation of all involved stakeholders within the organisation (Holloway, 2009). In such a setup, it needs to be clearly defined that design is “owned” by many different stakeholders, not just by the traditional design functions within an organisation (Carr et al., 2010).

Organisations especially struggle with the implementation of design thinking at the team level. The performance of innovation teams is highly dependent on the structure and rules put in place by an organisation (Alves et al., 2006). Design and innovation teams should generally be organised as dynamic

project teams, not as static entities (Brown, 2009; Kelley & Littman, 2006; Martin, 2005). In design thinking, many interconnected smaller teams are generally favoured over one large team (Brown, 2009). This contradicts how larger organisations are traditionally organised (Pacanowsky, 1996). From a series of interviews with experts from international IT companies, Lindberg et al. (2011) conclude that for employees reporting to more senior managers within a company, design thinking may be perceived as a risk due to its open and unstructured approach. These employees rather prefer more convergent and therefore more structured and goal-oriented innovation methods, even if this means that they will achieve less innovative solutions to existing problems. At SAP, such behaviour is minimised by making both junior and senior managers part of a commissioned project, including the field research. This allows for the cultivation of a shared understanding of design thinking across different hierarchical levels (Holloway, 2009).

For design thinking to work within an organisation, design methods as well as creative confidence and design sensibilities (see Section 2.2.7) need to be developed at an individual level. In the long run, this will allow an organisation to (re-)focus their innovation efforts and create clear differentiation from their competitors (Suri & Hendrix, 2010). Whereas traditional management thinking views organisational and market constraints as undesirable barriers, employees trained in design thinking will be more likely to see such constraints as opportunities for new creative solutions (Boland & Collopy, 2004; Dunne & Martin, 2006). They will favour developing insights through fast and cheap experiments as well as market tests (Skogstad & Leifer, 2011). This allows employees to overcome design fixation, where new radical ideas stay undiscovered due to mental “blind spots” and an over-fixation on proven practices (Viswanathan & Linsey, 2012). The outcome of such experiments cannot be accurately predicted (Skogstad & Leifer, 2011). Failure during these experimental phases is seen as an opportunity to learn and not as personal defeat (Brown, 2009; Kelley & Kelley, 2013). Many of these approaches are contrary to the analytic and rational decision making processes managers are generally being trained in (Suri & Hendrix, 2010). They are also contrary to how firms traditionally

measure success in hierarchical status and assigned budgets (Martin, 2005). Managers seek predictability and fear resource waste (Skogstad & Leifer, 2011). Relying on design sensibilities and design methods often feels uncomfortable to them, which may lead managers to discount the benefit design thinking can add to their organisation (Suri & Hendrix, 2010).

Many of the aforementioned organisations focus on developing design thinking capabilities in addition to already existing innovation approaches and practices. Most often, this means that if design thinking is introduced in an organisation, it will be existing employees who are confronted with this approach for the first time. These design thinking novices will be required to rationalise and unify this novel approach with existing practices and routines.

1.6. Aims and Objectives

The aim of this thesis is to understand and improve the education process for design thinking novices working in multidisciplinary teams.

To achieve this aim, a number of research objectives have been formulated to guide the research project. This thesis seeks to achieve the following objectives:

- Critically synthesise the current literature on design thinking and relevant connected areas of interest to shed light on under-researched themes in design thinking theory
- Critically identify research variables from key research themes which can be developed into testable hypotheses
- Devise quantitative measurement strategies and instruments for conducting longitudinal research on design thinking teams
- Collect an original longitudinal dataset from an appropriate population which allows the researcher to study the development process from novice to experienced design thinker
- Validate findings and conclusions drawn from the quantitative study
- Develop recommendations for design thinking practitioners and educators, as well as for researchers who intend to conduct further robust research

on the development of design thinking novices as well as multidisciplinary design thinking teams

Fulfilling this aim and these objectives will allow the author to add to the existing body of knowledge about design thinking and provide a substantial contribution to knowledge as highlighted when we revisit these in the final chapter of this thesis.

1.7. Research Philosophy, Methodology, and Limitations

The empirical study, which forms parts of this thesis, was built on the realist ontological worldview and the post-positivist stance of the researcher (see Section 3.2). These positions influenced both the research methodology as well as the specific research instruments developed and used within this study.

The quantitative study, described in later chapters, was designed as a longitudinal exploration of design thinking teams. Data was collected via various research instruments, such as weekly status surveys, communication behaviour surveys as well as personality traits inventories from October 2013 to July 2014. Over 11,700 individual data points were collected during this period.

The research process was guided by five research themes which were developed based on a thorough review of the current literature on design thinking (i.e. using design practice and competences beyond the traditional design context) and *designerly* thinking (i.e. how professional designers practice design). Variables and metrics, based on the research themes, were operationalised and used to test 13 hypotheses.

This empirical study specifically looked at design thinking teams as the unit of analysis. The main sample was comprised of 25 students and young professionals who were part of the 2013/2014 cohort of the Academic Program for Entrepreneurship (APE) – a multidisciplinary design thinking and entrepreneurship education programme in Munich. This programme is one of the leading entrepreneurship programmes in Germany and has produced

many successful entrepreneurs who have co-founded companies such as Freeletics and ProGlove, which were both ranked among the top 25 start-ups of 2015 (Horizont, 2015), as well as nearBees and Querfeld, which were both nominated for multiple social entrepreneurship awards. The longitudinal research design allowed the researcher to compare and contrast novice and experienced multidisciplinary design thinking teams. A second sample of business administration students formed a single-discipline control group for some of the statistical tests.

Semi-structured validation interviews were conducted with study participants and external professionals to strengthen the conclusions drawn from the quantitative data analysis and extend the presented theoretical arguments.

1.8. Thesis Structure

As the first chapter of this thesis, the previous introduction started out by highlighting the need for organisations to continuously innovate due to constantly changing market environments and rising organisational complexity. Organisations need to balance exploration and exploitation activities and develop dynamic innovation capabilities to secure a competitive advantage. In this quest, several organisations have already turned to the innovation methodology of design thinking, with many more organisations expected to follow. Although design thinking is a very accessible innovation methodology, many organisations still struggle with its implementation. Further research is warranted to demonstrate the usefulness of design thinking, develop potential areas of application and also identify potential domains and use cases, where design thinking does not add value to an organisation.

In the following Chapter 2, a thorough review of the current literature on design thinking is provided. Rather than committing to one of the several available definitions of design thinking, it is the author's intention to provide several perspectives through which design thinking can be critically conceptualised. Additional sections on entrepreneurship education, Kolb's learning styles and the Five-Factor Model of personality provide further

theoretical grounding for the empirical part of this thesis. Chapter 2 closes with an overview of five research themes, which pin-point areas of design thinking which warrant further scholarly investigation.

Chapter 3 introduces a critical discussion of the research methodology and methods which form the blueprint of the quantitative longitudinal study of design thinking teams presented later in this thesis. This chapter also contains detailed descriptions of the research context and sampling strategy. Testable research hypotheses are defined based on the previously introduced research themes. Good practices in quantitative research are discussed, before laying out the data collection procedures in detail to allow the reader a deeper interpretation of the findings presented in later chapters.

In Chapter 4, a comprehensive analysis of the collected data is presented. Each research theme is illustrated through the available data. For each research hypothesis, several statistical procedures were used to determine if the proposed alternative hypothesis could be accepted or had to be rejected in favour of the null-hypothesis. A short discussion follows each hypothesis test to critically examine the key findings.

In Chapter 5, 10 follow-up interviews are introduced. These interviews were conducted to validate the interpretation of the findings from the quantitative data analysis. Five interviews were conducted as in-sample validation interviews with study participants. Another five interviews were conducted with subject professionals who were invited to critically comment on the study's findings.

Chapter 6 concludes this thesis by discussing the key findings of this study as well as its limitations and implications on a more holistic level. This chapter also presents recommendations for design thinking practitioners as well as educators and lays out potential directions for future research.

2. Literature Review and Theoretical Development

2.1. Chapter Introduction

The last chapter illustrated how some organisations have started to turn to design thinking as a means to sustain their competitive advantages and foster new innovations. It was highlighted that many organisations still seem to struggle with understanding and implementing design thinking at various levels.

In this chapter, several perspectives are provided on how design thinking can be conceptualised. These perspectives summarise the current literature on design thinking. As the research study described in later chapters is embedded in a university setting with a strong focus on entrepreneurship, a brief discussion of the current state of entrepreneurship education will be had. Furthermore, short sections on Kolb's learning styles (Kolb & Kolb, 2005a; Kolb, 1984) as well as the Five Factor Model of personality (Costa & MacCrae, 1992; John & Srivastava, 2001; Pervin & Cervone, 2010) provide additional theoretical background for the research study. The literature review concludes with the presentation of five research themes. These themes provide the framework for the 13 research hypotheses presented later in Chapter 3.

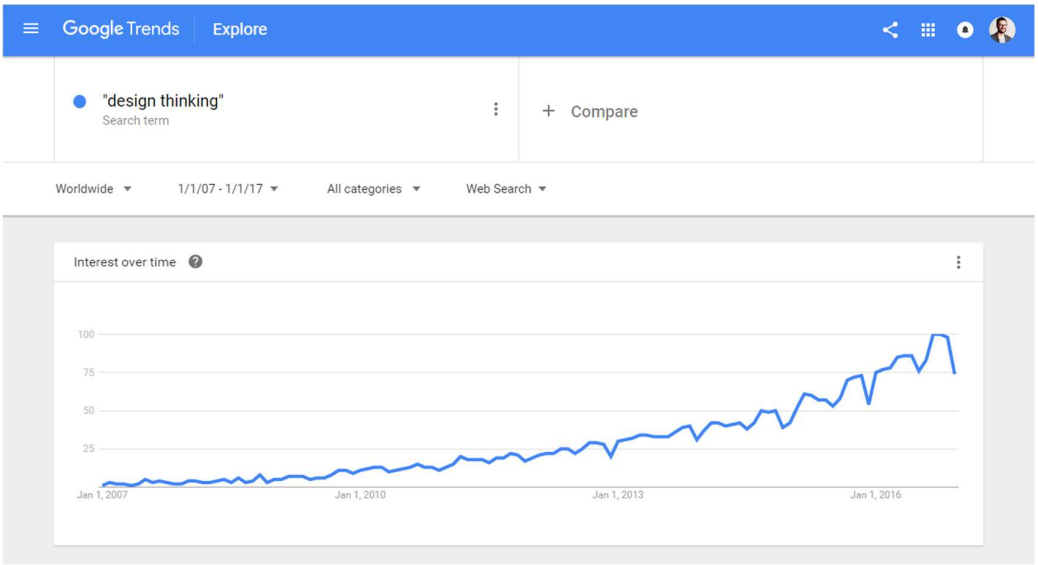
2.2. Design Thinking

Many authors note that the interest in design thinking, especially within the domain of management, has been increasing rapidly within recent years (Hassi & Laakso, 2011; Johansson-Sköldberg et al., 2013; Kelley & Kelley, 2013; Liedtka, 2015; Martin, 2004, 2009; Rauth et al., 2015). This is accompanied by a growing number of publications (Razzouk & Shute, 2012; Stewart, 2011), which mostly date after the year 2000 (Johansson-Sköldberg et al., 2013). Many of the current articles and books are aimed towards practitioners and are intended for a readership outside of the field of traditional design (Liedtka, 2015; Michlewski, 2008). So far, only a few

academic articles in ranked journals exist to supplement the growing interest in design thinking with insights from rigorous research. In their review article of the design thinking literature, Razzouk and Shute (2012) point out that experimental and quasi-experimental studies are almost non-existent.

The growing interest in design thinking also becomes apparent in people's online search behaviour. The Google Trends graphs in Figure 2.1 shows that targeted searches for the term "design thinking" have been growing globally since around 2007.

Figure 2.1: Growing Interest in Design Thinking



This graph shows cumulative online search behaviour for the term "design thinking" on Google Trends (google.com/trends) for the period from January 2007 to December 2016. The graph shows the popularity of the specific search term relative to the highest point in the chart. (Retrieved: 15th December 2016)

2.2.1. Design Thinking Within the Management Domain

Design, as the design of physical objects, is not a recent concept or practice (Cooper et al., 2010). It has been discussed in different areas and contexts for a long time (Liedtka, 2015). As Buchanan (1992) notes, design constantly

re-defines and expands its meaning. Throughout the 19th and 20th century, its focus slowly shifted from designing mainly physical products to include the design of immaterial things, such as organisations and systems (Cassim, 2013; Stewart, 2011). This development also impacted how design is practiced and theorised about today (Cooper et al., 2010).

One of the first books to introduce the value of design to the management domain is *The Science of the Artificial* by Nobel laureate Herbert Simon (1969, revised 1996). In his book, Simon proposes transferring principles and thought patterns from the field of design to the field of management. Simon suggests that this would introduce new strategies for dealing with increasing organisational complexity. In this sense, Simon (1969, revised 1996, p. 109) adopts a very loose definition of what design means:

> *"Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. […] Design, so construed, is the core of all professional training; it is the principal mark that distinguishes the professions from the sciences. Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design."*

During the time of the publication of Simon's book, a separation of the discourse on design had taken place. As several authors note, the discussions of how traditional design creates value and how design might enrich management practice have developed more or less separately from each other (Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015). In their recent article, Johansson-Sköldberg et al. (2013) therefore distinguish between (1) *designerly thinking*, i.e. how professional designers practice design (also see Cross (1982)) and (2) *design thinking*, i.e. using design practice and competences beyond the traditional design context. While acknowledging the comprehensive body of knowledge on designerly thinking, this dissertation is mainly focussed on the still evolving domain of design thinking and the application of design in a wider context, such as entrepreneurship and innovation.

The epicentre for the development of design thinking in the management context has been Silicon Valley, where both the international design consultancy IDEO and Stanford University are located (Gruber et al., 2015). Both institutions played a major part in the development of this innovation methodology. Many of the early sources of the human-centred innovation movement, which developed into the design thinking methodology via several detours, can be traced back to Stanford University. Some of them reach as far back as 1958 (Carleton & Leifer, 2009). For example, the books *Experience in Visual Thinking* by McKim (1972) and *Conceptual Blockbusting* by Adams (1974), both faculty members at Stanford University, exhibit many of the characteristics which are today part of design thinking theory. Both were key readings in the ME310 course offered within the engineering department at Stanford University. ME310, which dates back to 1967, is today often considered one of the origins of the design thinking movement. This course incorporates innovation projects sponsored by external industry partners into its curriculum to create immersive problem-based learning simulations for its students (Carleton & Leifer, 2009).

In 1978, David Kelley, a former graduate student at the engineering department at Stanford University set out to form his own design firm, while continuing to be an adjunct faculty member (Tischler, 2009). Later, his company merged with two other design companies to form the design consultancy IDEO (Tischler, 2009) which has since become one of the most influential design innovation companies worldwide (Nussbaum, 2004). IDEO has continually advanced and popularised design thinking through several books aimed at a business audience (Brown, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006) as well as a variety of articles in the business press (Brown, 2008; Nussbaum, 2004; Tischler, 2009). It was also at IDEO, where the term design *thinking* first emerged. In an interview, Kelley recounts that when IDEO moved from designing mainly products to designing novel solutions for business problems, they realised that the value they added for their multinational corporate clients was less about the actual designs (i.e. objects and services) and more about the thought process of how their designs were created (Tischler, 2009).

With $35m in funding from Hasso Plattner, one of the founders of the German software company SAP, David Kelley and several colleagues founded the Hasso Plattner Institute of Design (HPI) at Stanford in 2005, which is now mostly referred to as the d.school (Tischler, 2009). In 2007, a second HPI institute was established at the University of Potsdam in Germany, the alma mater of Hasso Plattner (Plattner et al., 2011). Both institutions have since contributed significantly towards the popularisation of design thinking through developing structured course curricula, offering workshops and seminars, sharing free teaching materials, and initiating an edited series on design thinking research (Plattner et al., 2011, 2012a, 2012b, 2012c, 2013, 2015, 2016). Other leading universities, such as the University of Toronto have since adopted and further developed the design thinking methodology (Dunne & Martin, 2006; Martin, 2004).

Amongst others, these developments have led to a growing influence of design thinking on the practice and theory of management over the last years (Brown, 2009; Kimbell, 2011, 2012; Martin, 2009). Some authors have even described it as “the best way to be creative and innovative” within the managerial realm (Johansson-Sköldberg et al., 2013, p. 121). The popularity of design thinking has led many organisations towards (re-)labelling existing and new innovation efforts with this term (for examples, see Section 1.4).

However, as many scholars note, design thinking within the business context is still an under-researched area which needs to be further developed (Carlgren et al., 2014; Dinar et al., 2015; Hobday et al., 2011; Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Razzouk & Shute, 2012).

2.2.2. Multiple Perspectives on Design Thinking

Buchanan (1992) explains that due to the fact that design constantly expands and re-defines its meaning, defining what and how design thinking actually is, remains a moving target. Many authors have stated that no universal definition of design thinking has yet emerged (Carlgren et al., 2016; Eppler & Hoffmann, 2012; Hassi & Laakso, 2011; Hobday et al., 2012; Johansson-

Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Rodgers, 2013; von Thienen et al., 2011). Johansson-Sköldberg et al. (2013) as well as Tynan et al. (2016 forthcoming) argue that the term “design thinking” rather has different context-dependant meanings. Tynan et al. (2016 forthcoming, p. 9) phrase their argument as follows:

> *“[A] singular definition of design cannot cover all the dimensions we perceive as design and different interpretations of design demand different perspectives. As such, the nature of design is influenced by contextual variables such as time, values, use of space, language and behavioural expectations.”*

Within the organisational context, design thinking has been theorised about and applied at different levels (Martin, 2013). As Leifer and Steinert (2011, p. 152) have put it, design thinking seems to be a “rather loosely labelled box” which combines different elements and dimensions of design.

In their comprehensive article on the current state of design thinking, Johansson-Sköldberg et al. (2013) differentiate between three streams of discourse relating to design thinking within the management domain, which all stem from different origins. The first stream can be described as “IDEO’s way of working with design and innovation”. As previously described, IDEO is heavily involved in the ongoing development of design thinking. Through a series of popular books about their approach to innovation (Brown, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006) and a number of articles in the business practitioner literature (Brown, 2008; Nussbaum, 2004; Tischler, 2009), IDEO has had great influence on what design thinking means today. The second stream originated at the University of Toronto where Roger Martin, another major proponent of design thinking, is based. He positions design thinking as an effective methodology for tackling indeterminate organisational problems and has frequently proposed design thinking as an essential skill for practicing managers (Dunne & Martin, 2006; Martin, 2004, 2005, 2009). Through the Rotman Magazine, which is edited and published by the Rotman School of Management at the University of Toronto, he has helped to disseminate a large number of practitioner articles

and an edited book (Martin & Christensen, 2013), bringing together many influential authors and scholars from this field. The third stream, identified by Johansson-Sköldberg et al. (2013) positions design thinking as part of management theory. This stream was heavily influenced by a series of workshops on the value of design in management, which brought together many proponents of improving management theory by studying and borrowing from design research. This series of workshops resulted in an extensive book edited by Boland and Collopy (2004).

As this thesis aims to capture the diversity of the current design thinking discourse, the following sections will present multiple perspectives on what design thinking is, rather than committing to only one of the available definitions.

2.2.3. Design Thinking as the Designer's Toolkit

At a very practical level, design thinking is about the application of tools and methods adapted from the practice of design (Cruickshank & Evans, 2012). Framing, for example, may be used to express the direction of a problem-solving approach (Kolko, 2013). Stakeholder maps can be adopted to visualise the connection between different decision influencers (Lojacono & Zaccai, 2004). Ethnographic user research can be employed to discover latent needs of potential users (Brown, 2009; Liedtka, 2011, 2015; Seidel & Fixson, 2013). Personas can be applied to aggregate market data into stereotypical users (Tonkinwise, 2011). Journey maps may help in understanding the use cases of a product or service at different points in time (Liedtka, 2011, 2015). Through a brainstorm session many different alternative solutions may be quickly discovered (Comadena, 1984). Building early rapid prototypes helps to uncover additional requirements of a proposed solution (Brown, 2009). Controlled experiment can be utilised to place small bets in the market and test the potential of a proposed solution (Liedtka & Ogilvie, 2011).

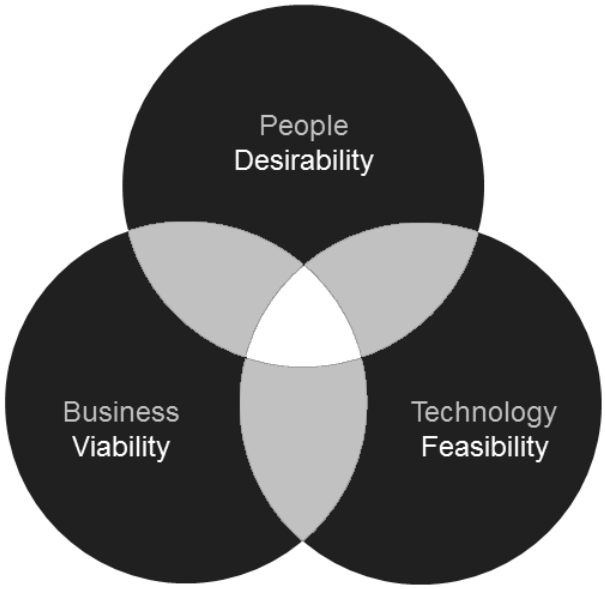
Tim Brown, the current CEO of IDEO, summarises those methods and tools as the "designer's toolkit" (IDEO, 2016). These tools can be used to

approach problems from three different points of view. First, an innovator needs to discover what would be desirable attributes of a solution from a customer point of view. Second, he/she needs to propose solutions which are technologically feasible. Third, the innovator needs to implement and scale the potential solution via a viable business model (Brown, 2009; Grots & Pratschke, 2009; Kelley & Kelley, 2013; Lockwood, 2010b). Brown (IDEO, 2016) therefore put forth the following definition of design thinking on the IDEO company website:

> *"Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success."*

As compelling as this definition is, a word of caution is warranted at this point. As Johansson-Sköldberg et al. (2013) point out, reducing design thinking to just being a "toolkit" would be too reductionist. Practitioners will also need to know when and how to use each tool. This requires extensive training and practice. However, the development and implementation of a toolkit provides an easily accessible first point of contact with several design thinking principles which will be further elaborated below.

Figure 2.2: The Intersection of Desirability, Feasibility, and Viability



This figure is based on Brown (2009, p. 4), Grots and Pratschke (2009, p. 19), Lockwood (2010a, p. xvii) and Kelley and Kelley (2013, p. 19).

2.2.4. Design Thinking as Multidisciplinary Teams

> *"[The] behaviors we want to study do not conform very well with customary disciplinary divisions. Accepting disciplinary concepts creates the polite fib that we are using appropriate frames of references when studying consumers. Evidence exists that we are not." (Zaltman, 1983, p. 1)*

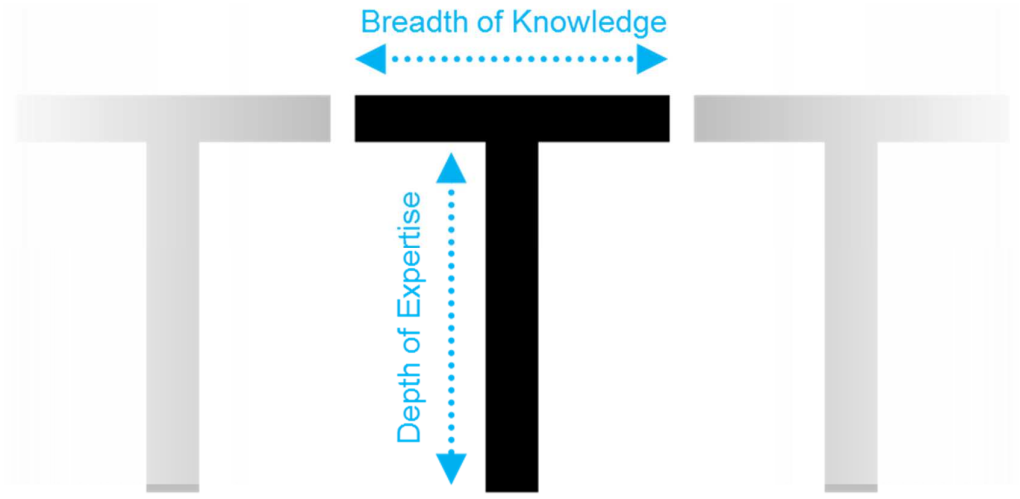
As Brown (2009) explains, the complexity of today's business problems favours a team-based approach over disconnected individuals. That is why teams are at the heart of design thinking (Kelley & Littman, 2006; Lockwood, 2010b). Many authors agree that these teams should be comprised of members who represent multiple disciplines (Alves et al., 2006; Brown, 2008, 2009; Carlgren et al., 2016; Dym et al., 2005; Fischer, 2000; Gruber et al., 2015; Kelley & Kelley, 2013; Kelley & Littman, 2006; Lojacono & Zaccai, 2004; von Thienen et al., 2011). As Fischer (2000) points out, this is especially the case if a team is confronted with ill-defined problems which

require multiple points of view. According to Alves et al. (2006), such multidisciplinary teams benefit from a wider variety of skills and competences. Fischer (2000, p. 527) illustrates that multidisciplinary teams are characterised by “symmetries of ignorance”, which force team members to aggregate their individual points of view into a shared understanding. In turn, this leads to higher levels of overall creativity. Hinsz et al. (1997) also show that when compared to individuals, groups form more reliable decisions due to less variability in their judgment and use external feedback more consistently. Kelley and Kelley (2013) argue that within organisational settings, such multidisciplinary teams are better able to cut through the structural and hierarchical barriers, which allows them a more holistic perspective and also enables them to tailor their ideas to a wider audience within their organisation. Ancona and Caldwell (1992) propose that within organisations a certain level of diversity within an innovation team may also be achieved by mixing different functions (e.g. different departments) and/or tenure-levels (how long one has been with the organisation). The authors explain that functional diversity will lead team members to communicate more effectively across team boundaries, whereas high tenure diversity will result in more communication within the team to clarify team goals and align project priorities.

Some authors in the design thinking literature suggest that innovators should be “T-shaped” (Brown, 2009; Brown & Wyatt, 2010; Design Council, n.d.; Dyer et al., 2011; Thoring & Müller, 2011), a term promoted by McKinsey & Company (Brown, 2009). The term “T-shaped” implies that each team member should have a solid foundation in a discipline (symbolised by the long stem of the letter “T”). Additionally, they should also be interested in other disciplines and try to bridge disciplinary boundaries (as symbolised by the bar of the letter “T” which extends in two directions). This requires passion and an appreciation for self-driven learning (Adams et al., 2011). Within a team, these “multiknowledge” individuals are able to contribute knowledge and insights from multiple domains which also has a positive effect on time efficiency (Park et al., 2009). To be an effective collaborator within multidisciplinary teams also means asking questions that might be

obvious to an expert, challenging assumption, listening to better understand, recognising and accepting differences as well as taking responsibility (Adams et al., 2011).

Figure 2.3: The "T-Shaped" Profile of Design Thinkers



This figure is inspired by Brown (2009, pp. 27-28), Brown and Wyatt (2010, p. 34), Thoring and Müller (2011, p. 138) and Dyer et al. (2011)

However, working in multidisciplinary teams complicates the process of working together (Adams et al., 2011; Fischer, 2000; Kelley & Kelley, 2013). Though, if managed properly, heterogeneous teams tend to outperform homogenous teams (Kayes et al., 2005). Nakui et al. (2011) suggest that heterogeneous teams outperform homogenous teams not by the number of ideas, but rather by the quality of ideas. The researchers have also discovered an intriguing insight about the effect between team diversity and team performance. They argue that the positive effect of team diversity on team performance is actually moderated by the team member's belief that diversity is good for team performance. Therefore, each team member needs to be committed to their multidisciplinary team setting and be willing to collaborate constructively with other team members (Welsh & Dehler, 2012).

Gilson and Shalley (2004) as well as Thatcher and Brown (2010) discovered a similar effect relating to the overall level of creativity within a team. They reveal that if a team thinks their current task requires high levels of creativity, the team will be more likely to show high levels of creativity. High levels of creativity are in turn partly enabled by the constructive disagreement between team members of multidisciplinary teams, which likely provokes further analysis of proposed ideas and overall leads to a deeper understanding than in single-discipline teams (Stempfle & Badke-Schaub, 2002). Another important factor in determining the performance of a team is the environment it is working in (Alves et al., 2006). Within organisational settings, Ancona and Caldwell (1992) find that team diversity may actually impede team performance. The researchers explain that the positive effects of team diversity are often mitigated by external political pressure and reward systems common in large organisations. In this context, multidisciplinary teams will only perform well, if they possess the necessary interpersonal skills for collaboration, such as negotiation as well as conflict resolution skills. The researchers explain that teams need to be given the necessary freedom to develop their own strategies for working together, e.g. by judging the team's performance on the overall output, not the process of how they get there. Many authors agree that overall, the performance of a multidisciplinary team strongly depends on the team's ability to create a shared understanding about the goals and tasks they are facing (Badke-Schaub et al., 2010; Fischer, 2000; Gilson & Shalley, 2004; Kleinsmann et al., 2010; Welsh & Dehler, 2012).

Putting the right people together to form a functioning team is not an easy task. As Kelley and Kelley (2013, p. 83) indicate, "[t]here is an art to putting teams together." Multidisciplinary teamwork needs to be "orchestrated" through actively connecting the different disciplines (Adams et al., 2011). According to Ancona and Caldwell (1992), simply forming a team with diverse individuals does not result in better performance. They argue that teams need to explicitly agree on the process of how to achieve objectives and find ways to deal with the negative aspects of multidisciplinary teamwork, such as miscommunication and the lack of a shared mental model. If a team

is put together to perform a certain task, the problem-solving approach of each member needs to be appropriate for that situation, otherwise the performance will suffer (Eisentraut, 1999). Based on their experience in coaching multidisciplinary innovation teams, Beckman and Barry (2007) as well as Beckman and Speer (2006) suggest that good groups will rotate the leadership positions within the team based on each team member's skill-set. If a certain skill or character attribute is beneficial to the team's performance at one point, it does not necessarily have to be beneficial throughout the other phases of a project. Hinsz et al. (1997) describe that which formal roles are assigned within a team also influences what is being discussed. Such a dynamic team leadership will result in a certain level of political behaviour among the individual team members (Dayan et al., 2012). Political behaviour in this regard includes negotiating, bargaining, and seeking power within the group. Interestingly, for their sample of 103 Turkish new product development teams Dayan et al. (2012) report a positive correlation between higher levels of political behaviour in a team with faster speed to market for created products. Hinsz et al. (1997) explain that if groups are highly diverse, negotiation or consensus groups are often formed, so that each individual's perspective is represented. This behaviour in turn, influences how teams process available information. Woolley et al. (2010) argue that functioning teams form a collective intelligence which partly explains a group's performance. The authors find that this collective intelligence is strongly correlated with the average social sensitivity of group members, the equality in the distribution of conversational turn-taking, and the proportion of females within a group. The authors also find that collective intelligence is only weakly correlated with the maximum individual intelligence of group members.

In her study of 329 work groups operating in different for-profit and non-profit organisations, Wheelan (2009) discovered that group size is a significant factor for both group development and overall productivity. She concludes that groups containing three to six members will reach higher group productivity than larger groups. Brown (2009) argues that, within organisational settings, multiple networked smaller teams should be favoured over one large team. In such a network of small team, informal

communication is crucial (Kratzer et al., 2008). From a network perspective this results in many more links between individual members of the different teams than formally defined by the organisation (Kratzer et al., 2008). These connections expand the resources available to each small team and increase the overall social capital of the team, which results in greater group effectiveness (Oh et al., 2006).

Hinsz et al. (1997) show that when a team is faced with restrictive deadlines, it will prioritise task completion. Gersick (1995) describes that in such cases, teams will tend to pace themselves and the work they have to do, almost like “track runners”. Chong et al. (2011) summarise that past research on new product development teams and time pressure shows, that both low and high levels of time pressure hinder performance. The authors explain that there appears to be a “sweet spot” of just enough pressure to push the project ahead, but also not to stifle team work with deadlines which are too tight. As Ashton et al. (2000) point out, this negative effect of too little or too much time pressure is partially mediated by team coordination. The authors further elaborate that good team coordination is fostered by collective team identification of all team members. In the case of student design teams, Gruenther et al. (2009) find that students with prior industry experience are better able to manage relative time allotments than students without prior industry experience.

Zárraga and Bonache (2005) describe that a good team atmosphere is important for team performance. The authors explain that a “high care” atmosphere positively impacts both the creation and transfer of knowledge within a team. Design thinking allows for all ideas to be contested. This creates a learning environment where critical comments are welcomed and not stigmatised (Welsh & Dehler, 2012). On a meta-level, teams also need a conversational space, where they can learn from their experiences by reflecting as a group (Kayes et al., 2005). In their in-depth study of three design teams, Stempfle and Badke-Schaub (2002) observe that effective teams spend about 2/3 of their time on the actual project work (content) and about 1/3 on the team process (reflecting their methods). The authors explain

that effective heterogeneous groups will use these discussions to create a shared mental model. According to Stempfle and Badke-Schaub (2002) these discussions lead to a deeper thought process, provoke further questions and overall improve output quality. Seidel and Fixson (2013) note that how much a team should reflect on its activities varies across a project. In their study of novice and experienced multidisciplinary product development teams, increased team reflexivity was positively associated with better project performance during concept generation, but negatively associated during concept selection. Teams should therefore transition between more and less reflexive ways of teamwork.

Janis (1982), Kayes et al. (2005), Rose (2011), and Riccobono et al. (2015) argue that one of the major pitfalls of working in highly connected teams is groupthink. According to Turner et al. (1992), groupthink can be categorised by two groups of symptoms. The first group includes the illusion of invulnerability, collective rationalisation, stereotypes of outgroups, self-censorship, mind guards, and an inherent belief in the morality of the team. Following the description by Turner et al. (1992), the second group of symptoms is usually associated with defective decision-making in teams and includes, incomplete surveys of alternatives and objectives, poor information search, failure to appraise the risk of preferred solutions, and selective information processing. Both Janis (1982) as well as Turner et al. (1992) state that the most common reason for engaging in groupthink within a team is the desire of individuals to maintain a positive view of the functioning of the group. Riccobono et al. (2015) describe that the negative effects of groupthink can be counterbalanced by high levels of perceived control and conscientiousness as well as continuous interpersonal evaluation. While Riccobono et al. (2015) claim that over-confidence in team members with previous relationships enhances the negative effect of groupthink, Hogg and Hains (1998) report that friendship is weakly negatively related to the symptoms of groupthink and actually improves the subjective and objective decision-making procedures within a team. Packer (2009) illustrates that team members who identify strongly with a group are more likely to voice dissenting opinions if they perceive an issue as collectively harmful.

Hogg and Hains (1998) highlight high team cohesion as one of the principle antecedents of groupthink. According to Hülsheger et al. (2009), team cohesion is one of the most widely studied team characteristics. Zenk et al. (2010) describe that communication networks and patterns, which influence team cohesion, emerge over time and affect the performance of new product development teams. In contrast to the potential negative effects of high team cohesion and groupthink, Hülsheger et al. (2009) list team cohesion as one of the preconditions to innovative work and explain that high cohesion within a team leads to more explorative behaviour. Liang et al. (2015) have discovered that high team cohesion and team cooperation also positively influence team helping behaviour. Hülsheger et al. (2009) report that team communication, enabled by team cohesion, permits a team to share knowledge as well as ideas and allows the team to benefit from individual past experiences.

Hülsheger et al. (2009) argue that communication with external partners, beyond the boundaries of an individual team, are especially beneficial for innovation. According to Tynan et al. (2016 forthcoming), interactions with networks outside of one's own team play an important role in developing and shaping ideas into new opportunities. In social network theory, the cohesive power of weak ties between individuals and groups are often discussed. For example, Granovetter (1973) has argued that these small-scale interactions often develop into large-scale patterns. Tynan et al. (2016 forthcoming) explain that for entrepreneurs, weak ties in the form of casual acquaintances often offer unique, idiosyncratic and sometimes unrelated pieces of information which foster the recognition of new opportunities. Kratzer et al. (2008) describe that if many teams are involved in collaborative R&D projects, informal communication, through a communication network of weak ties, is crucial. The authors explain that these networks are made up of many more links between individuals than the formally defined communication hierarchy might suggest.

2.2.5. Design Thinking as a Set of Attitudes and Behaviours

Design thinking can also be defined in terms of attitudes which shape the behaviour of its practitioners (Michlewski, 2008). Brown (2009) states that within an organisation, conceptualising design thinking as a set of shared attitudes allows a company to create and shape a continuous culture of innovation. In a variety of free teaching resources (e.g. d.school, 2016) the d.school at Stanford University has popularised a set of six principles which have often been used to describe the behavioural component of design thinking in practice. These attitudes should not be thought of as static properties, but instead be viewed as dynamic principles which are shaped by one's own experiences (Goldman et al., 2012; Kolko, 2015). Goldman et al. (2012) therefore refer to the development of these attitudes as continuous "mindshifts" which occur during the practice of design thinking and not as a static "mindsets".

In the following paragraphs the six attitudes introduced by the d.school are briefly summarised based on their available teaching materials (d.school, 2016) and the description provided by Doorley and Witthoft (2012). A seventh attitude ("abductive reasoning") was added based on the arguments of several other authors (e.g. Collins, 2013; Dorst, 2011; Liedtka, 2000, 2015; Martin, 2004, 2009; Penaluna et al., 2014; Scott et al., 2016; Tynan et al., 2016 forthcoming).

Focus on Human Values

Although, many different definitions of design thinking have been put forward, most authors agree that it is a human-centred activity (Brown, 2008, 2009; Grots & Pratschke, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Leifer & Steinert, 2011; Liedtka, 2015; Rodgers, 2013; Tynan et al., 2016 forthcoming; von Thienen et al., 2011). This means that the insights developed through the interactions with potential users of a product or service and other stakeholders should guide and shape the decision-making process within a project (Doorley & Witthoft, 2012). Prioritising these insights

will significantly increase the chances for future success of a novel concept (Keinz & Prügl, 2010; Liedtka & Mintzberg, 2006).

Be Mindful of the Process

Several authors have proposed various process models for design thinking (e.g. Brown, 2008, 2009; d.school, 2016; Design Council, n.d.; Grots & Pratschke, 2009; Huber et al., 2014; Kelley & Kelley, 2013; Kelley & Littman, 2001; Liedtka & Ogilvie, 2011; Meinel & Leifer, 2011; Stickdorn, 2010). These models should not be seen as prescriptive step-by-step instructions, but rather as sets of connected activities (Brown, 2008, 2009). Using such models enables a team to break down their project into more manageable tasks (Ho, 2001), which allows the team to increase its focus on individual activities, while still being aware of the larger context of the project (Doorley & Witthoft, 2012). Several current process models will be further elaborated in Section 2.2.6.

Collaborate Across Boundaries

As previously stated in Section 2.2.4, design thinking is a team-based activity which benefits from having multiple disciplines and points of view represented within a team (Alves et al., 2006; Brown, 2008; Fischer, 2000; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Lockwood, 2010b; Lojacono & Zaccai, 2004; von Thienen et al., 2011). To turn a diverse group of individuals into a working team requires each team member to collaborate across disciplinary and hierarchical boundaries (Doorley & Witthoft, 2012; Kelley & Littman, 2006). Being aware and actively managing collaboration tends to lead to a “cross-pollination” of domains and ideas (Kelley & Littman, 2006) and an overall increased performance of an innovation team (Kayes et al., 2005; Nakui et al., 2011).

Bias toward Action

As Doorley and Witthoft (2012) explain, teams should stress reflective action over contemplation in a design thinking project. Active experimentation

provides a great way to uncover new insights and directions (Brown, 2008, 2009; Dow et al., 2012; Dow & Klemmer, 2011; Goldman et al., 2012; Leifer & Steinert, 2011). Reflecting on how such new findings were discovered and what this means for a project will accelerate the learning process within a team and increase its innovation capabilities overall (Brown, 2009; Dow et al., 2012; Kelley & Littman, 2001; Leifer & Steinert, 2011).

Embrace Experimentation

Effective design thinking teams turn implicit thoughts and ideas into tangible objects and prototypes throughout a project (Doorley & Witthoft, 2012; Meinel & Leifer, 2011). Conceptualising and constructing low-resolution prototypes with varying foci, which can be tested with potential users, enables a team to gain a deeper understanding of underlying problems and user needs (Skogstad & Leifer, 2011). This decreases the chance of investing in ideas which do not show a sufficient market potential (Brown, 2009; Dow et al., 2012; Skogstad & Leifer, 2011). Learning through low-resolution prototyping allows a team to continually make progress without over-investing resources (Doorley & Witthoft, 2012).

Show Don't Tell

In design thinking, ideas should be conveyed through details rather than speculation (Doorley & Witthoft, 2012). Visualisation therefore plays a key role in communicating thoughts, ideas, and the vision of a project (Liedtka, 2015). The goal is to create sharable experiences and gain empathy through sharing rich stories as an addition to the gathered factual information (d.school, 2016; Doorley & Witthoft, 2012). This will aid in creating a shared understanding within the team (Fischer, 2000; Gilson & Shalley, 2004; Kleinsmann et al., 2010; Welsh & Dehler, 2012).

Abductive Reasoning

Traditionally, two modes of reasoning are distinguished. Whereas in inductive logic, phenomena are proven through observation and measurement,

deductive logic focuses on proving something through reasoning (Liedtka, 2000). Several authors have proposed that design thinking heavily relies on abductive logic, as a third way of reasoning (Collins, 2013; Dorst, 2011; Leavy, 2010; Liedtka, 2015; Martin, 2005; Scott et al., 2016; Tynan et al., 2016 forthcoming). Abductive reasoning is concerned with envisioning new phenomena without having definitive proof for its existence. Liedtka and Ogilvie therefore call it the logic of "what might be" (Liedtka, 2011; Liedtka & Ogilvie, 2011). An attitude of abductive reasoning allows a team to think creatively about new solutions (Penaluna et al., 2014). Often, such creative speculations cannot be determined logically (Liedtka, 2000), but can only be iteratively tested through user feedback gathered via low-resolution prototypes.

2.2.6. Design Thinking as an Iterative Process

Looking at design from a process point of view provides yet another perspective on how to conceptualise design thinking. Breaking down design thinking projects into manageable and moderately-sized tasks instils a feeling of control and moving forward, even if the end state is still uncertain (Gerber & Carroll, 2012). Structured process models provide a sense of predictability for innovation projects (Skogstad & Leifer, 2011). Several authors have suggested a variety of process models for design thinking (e.g. Brown, 2008, 2009; d.school, 2016; Design Council, n.d.; Grots & Pratschke, 2009; Huber et al., 2014; Kelley & Kelley, 2013; Kelley & Littman, 2001; Liedtka & Ogilvie, 2011; Meinel & Leifer, 2011; Stickdorn, 2010). As Brown (2008, 2009) clarifies, these process models should not be seen as prescriptive step-by-step instructions, but rather as a series of overlapping and connected activities. Otherwise, the benefit of the experimental nature of design thinking is lost (Skogstad & Leifer, 2011). At first glance, these models appear to be quite different from each other. For example, Brown (2008, 2009) proposes a three-step model ("inspiration", "ideation" and "implementation"), whereas Liedtka and Ogilvie (2011) conceptualise design thinking as four consecutive guiding questions ("what is?", "what if?", "what wows?" and "what works?"), and Grots and Pratschke (2009) suggest a six-step model ("understand",

“observe”, “synthesis”, “ideas”, “prototype” and “test”). However, once these models are compared side-by-side, many similarities become apparent. It becomes clear that most models share similar intentions and a similar logic of progression. Interestingly, these models appear not to be too different from very early attempts by Wallas (1926) to conceptualise creativity as a process. A detailed overview of several current design thinking process models is provided further below in Figure 2.5.

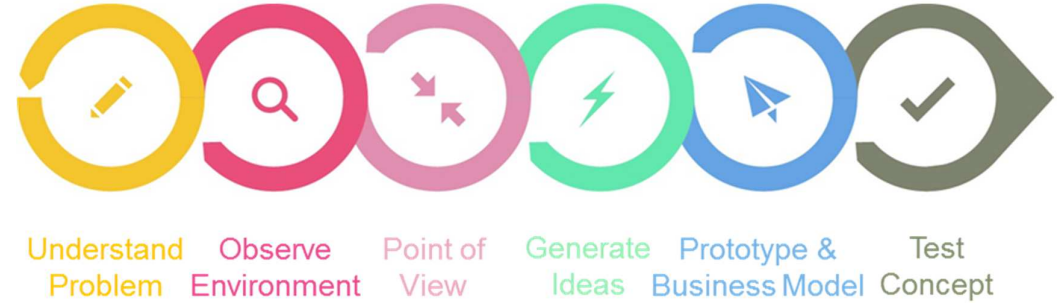
One of the shared principles found in all these models is the interplay of divergent and convergent thinking (Penaluna & Penaluna, 2009). While divergent thinking provokes the generation of multiple alternative choices, convergent thinking stimulates the narrowing down of choices to a few promising favourites (Brown, 2009; Dym et al., 2005). Dym et al. (2005) illustrate that during divergent activities, teams operate in the concept domain, while during convergent activities they operate in the knowledge domain. It is important that both modes of thinking are stressed at different times during a project (Brown, 2009; Grots & Pratschke, 2009).

A second shared principle found in most process formulations of design thinking is that of iteration. Iteration describes the fact that the proposed models are not intended to be used in a strictly linear way, but instead allow teams to move forwards and backwards between the different activities more dynamically (Carlgren et al., 2016; Gerber & Carroll, 2012; Glen et al., 2015; Grots & Pratschke, 2009; Gruber et al., 2015; Kolko, 2015; Leifer & Steinert, 2011; Liedtka, 2000; Rodriguez & Jacoby, 2007; Tonkinwise, 2011; Tynan et al., 2016 forthcoming). Diverging from a linear application of a process therefore is not seen as “failure”. Instead, it is viewed as an encouraged mechanism to include learning loops during design thinking activities (Brown, 2009; Gerber & Carroll, 2012; Kelley & Kelley, 2013; Rodriguez & Jacoby, 2007; Tonkinwise, 2011).

At the Strascheg Center for Entrepreneurship (SCE), a modified version of the six-step process suggested by Grots and Pratschke (2009) is used (Huber et al., 2014). This model is used to teach design thinking in an entrepreneurship context (see Figure 2.4). Many participants in

entrepreneurship education programmes at the SCE chose to implement the developed concepts after their project has been completed. Each project is initiated by a design brief (Blyth & Worthington, 2010; Paton & Dorst, 2011; Petersen & Phillips, 2011), which is either proposed by industry partners or the course instructors.

Figure 2.4: SCE Design Thinking Process Model



This figure is adapted from SCE course material (Huber et al., 2014, pp. 2-3). The model was inspired by Grots and Pratschke (2009, p. 20).

In the following sections, each phase of the SCE process model will be explained in more detail. As described before, various authors propose different process models of design thinking, but at their core, these models share similar intentions and a similar logic (as shown in Figure 2.5). The author does not claim superiority of the SCE process formulation. The author chose to focus on this model, as it also provided parts of the research framework for the following quantitative study presented in later chapters.

The Design Brief as a Starting Point

In many cases, projects are initiated by an impulse to improve a certain problem, product, service, or system (Brown, 2009). In client projects, the initial negotiation and briefing process most often results in a design brief (Paton & Dorst, 2011), which generally tends to be between 500 and 1.500 words (Petersen & Phillips, 2011). This design brief is the result of the

evolutionary briefing process with a client and describes the formalised decisions and actions to be taken (Blyth & Worthington, 2010). During this process, designers tend to elicit the client's frame, potentially reframe it into something more workable and reflect it back to the client (Paton & Dorst, 2011).

A good design brief clearly articulates the problem which to be solved by the design team (Petersen & Phillips, 2011). It should focus on "articulating the aspirations of the client, and stimulating the design team" (Blyth & Worthington, 2010, p. xvi). Due to the nature of ill-defined and wicked problems (see Section 2.2.8), the design brief should only define the client's goals, without prescribing predefined ways to achieve these goals (Brown, 2009). Cross (1999, p. 30) describes that experienced designers generally interpret the design briefs more as a "kind of partial map of unknown territory" than as a set of rigid specifications for a solution.

In organizational contexts, Petersen and Phillips (2011) have shown that if design briefs are properly balanced between expression content and strategic criteria, it improves a designer performance by 30 % and reduces the risk of going over budget by 60 %.

In educational settings, Sas and Dix (2007) illustrate that constructing a design brief based on an already established technology allows students to narrow down the necessary exploration in the "problem space", which enables them to more quickly progress to the "solution space" in a project. The authors demonstrate, that such design briefs can increase student learning in educational settings with constrained timeframes.

Understand Problem

According to Glen et al. (2015), the initial problem should not be defined in terms of potential solutions, as this would impede the creative search for a wide variety of subsequent solutions. In the beginning, the team will set out to increase their working knowledge in the proposed context through analytical research. This is the first step in framing a project and helps with aligning the

project team members through creating shared knowledge (Hey et al., 2008). There are several design tools which can be used to structure and evaluate the gathered information. For example, a stakeholder map – a visual representation of all parties involved in a certain problem – can be used to identify people and entities which will likely influence proposed solutions (Lojacono & Zaccai, 2004). Working visually and utilising all team members and disciplines will allow the team to create a shared understanding from the collected factual information (Liedtka, 2015).

Observe Environment

In design thinking projects, it is important to establish a deep understanding of the people you are creating something for (Carlgren et al., 2016; Gruber et al., 2015; Liedtka & Ogilvie, 2011; Welsh & Dehler, 2012). Therefore, gaining empathy for these people and understanding their emotional needs is a critical step in every project (Brown, 2008, 2009; Kelley & Kelley, 2013; Kolko, 2015; Liedtka & Ogilvie, 2011; Tynan et al., 2016 forthcoming; Welsh & Dehler, 2012). This deep emotional understanding of potential users will enable a project team to discover novel insights and user needs which can later be leveraged into demand for the created artefact (Brown, 2009). Glen et al. (2015) as well as Kelley and Littman (2001) advise that this discovery process should involve potential users with extreme opinions about the problem to be solved. Rodriguez and Jacoby (2007) describe this approach as a fundamental way to reduce one's risk of failure, whereas Michlewski (2008) describes it as developing commercial empathy (in addition to the emotional empathy described above). They explain that designing products, services or systems based on such a deep understanding of a potential user group will reduce the likelihood of investing in an idea which might later lack a clear unique selling proposition and therefore might fail to gain traction in a market. Insights from this user research phase also help to refine the boundaries of a project and re-define potential trajectories for possible solutions (Hey et al., 2008). Keinz and Prügl (2010) discovered that the benefits of user research are not limited to just low-tech consumer products or services. Based on an extensive case study, they argue that within

high-technology commercialisation projects, early user research is a crucial strategy to increase the chances of discovering far-distant application areas. Lojacono and Zaccai (2004) add that within organisations, ongoing design research about latent and explicit user needs is a useful way to systematically capture new perspectives for future innovation projects. Skipping this phase in the design thinking process will greatly diminish the scope and overall potential outcome of a project (Lojacono & Zaccai, 2004).

There are many different tools which are used to conduct user research such as user observations, ethnographic research methods, unstructured and semi-structured interviews as well as shadowing (i.e. following and observing individuals across an extended period).These methods vary by the degree of user involvement (Lojacono & Zaccai, 2004). Glen et al. (2015) suggest that in-person methods, where the innovator and the potential customer are in direct contact, are most powerful. Tools in this phase are often summarised as “needfinding” tools (Brown, 2009; Seidel & Fixson, 2013). Needfinding is not only concerned with individual needs, but also the social norms within groups of people and the communication patterns of different stakeholder groups (Postma et al., 2012). Images of interesting insights gathered during this period of user research are a rich source of inspiration for following activities and allow team members to share contextual information more easily (Gonçalves et al., 2014). As Suri (2008) describes, this period of user research can be used in a generative way to provide new insights and opportunities as well as in an evaluative and formative way to refine assumptions throughout a project. Glen et al. (2015) suggest that it is very important that during this period, the instant gratification of formulating concrete solutions early on, is deferred to a later stage within the projects. Penaluna et al. (2010) as well as Penaluna et al. (2014) warn that otherwise, the premature articulation of ideas will diminish the creative capacity of a team overall.

Point of View

In the “point of view” phase, raw information from other phases of the process are synthesised to extract meaningful patterns (Brown, 2009). Kolko

(2013) proposes that this phase should be regarded as two distinct stages. The first stage is concerned with sense-making. Kolko (2013, p. 216) describes this as “a motivated, continuous effort to understand connections – among people, places, and events – in order to anticipate their trajectories and act effectively”. The second stage consists of re-defining the frame of a design thinking project. At this point, the synthesised information allows a team to adopt an active perspective on what underlying problems they are trying to solve and how they should move forward towards tangible solutions for those problems (Kolko, 2013).

Visualising information throughout this phase is crucial (Liedtka, 2015). One tool which lends itself well to this task is thinking maps. Thinking maps are highly visual conceptual maps combining both prior knowledge about a subject of domain with new insights gathered during the user research process (Oxman, 2004). Defining personas provides another way to summarise the different attributes as well as latent and explicit user needs to create stereotypical user profiles (Tonkinwise, 2011). Personas are a good starting point for other tools such as journey maps (Liedtka, 2011, 2015). Journey maps introduce the dimension of time to the gathered information. They represent a defined period in time of an individual user or a persona and enable the team to structure their collected information longitudinally. This often leads to interesting conclusions about when and how a certain need of a user expresses itself (d.school, 2016).

Generate Ideas

In this phase, teams start to conceptualise potential solutions which build on the synthesised insights from the previous research to subsequently select a small number of potential concepts to further refine in the next stages. This means that teams will use both divergent as well as convergent thinking (Brown, 2009). As Glen et al. (2015) note, this process is often initiated by several stimulus questions which are inspired by the previous research and analysis. As Doorley and Witthoft (2012) advise, the tasks of generating ideas and selecting ideas should be regarded as separate activities. During this phase, the team’s creative thinking is enabled by employing abductive

reasoning leveraged by the insights developed during the previous user research (Scott et al., 2016; Tynan et al., 2016 forthcoming). Through the abductive logic of “what might be” (Liedtka, 2011; Liedtka & Ogilvie, 2011) radical solutions are envisioned for the identified problems (Collins, 2013; Dorst, 2011; Leavy, 2010; Martin, 2005). According to Christensen and Schunn (2009), the created mental models in this phase will greatly reduce the uncertainty about potential solutions. The authors advise that mental models should be refined by each person individually, before sharing them with groups. Team members should avoid articulation ideas prematurely, as this tends to lead to individuals discounting thoughts before they are subconsciously evaluated (Penaluna et al., 2010; Penaluna et al., 2014).

These findings would favour tools for idea generation which are applied individually and only later on shared with the team. However, in their study of student and professional designers, Gonçalves et al. (2014) conclude that team-based brainstorming is the most frequently used ideation technique, both for novice and experienced design teams. Within brainstorming groups who do not know each other well, Comadena (1984) shows that individuals, who excel in brainstorming activities, are the ones who perceive the brainstorming task as attractive, are low in communication apprehension and exhibit a high tolerance for ambiguity. Seidel and Fixson (2013) found out that for novice design thinking teams, an increased number of brainstorming sessions actually decreases the overall team performance, unless new members join the team.

Prototype & Business Model

Building rapid prototypes throughout a project is a crucial component of design thinking (Glen et al., 2015; Gruber et al., 2015; Kolko, 2015; Liedtka, 2011, 2015; Liedtka & Ogilvie, 2011; Skogstad & Leifer, 2011). Through this experimentation with physical representations of an idea, the discovery and learning process is greatly accelerated (Brown, 2009; Kelley & Littman, 2001; Rodriguez & Jacoby, 2007). Prototyping often leads to new and unexpected insights (Kolko, 2015; Skogstad & Leifer, 2011) and helps to uncover shortcomings of proposed ideas (Viswanathan & Linsey, 2012). Brown (2009,

p. 89) therefore refers to this prototyping component as “thinking with your hands”. Rapid prototypes, as a physical representation of a mental model of an idea, allow a design thinking team to further reduce the uncertainty associated with a proposed solution (Christensen & Schunn, 2009; Gerber & Carroll, 2012; Viswanathan & Linsey, 2012). Through the process of prototyping, naive assumptions about the technical aspects of an idea are continuously validated (Dow et al., 2012; Viswanathan & Linsey, 2012). Additionally, prototypes encourage a team to test key assumptions of proposed solutions by collecting feedback from different stakeholder groups throughout the project (Rodriguez & Jacoby, 2007; Skogstad & Leifer, 2011). Externalising ideas through prototypes also allows a team to experience small wins, which drive the project forward and strengthen the group’s beliefs about their own creative ability (Gerber & Carroll, 2012).

In this regard, prototyping in design and prototyping in engineering slightly differ, as Glen et al. (2015) point out. The focus of prototyping in design is on continuous learning about underlying problems by creating artefacts which can be used to elicit feedback from potential target groups. As the main goal at this point is continuous learning, the team should not yet strive towards building refined and fully-functional products (Brown, 2009). Instead they should focus on creating multiple prototypes with varying foci which allow the team to discover new insights (Brown, 2009; Glen et al., 2015; Rodriguez & Jacoby, 2007). As Brown (2009, p. 90) clarifies, these “[e]arly prototypes should be fast, rough, and cheap”. Overinvesting in refining an idea early on, which is sometimes referred to as design fixation (Viswanathan & Linsey, 2012) or entrapment (Liedtka, 2000), tends to make a team less receptive for other opportunities which might show more potential (Brown, 2009). When novice designers shared multiple rapid prototypes in a research study, Viswanathan and Linsey (2012) conclude that design fixation does not significantly influence the design process.

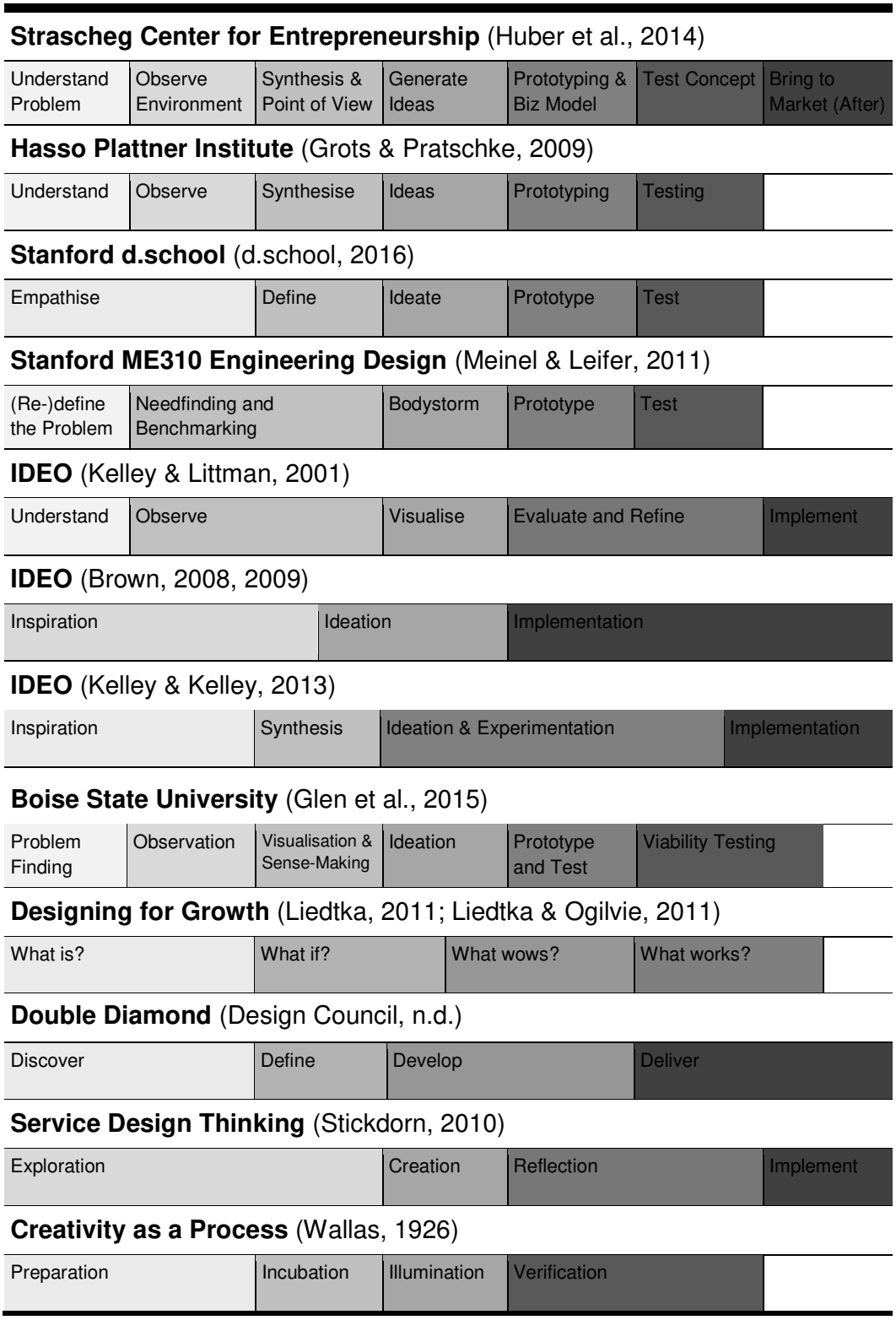
As Lockwood (2010a) points out, an aspect which is not present in many design process models, is concurrent business analysis (also see Figure 2.5). He explains that evaluating the business perspective within commercial

design projects should not be an afterthought which is only added on later, once a product or service idea is almost fully formed. Instead, business modelling should be a continuous endeavour throughout a project. According to Teece (2010), a business model, in essence, is a conceptual rather than a financial model of a business idea. As “The Lean Startup” movement (Ries, 2011) as well as the framework put forth by Osterwalder and Pigneur (2010) show, creating and evaluating potential business models for an idea early on, can be another way to stimulate learning within a project. Therefore, the SCE design thinking process conceptualises this activity as part of the prototyping phase (see Figure 2.4).

Test Concept

The final phase in this design thinking process model consists of the continuous activity of testing proposed ideas and concepts (Gerber & Carroll, 2012; Grots & Pratschke, 2009; Rodriguez & Jacoby, 2007). At this point, previously developed prototypes are tested with potential users and other stakeholder who might influence the success of a proposed concept (Brown, 2009; Grots & Pratschke, 2009). Feedback will lead to learning loops, i.e. going back to previous phases or moving forward to other activities, which allow the team to refine a concept iteratively (Skogstad & Leifer, 2011). Suri (2008) calls this phase the predictive part of design research, where the overall scale and potential of a concept is assessed. To achieve such predictions, Liedtka and Ogilvie (2011) propose a strategy of placing small bets in the market. In their book, the authors describe that new concepts can be tested in a cost-effective way by introducing them to small test groups or test markets. PepsiCo for example, frequently tests product innovations iteratively in small regional markets before they roll them out globally (Nooyi & Ignatius, 2015).

Figure 2.5: Comparing Different Design Thinking Process Models



In this figure, the six-step process used at the SCE acts as a baseline. All other models were arranged to offer comparisons to the SCE model as a point of reference.

Other Process Models

As stated before, several authors provide models for conceptualising design thinking as a process. A side-by-side comparison of various such models, which were identified during the systematic review of the available literature for this thesis, is shown in Figure 2.5. In this figure, the SCE design thinking process model is used as a point of reference to highlight similarities between the different models. As stated before, the author does not intend to claim superiority of the SCE model.

Criticism of the Process Perspective on Design Thinking

Teal (2010) has critically argued that trying to reduce design thinking to a couple of steps dilutes its meaning and over-simplifies the complexity of the world. In an online article in Fast Company, Walters (2011) has also disputed that the formulation of design thinking as a process leads to a simplistic view of innovation. She argues that a "repeatable, reusable practice contradicts the nature of innovation, which requires difficult, uncomfortable work to challenge the status quo of an industry". In her view, the need to impose a more or less artificial frame on the methodology is mostly required by larger companies which are structured around sets of processes. These processes usually have a determined end state with a measurable goal and can be repeated to continuously until the goal is achieved. This thinking, she argues, is contradictory to innovation. Radical innovation needs a certain level of ambiguity to allow for new concepts and ideas to emerge (Gerber & Carroll, 2012; Skogstad & Leifer, 2011). Brown (2008) has therefore suggested that the different parts of a design thinking process model should be viewed as a system of related activities, rather than a process. However, Teal (2010) contends that generally, people are very heavily influenced by the linear causal schemas we are taught early on in life. So, if a set of activities is introduced to us as something resembling a linear sequence, people will likely treat it as a linear process, even if the principle of iteration is stressed as key behavioural component of design thinking.

The author of this thesis recognises these points of criticism, but also agrees with Ho (2001) who notes that process models allow novice design thinkers to break down their project into more manageable tasks which, in turn, enables them to increase their focus on individual activities while still being aware of the larger context of their project. The author also agrees with Leifer and Steinert (2011) who point out that process models provide some predictability for a project, which is needed in settings where fixed deadlines occur and external stakeholders need to be briefed on the status of a project in regular intervals. The author re-emphasises the argument made by Brown (2008, 2009) that even if formalised process models are formulated, the individual parts should be viewed as inter-connected activities rather than clearly separated process steps.

2.2.7. Design Thinking as Creative Confidence

Kelley and Kelley (2013) propose that design thinking can also be conceptualised as developing creative confidence. Jobst et al. (2012, p. 35) define creative confidence as “one’s own trust in his creative problem solving abilities.” This includes being comfortable with the inherent uncertainty and ambiguity of wicked problems in design thinking (Gerber & Carroll, 2012; Hobday et al., 2012; Jobst et al., 2012; Kelley & Kelley, 2013; Leifer & Steinert, 2011). Michlewski (2008) proposes that teams need to learn to embrace discontinuity and open-endedness. According to Dym et al. (2005), such teams continually need to negotiate different options to deal with the inherent ambiguity of a design challenge. Glen et al. (2015) illustrate that the level of ambiguity generally rises over the course of a project. The researchers warn that if high levels of ambiguity are not addressed and managed properly, they can turn into anxiety for the individual team members. Zenasni et al. (2008) describe that a high tolerance for ambiguity shows a significant positive correlation with overall creativity. Hence, the researchers conclude that individuals and teams who have developed a tolerance for ambiguity tend to create more original and unique ideas.

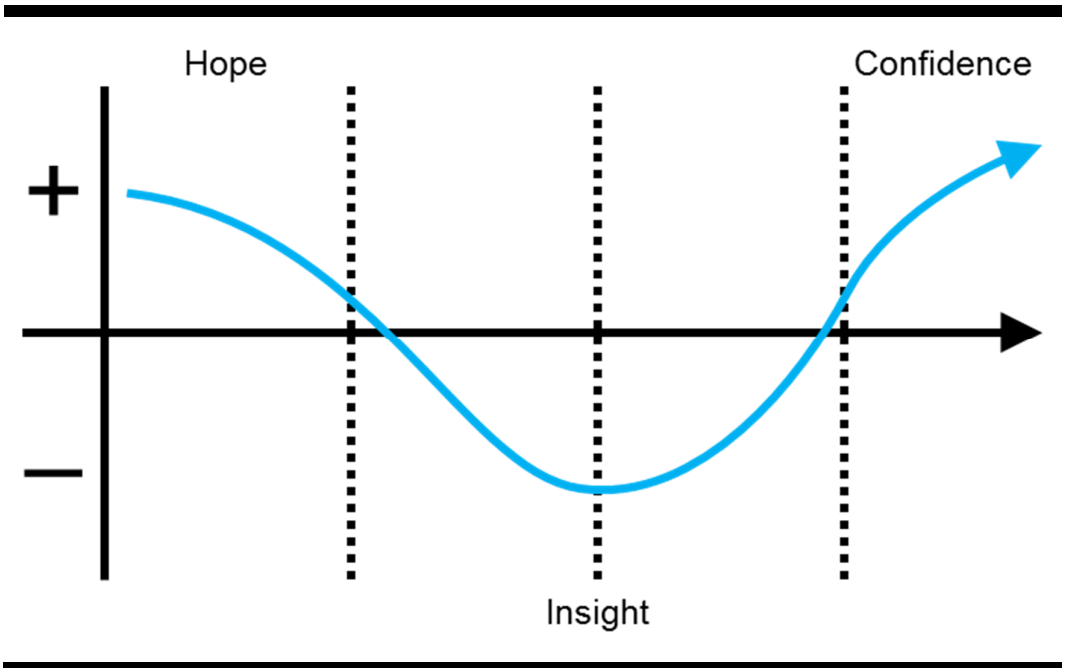
Previously, other authors have described this ability as developing and relying upon an informed intuition as a design thinking practitioner (e.g.

Rodriguez & Jacoby, 2007; Suri, 2008; Suri & Hendrix, 2010). This is not to say, that decisions should only be made based on one's intuition while disregarding factual evidence. An informed intuition should rather be used as an additional filter through which factual evidence can be interpreted and leveraged into possible new concepts (Suri, 2008). Through this combination of both evidence and intuition, project teams are able to increase their potential for creating successful new solutions (Rodriguez & Jacoby, 2007; Suri & Hendrix, 2010).

Several authors have argued that such intuitive capabilities can be developed over time, even if a person is grounded in traditionally analytic and rational disciplines such as business management or engineering (Jobst et al., 2012; Kelley & Kelley, 2013; Suri & Hendrix, 2010). Glen et al. (2015) find that students who have completed their first design thinking project are more enthusiastic about following projects and are therefore better able to handle uncertainty. In other words, the researchers propose that dealing with ambiguity is a transferrable skill. Jobst et al. (2012) suggest that fostering this creative confidence should be the primary aim of any design thinking education programme. As Glen et al. (2015) point out, the process of building creative confidence and a tolerance for ambiguity should be actively guided by educators and project facilitators.

In his widely-read book *Change by Design*, Brown (2009) proposes that the overall confidence within a team changes throughout the course of a project in a U-shaped pattern. This pattern is characterised by an initial euphoric state of "hope", followed by a decline in confidence while being confronted with discovered "insights" during a project, and an increased level of confidence once a team has narrowed in on potential solutions for a problem (see Figure 2.6).

Figure 2.6: Expected Team Confidence During a Project



This figure was adapted from Brown (2009, p. 65) and shows expected team confidence during a design thinking project.

The development of creative confidence is closely linked to the already established theory of perceived self-efficacy as defined by Bandura (Kelley & Kelley, 2013). Bandura (1977, 1982) argues that a person's individual context-specific belief system influences their ability to accomplish tasks and reach goals. The concept of creative confidence can be seen as an extension of this theory into the field of design thinking (Jobst et al., 2012; Kelley & Kelley, 2013).

Based on the arguments presented above, the author concludes that creative confidence is heavily influenced by the belief that one possesses the necessary abilities and tools to be effective in a proposed design thinking task. This results in a sense of "feeling effective" during the application of design thinking to a project. The author also argues that this perceived effectiveness, in turn, leads to a sense of "feeling at ease" during a project which allows individuals to better cope with the inherent ambiguity and uncertainty. Building on the findings presented by Glen et al. (2015), the

author proposes that both the sense of “feeling effective” and the sense of “feeling at ease” are, at least partly, transferable to new projects and teams.

2.2.8. Design Thinking as Solving Wicked Problems

Another perspective on design thinking can be derived from classifying the types of problems it is trying to address. In design theory, several authors have argued that design problems are mostly ill-defined or wicked in nature (Buchanan, 1992; Coyne, 2005; Gruber et al., 2015; Stewart, 2011; Tynan et al., 2016 forthcoming) and that designers will initially treat all problems as wicked problems (Buchanan, 1992). This discussion was extended into the current debate about the nature and purpose of design thinking in fields outside of traditional design (Adams et al., 2011; Cassim, 2013; Dunne & Martin, 2006; Johansson-Sköldberg et al., 2013; Liedtka, 2015; Stewart, 2011; Welsh & Dehler, 2012). To better grasp the nature of wicked problems, Rittel and Webber (1973) formulated ten criteria to classify wicked problems which also found their way into the early management discourse (e.g. Churchman, 1967). Conklin and Christensen (2009, p. 19) later reduced these criteria to six characteristics which describe wicked problems. They explain that with wicked problems “[y]ou don’t understand the problem until you have developed a solution.” Wicked problems also do not have a “stopping rule”, which implies that an innovation process will likely be terminated because you ran out of resources such as time, money or energy, and not because you have reached an optimal solution. Furthermore, solutions cannot be “right or wrong”. This is connected to their forth characteristic which states that every wicked problem is “essentially unique and novel”. This is why you cannot judge a solution to be right or wrong. You can simply assert if it is better or worse than the solution which was in place when you started. Additionally, with wicked problems “[t]here is no given alternative solution”, which means that there are no points of reference and it is up to the innovator to decide which concepts should be advanced. Every solution to a wicked problem has consequences, because you can only learn about the quality of your solution by trying them out in a real setting. Every time you implement a solution, you spend resources and affect the

environment in which you place the solution, making many attempts at solving wicked problems “one-shot operations”.

To further define their list of characteristics, Rittel and Webber (1973) contrast wicked problems with so called tame problems, which they defined as followed:

> *“[The mission of tame problems] is clear. It is clear, in turn, whether or not the problems have been solved. […] For any given tame problem, an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem …”* (Rittel & Webber, 1973, pp. 160-161)

In their influential essay, Rittel and Webber (1973) further argue that problems which possess the outlined characteristics of wicked problems may be used to demarcate the practice of design from the practice of engineering and science, which they argue, deals largely with tame problems. This claim was recently refuted by Farrell and Hooker (2013) who claim that the ten original criteria stem from only three more general problem criteria which are common to both science/engineering and design. Conklin and Christensen (2009) state that one of the most common criticisms about the classification by Rittel and Webber (1973) is that in practice, it is very hard to use the list of characteristics to classify a problem as undeniably wicked. They argue that in reality, there are several “degrees of wickedness”. Nonetheless, the distinction between wicked and tame problems allows for a more precise description of problems and has sparked academic research and discourse for more than forty years (Xiang, 2013).

As Lindberg et al. (2011) argue, one of the aims of design thinking is to provide concrete solutions to different sets of problems. Mostly, these problems are not clearly defined, cannot be observed directly, and are highly ambiguous in nature (Stewart, 2011). Therefore, several authors have drawn parallels between the original discourse on wicked problems in planning theory and the field of design (Buchanan, 1992; Coyne, 2005; Glen et al., 2015; Stewart, 2011; Tynan et al., 2016 forthcoming) and design thinking

(Adams et al., 2011; Cassim, 2013; Dunne & Martin, 2006; Hobday et al., 2012; Johansson-Sköldberg et al., 2013; Liedtka, 2015; Stewart, 2011; Welsh & Dehler, 2012). It is being argued that with its iterative approach (see Section 2.2.6), its continuous interplay between divergent and convergent thinking (see Section 2.2.6) as well as its approach to continually frame and re-frame underlying problems and potential trajectories (Cross, 2004; Dorst, 2011; Hey et al., 2008), design thinking lends itself well for approaching wicked problems. The multidisciplinary team approach in design thinking (see Section 2.2.4) also enables innovators to analyse wicked problems from multiple angles and make sense of ambiguous information faster (Pacanowsky, 1996). In a recent study using functional Magnetic Resonance Imaging technology, Alexiou et al. (2011) demonstrate that the levels of brain activity and patterns of functional interactions between brain regions actually differs between solving ill-structured and solving well-structured problem solving.

2.2.9. Design Thinking as Learning Environments

As Brown (2009) as well as Alves et al. (2006) point out, the right project space can fuel innovation and affect project performance in a positive way. According to Kelley and Littman (2001), a proper project space acts like a greenhouse which helps you grow your idea step by step. Professional designers often work in design studios, where different sources of inspiration, artefacts from former projects and remnants of current projects are taking over large parts of the available space. According to Welsh and Dehler (2012), a studio setup allows for deep immersion during problem-solving activities, self-guided learning and high levels of collaborative engagement.

Leifer and Steinert (2011) illustrate that physical spaces also influence the learning process in educational settings. Thoring et al. (2016) note that such learning spaces need to be consciously created. In their book *Make Space*, Doorley and Witthoft (2012) provide a comprehensive guide of how learning environments can be modelled to allow for studio-like learning experiences. Both authors attribute much of the current success of the Stanford d.school, to how the learning environment was carefully crafted to provide a studio-like

learning environment based on the student's actual needs. Thoring et al. (2016) propose that good design learning environments consist of five different types of spaces. They should include spaces for deep work, spaces for collaboration, spaces for presentation, spaces for making and spaces for intermissions.

Zárraga and Bonache (2005) explain that working in a studio environment fosters a productive team atmosphere. According to Penaluna et al. (2010) as well as Tynan et al. (2016 forthcoming), these environments encourage experimentation, foster the curiosity of students and allow them to learn based on reflection. Welsh and Dehler (2012) describe that design learning environments better enable learners to contest each other's ideas and create a climate where critical comments during the design process are welcome and not stigmatised. Kelley and Kelley (2013) state that a studio environment also provides a natural conversation space for the involved learners. According to Kayes et al. (2005), by reflecting on their experiences as a group, teams can take ownership of their learning and further increase its effect. Stempfle and Badke-Schaub (2002) have found that successful design teams spend about one third of their time jointly reflecting and refining their methods. In their study of novice and experienced multidisciplinary product development teams, Seidel and Fixson (2013) have discovered that increased team reflexivity is positively associated with better performance during concept generation activities, but negatively associated with performance during concept selection activities.

2.2.10. Novice vs. Experienced Design Thinkers

Several authors have studied the differences and similarities between novice and experienced or expert designers (Cross, 2004). Yet, as Razzouk and Shute (2012) note, the research community still only has a limited understanding of how experts differ from novice designers in their thinking processes. What is generally accepted is the fact that becoming an expert in design requires extensive and deliberate practice with the explicit goals of improvement (Cross, 2004). From research on expert performance in other fields, it is also established that the effect of deliberate practice can be

increased through appropriate mentoring by an expert teacher (Ericsson & Charness, 1994). This process of developing into an expert is “always open-ended and incomplete” (Adams et al., 2011, p. 590).

According to Hargadon and Sutton (1997), new product design teams often rely on patterns and insights from past projects to design products or services for other contexts. In this regard, experts have generally gathered experiences with a larger variety and diversity of problems and solutions over time (Razzouk & Shute, 2012). Cross (2004) argues that experts are able to access this information as larger chunks in an evaluative “breath-first” approach, while novices employ a “depth-first” approach in which sub-problems are identified and then dealt with sequentially. The expert’s experience also allows them to distance themselves from their work and evaluate it in more abstract terms (Ho, 2001). According to Ho (2001), experienced designers therefore frequently chose working-forward strategies for problem solving, where rules are applied from the initial stages. Novices, on the other hand, tend to employ working-backwards strategies, where goal-driven search mechanisms are utilised. Experienced designers are also likely to make some decisions early on in the process which narrow their field of search. These decisions are often based more on personal judgement stemming from prior experience than on evidence gathered for the specific project. This leads the experienced designer to be more solution-focused rather than problem-focused (Weth, 1999). Cross (2004) therefore calls experienced designers “ill-behaved” problem solvers, in the sense that they spend less time defining a problem and more time scoping a problem and prioritising criteria for potential solutions. According to Cross (2004), an over-concentration on problem definition is less likely to lead to successful project outcomes. Günther and Ehrlenspiel (1999) partly attribute this behaviour to the risk of getting trapped in gathering information instead of working towards a solution. Therefore, an “ill-behaved” problem solving approach is more efficient in approaching complex design problems. However, such an approach also increases the difficulty of course-corrections in later stages of a project (Weth, 1999).

In a study about which design methods novice and expert designers prefer, Seidel and Fixson (2013) discovered that formal design methods for both divergent (concept generation) and convergent (concept selection) are mostly helpful for novice design thinkers. Experts, on the other hand, tend to embrace more flexible approaches and therefore do not rely on formalised design methods as much. These findings are in line with prior conclusions by Chua and Iyengar (2008), who have found that experts with domain-relevant experience tend to benefit from a larger variety of choices during the design process, whereas this has no effect on the creativity of novice designers.

2.2.11. Design Thinking Education Programmes

With its growing popularity in various industries, designated design thinking modules and programmes have also emerged in university settings. One of the oldest programmes, with a documented legacy going back as far as 1967, is the ME310 capstone course taught at the engineering department at Stanford University (Carleton & Leifer, 2009). Similar to many other design thinking programmes today, it incorporates industry partners into the programme to create realistic learning environments for students (Carleton & Leifer, 2009). The course centres on problem-based learning, deep immersion into different subject areas, and the simulation of different training grounds for its students (Carleton & Leifer, 2009). Over the years, ME310 has transformed from a local capstone course into a global network of around twenty universities wanting to bring attention to design thinking (Steinbeck, 2011).

Another major influence in the popularisation of design thinking centres around the Hasso Platner Institute for Design, established in 2004 at Stanford University and the Hasso Plattner Institute for IT Systems Engineering, established in 2007 at the University of Potsdam (Kelley & Kelley, 2013; Tischler, 2009). Through their structured multidisciplinary design thinking training programmes, their close connection to the design innovation company IDEO (Kelley & Kelley, 2013), their network of participating industry partners, and the many free teaching resources (e.g.

d.school, 2016), these institutes demonstrated the usefulness of design thinking to a larger audience.

Other universities have followed arguments, for example by Liedtka (2000), that design should play a bigger part in management education. One example is the Rotman School of Management at the University of Toronto, where design thinking is now taught as an integral part of management education at different levels (Martin, 2004, 2005, 2009). Similarly, Liedtka (2010) has integrated design thinking into graduate degree programmes at the Darden Graduate School of Business at the University of Virginia.

Other documented uses of design thinking include its integration in two entrepreneurship education programmes in Germany. Both the University of Koblenz and Landau (von Kortzfleisch et al., 2010; von Kortzfleisch et al., 2013) and the Munich University of Applied Sciences (Huber et al., 2014; Turgut-Dao et al., 2015) have adapted models of design thinking to supplement their entrepreneurship teaching activities. At the Open University on the other hand, design thinking is being applied to foster the creativity of its students. As Lloyd (2012) reports, this is achieved via one of the first distance-learning modules in design thinking.

Besides these published accounts of design thinking programmes anchored in different universities, many more unpublished cases exist. What most of these programmes have in common, are the goals which they share. According to Glen et al. (2015), the favoured approach for learning design thinking is a project-based approach. Tynan et al. (2016 forthcoming) explain that in such projects, students “learn by doing” in a learning space which offers students an environment in which they can experience both formal and informal learning from lecturers and fellow students. Project-based learning also allows students to start their learning journey at different points, Scott et al. (2016) explain. Penaluna et al. (2010) argue that a design educator should strive to develop student’s instincts, so that they are better prepared to respond intuitively and promptly to constantly evolving challenges in the fast-paced commercial environment. Many design thinking education programmes also incorporate a multidisciplinary approach to problem-solving

(Kelley & Kelley, 2013; Tischler, 2009; von Thienen et al., 2011; Welsh & Dehler, 2012). For non-designers, such programmes are often an encouragement to solve more complex problems (Lloyd, 2012). In design environments, all ideas can be contested, which creates learning spaces where critical comments are welcome and not stigmatised (Welsh & Dehler, 2012). These settings allow students to develop into integrative thinkers and intentional learners (Welsh & Dehler, 2012), build their creative confidence (Jobst et al., 2012) and prepare them to deal with risk and failure (Royalty et al., 2012). Welsh and Dehler (2012) find that in such learning environments, having high expectations of students will lead to higher student team performance.

2.2.12. Embedding Design Thinking Within Organisations

As Martin (2005, p. 5) acknowledges, "[t]he topic of design is hot these days", especially in areas outside of the traditional design domain. Whereas design thinking in the traditional design domain has been "partly ignored" (Johansson-Sköldberg et al., 2013), its influence on management practices has grown steadily over the last few years (Boland & Collopy, 2004; Brown, 2009; Fraser, 2010; Glen et al., 2015; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Kimbell, 2011, 2012; Kolko, 2015; Liedtka & Mintzberg, 2006; Liedtka & Ogilvie, 2011; Martin, 2004, 2009). Organisations such as Proctor & Gamble (Martin, 2004), IBM (Clark & Smith, 2008; Kolko, 2015),General Electric (Kolko, 2015), SAP (Holloway, 2009), 3M (Porcini, 2009), Hewlett-Packard (Sato et al., 2010), PepsiCo (Nooyi & Ignatius, 2015), Pfizer (Liedtka, 2011; Liedtka & Ogilvie, 2011), Bank of America (Brown, 2008), and the Bill & Melinda Gates Foundation (Gates, 2015) already have successfully embedded design thinking principles and approaches into their management practices.

Embedding design thinking within an organisation offers several benefits. If properly implemented, it encourages innovation and growth (Liedtka, 2015; Martin, 2005), opens up new opportunities and allows the organisation to evolve existing business models based on customer needs (Cruickshank & Evans, 2012; Fraser, 2010). This is especially true, if it is used to engage

ill-defined and wicked business problems (Dorst, 2011; Liedtka & Ogilvie, 2011; Liedtka & Parmar, 2012; Stewart, 2011), where strictly analytical approaches are failing (Collins, 2013). According to Michlewski (2008), design helps organisations to consolidate meanings and therefore better equip themselves for dealing with the inherent ambiguity and uncertainty in innovation activities. The abductive logic in design thinking allows an organisation to break with established patterns of thinking and focus on "what might be?" to better align its activities with future challenges (Collins, 2013; Dorst, 2011; Leavy, 2010; Liedtka, 2000, 2015; Scott et al., 2016; Tynan et al., 2016 forthcoming) and embrace constraints as an impetus to creative solutions (Boland et al., 2006; Dunne & Martin, 2006). The iterative nature of design thinking encourages a continuous process of framing and reframing of problems and opportunities (Brown, 2008, 2009; Dorst, 2011; Gruber et al., 2015; Kolko, 2013). Furthermore, design thinking adds an open and experimental component to strategic activities, which helps decision makers in dealing with ambiguity and uncertainty (Leifer & Steinert, 2011; Liedtka, 2010) and encourages them to become more hypothesis-driven (Liedtka & Parmar, 2012). Together with the customer-centric focus of design thinking (Brown, 2008, 2009; Grots & Pratschke, 2009; Kelley & Kelley, 2013; Kelley & Littman, 2001, 2006; Liedtka & Ogilvie, 2011; Rodgers, 2013; Venkatesh et al., 2012; von Thienen et al., 2011), this reduces decision maker's individual biases and allows them to make better strategic decision (Liedtka, 2015). Multidisciplinary cooperation in design thinking teams allows such groups to look at problems and opportunities from multiple perspectives (Alves et al., 2006; Brown, 2009; Fischer, 2000; Kelley & Kelley, 2013; Kelley & Littman, 2006; Lojacono & Zaccai, 2004; von Thienen et al., 2011). Such teams are better able to overcome design fixation (i.e. thinking beyond proven concepts) and blind spots, which allows them to propose more radical new ideas (Viswanathan & Linsey, 2012). Nakui et al. (2011) conclude that the performance of such multidisciplinary teams partly depends on the team member's belief that diversity is beneficial for team performance. Liang et al. (2015) therefore note that organisations have to actively manage this diversity across teams and the larger organisational structures.

After extensive research on the implementation of design thinking within larger organisations, Rauth et al. (2015) propose five different types of activities to create and sustain support for design thinking within an organisation. First, the usefulness of design thinking needs to be demonstrated by, for example, distributing external and internal success stories and developing new metrics for the success of design thinking projects. Second, design thinking needs to be meshed with the existing organisational culture and practices. This requires the inclusion of key stakeholders within the organisation early on in the process. Rauth et al. (2015) also suggest finding a new company-wide label which summarises the resulting new approach to innovation. Third, individual members of the organisation need to be convinced through experience. This may be achieved by, for example, including executives and employees in design thinking workshops and field projects. Fourth, an ambassador network should be created by, for example, recruiting the top management as spokespeople for the new approach to innovation. Fifth, physical spaces and artefacts need to be created as tangible stimuli to engage in this new approach to innovation.

Howard (2012) suggests a three step approach for embedding design thinking within an organisation. First, a concept of design thinking is developed and adapted for the specific context of the organisation. Second, design thinking capabilities are established to allow for the concept to be executed. Third, practices are promoted to turn the design thinking approach into action and implement it in daily practice.

Step One: Developing Design Thinking as a Concept

As previously described, a universal definition of design thinking does not exist (Carlgren et al., 2016; Eppler & Hoffmann, 2012; Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Rodgers, 2013; von Thienen et al., 2011). How design thinking is defined rather depends on the context of where it is used (Johansson-Sköldberg et al., 2013). According to Carlgren et al. (2016), organisations therefore first need to define what design thinking means for them and how specific elements, such as explicit methods from the “designer’s toolkit” (see Section 2.2.3), multidisciplinary teams (see

Section 2.2.4), attitudes and behaviours (see Section 2.2.5) and creative confidence (see Section 2.2.7), should be used within their specific context (Howard, 2012). As Venkatesh et al. (2012) point out, to successfully embed design orientation and design thinking practices within an organisation, it should be embraced as a company-wide phenomenon. In most organisations, this will be a large-scale effort (Howard, 2012) which requires a holistic understanding of both design thinking and the organisational structures in place (Choi & Moon, 2013). Consequently, design will no longer only be owned by specialised design departments and functions (Carr et al., 2010), but also empower non-designers to contribute towards new product design, service design, and systems design (Liedtka & Ogilvie, 2011). This will partly shift the focus of the organisation from the "delivery end of the thinking cycle" to the "discovery end", where spotting and developing new alternatives, instead of incremental improvement and execution, is given a higher priority (Conklin & Christensen, 2009, p. 20). For this transition to work, organisations have to partly move away from linear decision making processes and hierarchical models of management (Pacanowsky, 1996).

Step Two: Developing Design Thinking Capabilities

Design thinking capabilities need to be developed both in terms of human capital and organisational frameworks (Howard, 2012). At an individual level, employees and managers need to be trained in relevant methods from the "designer's toolkit" (see Section 2.2.3) and iterative frameworks (see Section 2.2.6). As design thinking is a multidisciplinary approach (see Section 2.2.4), small networked project teams need to be created (Brown, 2009; Martin, 2005). Such teams are well equipped to cut through existing structural and hierarchical barriers within an organisation and "cross-pollinate" existing insights and ideas to form new solutions and strategies (Kelley & Kelley, 2013, p. 189). How well these teams perform will greatly depend on the structures and rules an organisation puts into place (Alves et al., 2006). As the outcome of iterative and experimental design thinking projects cannot be accurately predicted (Skogstad & Leifer, 2011), different performance metrics need to be put in place (Martin, 2005). Learning spaces for these projects

need to be created, where ideas can be developed and critically discussed (Welsh & Dehler, 2012) without the interference of existing structures and practices (Auernhammer & Hall, 2014). “Failure” during these projects should be seen as an opportunity to learn, rather than being stigmatised or even punished (Brown, 2009; Kelley & Kelley, 2013; Welsh & Dehler, 2012). As Howard (2012) points out, during this development process, the role of many participating employees might change significantly. As Rauth et al. (2015) note, tangible proof of the usefulness of design thinking is required within an organisation after the initial honeymoon period has ended.

Step Three: Developing Design Thinking Practices

For design thinking and practice to take root within an organisation, its concepts need to be integrated into daily practice. According to Glen et al. (2015) many business professionals experience confusion and frustration when engaging in design thinking projects for the first time. As Howard (2012) describes in his account of the implementation of design thinking at Deloitte Australia, most managers and employees describe design thinking tools, methods, and frameworks as very comprehensible, but to use and develop them in daily practice requires significant practice and deep understanding. The development of design thinking capabilities, creative confidence and design sensibilities is therefore always an ongoing process (see Section 2.2.7). Buy-in for these practices can be increased by making different stakeholders from various functions and levels within an organisation a part of these activities (Holloway, 2009). Rauth et al. (2015) suggest that such proponents of design thinking within an organisation should actively be involved in legitimising the usefulness of design thinking by continuously demonstrating its value.

2.2.13. The Future of Design Thinking

At the moment, design thinking is still growing in popularity (see Section 2.2). Much of this growth stems from fields outside of traditional design, which are looking to adopt design thinking methods, frameworks as well as problem-solving strategies and merge them with current models and theories

in their field (Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Razzouk & Shute, 2012). Especially within the fields of management and innovation, design thinking is viewed as a promising new approach for building innovation capabilities, discovering new growth opportunities and evolving existing business models (Cruickshank & Evans, 2012; Fraser, 2010). Several companies from various industries have already successfully implemented design thinking into their organisations (see Section 1.4). This has been accompanied by a growing number of available publications, mostly aimed at practitioners outside of traditional design (Johansson-Sköldberg et al., 2013; Liedtka, 2015; Razzouk & Shute, 2012; Stewart, 2011). Several authors have also proposed that design thinking should play a more crucial role in business and management education (Boland & Collopy, 2004; Fraser, 2010; Liedtka & Mintzberg, 2006; Liedtka & Ogilvie, 2011; Martin, 2004, 2009). As a result, design thinking has already been adapted into several business education programmes around the world (see Section 2.2.11).

As mentioned at the beginning of this section, despite its growing popularity, the theoretical underpinnings of design thinking within the business context remain poorly understood and under-researched (Carlgren et al., 2014; Dinar et al., 2015; Hobday et al., 2011; Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Razzouk & Shute, 2012). In a critical article about the development of design thinking Nussbaum (2011) went so far as to call it a “failed experiment” due to the failure of the business and research communities to substantiate this practice-oriented approach with appropriate theory. In their reviews of the available scholarly literature on design thinking, Razzouk and Shute (2012), Carlgren et al. (2014) as well as Dinar et al. (2015) point out that rigorous scholarly contributions are very rare. Dinar et al. (2015) also criticise that only very few longitudinal project-based observations have been conducted, although such studies are needed to refine a holistic understanding of the subject matter. In their recent review of the available empirical studies of design thinking, Dinar et al. (2015) conclude that there are still no rigorous standard for designing, collecting and analysing data in design thinking research. They also point out that overall,

many studies, even in high quality design journal, use very small sample sizes and only show little awareness of reflecting the interplay of the many interconnected factors at play in real-world design situations. Johansson-Sköldberg et al. (2013, p. 127) add that overall, the discourse on design thinking (i.e. using design practices and competencies beyond the traditional design context) is “less thoughtful and robust” than many of the existing models of designerly thinking (i.e. academic treatment of the practice of design). The authors therefore propose to increase the link between these two separate discourses in future research. According to Liedtka (2015), future research within the business context also needs to connect design thinking more closely with existing management theories and approaches such as the literature on learning organisations.

Carr et al. (2010) propose that for design thinking to keep growing within the business domain its concepts need to be articulated more clearly and “translated” into management language. Researchers in this domain have to facilitate a dialogue between the empirical research and the business world (von Thienen et al., 2011) and find ways to clearly demonstrate and measure its effect and potential (Carr et al., 2010).

2.3. Entrepreneurship Education

As the research study described in the coming chapters is embedded in a university setting where design thinking forms an integral part of student’s entrepreneurship education, a brief discussion of the current state of entrepreneurship education is covered in this section.

As Kuratko (2005, p. 577) boldly put it, “[e]ntrepreneurship has emerged over the last two decades as arguably the most potent economic force the world has ever experienced.” This “force” is powered by the many individual entrepreneurs, who, in teams, or sometimes even by themselves, start and grow businesses, create jobs, and sometimes within less than a decade become highly influential players among companies which have existed far longer than them (e.g. Facebook, Twitter, and recently Airbnb as well as Uber). It is the vision and work of those entrepreneurs which has transformed

many parts of our daily lives. They are often driven by their resolve to fix a specific problem. According to Kawasaki (2015), this problem is often one that they have experienced themselves and that they now want to get rid of to make their lives, and other people's lives, better.

Thus, many government bodies are trying to increase entrepreneurial activities in their countries and regions (Anderson et al., 2014; Leitão & Baptista, 2009). One of the mechanisms being used to achieve this growth in entrepreneurial activity are entrepreneurship education initiatives, which predominantly focus on students at the university level. The popularity of entrepreneurship education at the university level has dramatically increased over the last two decades (Fayolle & Gailly, 2008; Fiet, 2000a; Lorz et al., 2013). As the authors of the fifth report by the All-Party Parliamentary Group for Micro Businesses points out, entrepreneurship education needs to be offered across all subjects and levels of tertiary education to improve both the number of start-ups and their quality (Anderson et al., 2014). Penaluna and Penaluna (2008) argue that entrepreneurship education programmes need to be tailored to their target group. The authors explain that, for example, an entrepreneurship education programme in the creative industries needs to be designed differently than a programme offered at a business school. Anderson et al. (2014) also reveal that entrepreneurship education is predominantly recognised at university-level, but is still neglected at the primary and secondary level. The authors therefore suggest that entrepreneurship education should start much earlier and be mandatory in the curriculum for four to 18-year olds in the UK.

2.3.1. Can Entrepreneurship be Taught?

A persistent and fundamental question which is often posed to entrepreneurship researchers by people outside this field is: Can entrepreneurship actually be taught? (Henry et al., 2005; Klein & Bullock, 2006; Penaluna & Penaluna, 2008). As Fayolle and Gailly (2008) state, the idea of "born entrepreneurs" which possess their entrepreneurial abilities rather than having developed them has still not fully disappeared. But over time, many research studies have found positive links between

entrepreneurship education and consequential entrepreneurship performance. For example, Kolvereid and Moen (1997) have shown that graduates from entrepreneurship education programmes have stronger entrepreneurial intentions and are more likely to start a new venture in the future. Kuratko (2005) has argued that the sheer number of entrepreneurship education programmes which have been established in the last decades should be considered proof of the positive effects of such programmes. To settle this discussion, Martin et al. (2013) recently conducted the first rigorous quantitative meta-analysis of entrepreneurship education outcomes (42 individual samples, n = 16,657). The authors report a significant relationship between entrepreneurship education training and entrepreneurship-related human capital assets, e.g. knowledge, skills, competencies, positive perception of entrepreneurship as well as intentions to start a business. They also report a significant relationship between entrepreneurship education training and entrepreneurship outcomes, such as nascent behaviours like writing a business plan or seeking external funding, and entrepreneurship performance. Interestingly, these positive effects of entrepreneurship education are not just limited to careers as entrepreneurs. As Charney and Libecap (2000) have shown in their study at the University of Arizona, entrepreneurship students often also outperform students from other disciplines in non-entrepreneurial careers. The authors found that an entrepreneurial mindset developed through targeted entrepreneurship educations programmes will make graduates better able to create wealth, more likely to be involved in developing new products and R&D, and more self-sufficient in smaller and larger organisations alike. According the authors, this results in a willingness of employers to pay higher salaries to graduates from entrepreneurship majors.

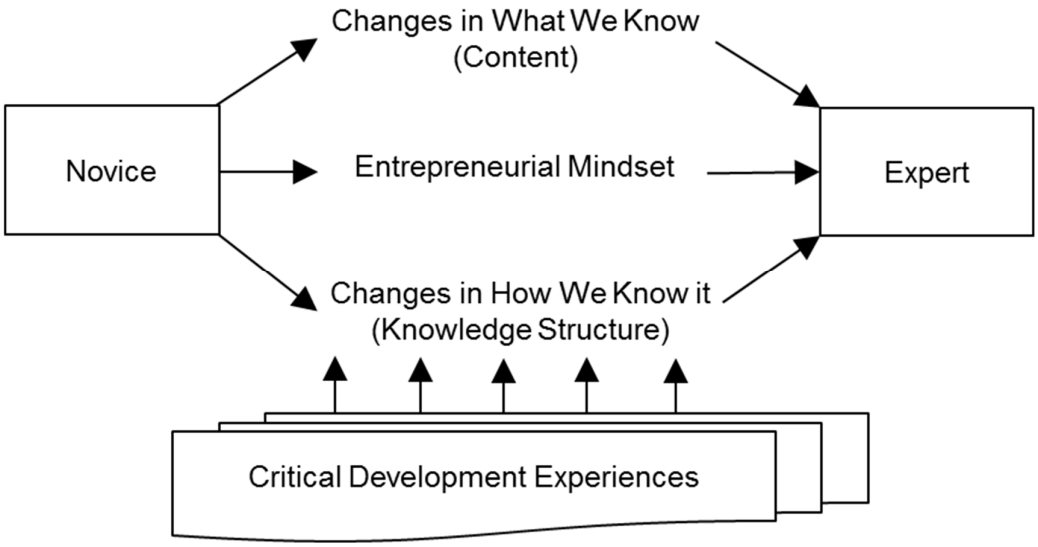
In his study on the status quo and prospective developments of entrepreneurship education, Kuckertz (2013) points out an interesting distinction about goals of entrepreneurship education programmes. He separates potential goals in three categories. Programmes can either focus on educating people to become entrepreneurs, or on making them better entrepreneurs, or on establishing entrepreneurship as a valid career option in

addition to more traditional careers. In his opinion, entrepreneurship educators should largely focus on the third option. This implies that entrepreneurship as a subject needs to be taught differently than other business topics (Neck & Greene, 2011; Penaluna & Penaluna, 2008).

2.3.2. The Expert Entrepreneurial Mindset

There have been many debates, both academic and professional, on how to become an expert at a specific task (Cross, 2004; Ericsson & Charness, 1994; Ho, 2001). In their prominent study, Ericsson and Charness (1994) looked at experts from a diverse set of professions, such as chess grandmasters, musicians, and pole vaulters. They argue that these experts certainly possess a lot of knowledge about their profession, but not necessarily more than novice colleagues. What set them apart from novices in those professions is how these experts have structured their knowledge. They conclude that, contrary to common belief, expert performance can be developed and is not an innate trait which people are born with. In the entrepreneurship community, Krueger et al. wrote several published articles and book chapters linking the discussion of expert performance with the on-going debate on how entrepreneurial mindsets can be developed (Kaffka & Krueger, 2012; 2007, 2009; Neergaard et al., 2012). Much like Ericsson and Charness (1994), they argue that a novice entrepreneur and an expert entrepreneur do not necessarily need to differ in the knowledge they possess. Rather, there will be differences in how this knowledge is structured and subsequently applied. Krueger writes that expert entrepreneurs “consistently and reliably follow recognisable, if highly complex, cognitive behaviours and processes” (Krueger, 2007, p. 123).

Figure 2.7: From Novice to Expert Entrepreneur



This figure was adapted from Krueger (2009, p. 38).

The progression from novice to expert entrepreneur suggested by Krueger (2009) is shown in Figure 2.7. In this model, three areas need to be addressed in the development from novice to expert. First, an entrepreneurial mindset needs to be developed. As many authors have shown, entrepreneurs have a different way of seeing the world, which includes various facets such as opportunity recognition, achievement motivation, propensity to take risks, and locus of control (Brandstätter, 2011; Collins et al., 2004; Gedeon, 2014; Parker, 2006; Rauch & Frese, 2007; Shane et al., 2003; Stewart & Roth, 2007). Second, novice entrepreneurs need to be given opportunities to learn and build knowledge about the different aspects of entrepreneurship. In past decades, this has largely been seen as the main objective of entrepreneurship education, as will be explained in the next section. Third, novice entrepreneurs need to develop an individual knowledge structure, which allows them to act on their acquired knowledge and leverage their entrepreneurial mindset. According to Krueger (2007, 2009), novice entrepreneurs also need to be provided with learning environments, which allow them to rearrange what they already know (knowledge structure), so

that they can reframe that knowledge to fit their entrepreneurial aspirations. When forming expectations about entrepreneurial activities, entrepreneurs give much greater weight to their prior beliefs. On average, new information (vs. prior knowledge and beliefs) only accounts for around 16 % when entrepreneurs are thinking about such decisions (Parker, 2006). The most important part in the model proposed by Krueger (2009) are the critical development experiences. These learning experiences allow novice entrepreneurs to continuously learn about their environment and themselves, adjust their knowledge structure, and act on identified opportunities. Krueger (2007, 2009) strongly links the facilitation of such experiences to constructivist entrepreneurship education pedagogy. Only if students are able to continuously test and anchor their cognitive changes through critical experiences (e.g. working on an start-up project while being supervised by experienced mentors) will the education intervention have a lasting effect (Krueger, 2007, 2009).

2.3.3. Experiential Entrepreneurship Education

Experiential learning practices are now considered to be the status quo of effective entrepreneurship education (Krueger, 2007, 2009; Kuratko, 2005; Löbler, 2006). Whereas an objectivist approach focuses largely on conveying skills and facts through rote memorisation and repetitive drilling, a constructivist experiential learning approach focuses on mechanisms which encourage students to come up with their own ways of structuring their knowledge (Krueger, 2009). Fiet (2000a) as well as Krueger (2009) explain that constructivist pedagogy is much closer to how people actually learn in their daily lives: By trial-and-error while being embedded in a social setting.

Scott et al. (2016) argue that experiential learning is potentially more effective than traditional objectivist entrepreneurship education. The authors claim that experiential learning likely improves the achievement of learning outcomes, especially in teamwork-based entrepreneurship education, although this claim has not yet been sufficiently backed up by rigorous research. It is not surprising that almost all recent successful entrepreneurship teaching initiatives, especially outside university settings, favour a constructivist

approach, which is in line with current research on entrepreneurial learning (Fiet, 2000a; Gedeon, 2014; Krueger, 2007, 2009; Löbler, 2006). Tynan et al. (2016 forthcoming) point out, that this form of project-based learning-by-doing education is already liberally accepted in design education. Many universities are now embracing the idea of more constructivist approaches for learning, especially for entrepreneurship-related subjects, but as Turgut-Dao et al. (2015) illustrate, regulatory requirements such as semester-based class schedules, credit point requirements, and grading regulations make the transition away from behaviourist approaches difficult.

Penaluna and Penaluna (2009) caution that overly restrictive curricula, where students are driven towards precisely pre-determined goals and outcomes, significantly impede the potential of team-based experiential entrepreneurship education. Penaluna and Penaluna (2008) argue that teachers need to respond to the practicalities of entrepreneurship education. In the constructivist experiential entrepreneurship education paradigm, the roles of teacher and student are deliberately blurred. Within the learning process, it is the aim of the educator to frequently answer learner's questions with theory (Krueger, 2007). Krueger (2007, 2009) has identified mentoring and focused feedback as an effective way to evolve both the mindset and the business ideas of entrepreneurs. According to Penaluna et al. (2014) as well as Scott et al. (2015), this requires the educator to shift into the role of facilitator and collaborator who engages with the student's own thinking. Regular presentations and pitches help the entrepreneurs to reflect on various aspects of their business ideas and act as "catalysts" for their learning process (Kaffka & Krueger, 2012). These presentations should be followed by a process of constructively critiquing each student's approach and results (Penaluna & Penaluna, 2009). Fiet (2000a) even argues for a student-approved system wherein educators obtain the approval of students on the specifics of the course structure and content. The author explains that this intensifies the commitment of each student to be in-charge of their own learning and increases the effect of entrepreneurship education overall. This means that the learning process needs to be guided by the student's thought process and not by the educator's (Löbler, 2006). Students' suppositions

need to be addressed to allow them to find meaning in the course content (Brooks & Brooks, 1999). Lectures should therefore predominantly rely on coaching as well as mentoring and not on traditional lecturing. Fiet (2000a) therefore suggests structuring class activities and projects according to what the students want to do to practice their skills. He also suggests that the educators should frequently back up answers to students' inquiries by relating it to relevant entrepreneurship theory. This process is aided by a less formal style of interaction between students and educators as well as by peer-learning among the students (Krueger, 2009). According to Jones et al. (2014), the way in which students in experiential entrepreneurship education settings are assessed also needs to be given more attention in the future, so that ways can be found to incorporate the assessment into the ongoing learning activities of the students.

2.3.4. Measuring the Impact of Entrepreneurship Education

As Krueger (2009) as well as Jones and Penaluna (2013) point out, entrepreneurship researchers are still uncertain about the exact constructs and metrics which should be used to adequately evaluate the effects of entrepreneurship education. Entrepreneurial behaviour tends to be sporadic, not easy to observe and contains irregular time lags (Kautonen et al., 2015; Krueger et al., 2000). The effects of entrepreneurship education are also hard to measure, because they do not necessarily influence career choice directly (von Graevenitz et al., 2010). Many graduating students chose to work in an industry position for several years before they consider starting their own venture. Most metrics currently in use are not accurately measuring the impact of entrepreneurship education programmes on students (Lorz et al., 2013). Fiet (2000b) even argues that the field of entrepreneurship education has not yet evolved enough to be able to provide a consistent theoretical framework on how to train people in entrepreneurship. Not being able to build on such a common theoretical framework makes measurement developments difficult and inconsistent across the available research studies on this matter. Therefore, much of the available studies regarding the impact of entrepreneurship education have focused on measuring different

antecedents of entrepreneurial behaviour, such as self-efficacy, risk-perception and creativity (Fayolle et al., 2006). So far, one of the most commonly used and accepted antecedent is entrepreneurial intention (Kautonen et al., 2015; Krueger et al., 2000) which is based on Ajzen's Theory of Planned Behaviour (Ajzen, 1991).

In their recent quantitative meta-analysis of entrepreneurship education outcomes (42 individual samples, n = 16,657), Martin et al. (2013) caution readers about a number of methodological weaknesses among the analysed studies. They explain that especially those studies with lower methodological rigor were bound to overstate the effect of entrepreneurship education. In a recent systematic review of the methods of impact studies of entrepreneurship education programmes, Lorz et al. (2013, p. 123) conclude that many of the recently published impact studies show significant methodological deficiencies. The authors question the "overwhelmingly" positive impact of entrepreneurship education which has been portrayed in recent publications. Likewise, in their review of empirical studies from the last decade on the outcomes of university-based entrepreneurship education, Rideout and Gray (2013) argue that a majority of entrepreneurship education programmes still lack evaluation methodologies that are robust enough to produce dependable results.

2.3.5. Linking Entrepreneurship Education and Design Thinking

Jones et al. (2014, p. 771) state that entrepreneurship education "has much to gain from working closer with the arts and other areas where creativity, problem solving and exploration are commonplace". Many concepts formulated in the domain of design thinking show parallels to current practices in entrepreneurship education. In general, the formulation of wicked problems in design theory bears great resemblance to the problems encountered by entrepreneurs (see Section 2.2.8). In both fields, tools have been formulated to allow educators and students to quickly dive into project-based learning (see Section 2.2.3). Both fields favour multidisciplinary and team-based approaches to learning (see Section 2.2.4). Both in entrepreneurship as well as in design theory, process models have been

formulated to guide practitioners through the discovery and execution phases in iterative ways (see Section 2.2.6). Furthermore, both streams of practice ultimately strive towards the development of attitudes and behaviours as well as creative confidence which allow practitioners to continuously adapt and improve their potential (see Sections 2.2.5 and 2.2.7). Therefore, both Penaluna et al. (2010) as well as Tynan et al. (2016 forthcoming) have pointed to an increasing recognition of the benefits of incorporating design-based methodologies into entrepreneurship education. The authors argue that design thinking may enrich entrepreneurship education by teaching students to solve challenging problems in more creative ways, whilst better being able to cope with the inherent uncertainty and ambiguity of business problems.

2.4. Kolb's Learning Styles

2.4.1. Kolb's Experiential Learning Theory

Experiential Learning Theory (ELT) provides a holistic model of the learning process and a multilinear model of adult development (Kolb & Boyatzis, 2001). Initially, it was developed by David Kolb. Other researchers have since added to its theoretical development. ELT draws from previous learning models formulated by notable psychologists such as John Dewey, Kurt Lewin and Jean Piaget (Kolb, 1984). ELT was first conceived in 1969 as a self-assessment exercise for a curriculum development project at MIT (Kolb & Kolb, 2005a). In the more than 40 years since its initial publication, it has been applied to research in many different fields, from education to management to information science (Kolb & Boyatzis, 2001). In one of the early publications on ELT, Kolb (1984, p. 41) states that learning is defined as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience". Another way to think about ELT is by contrasting it to the behaviouristic learning approaches which have dominated the first half of the last century (Kolb, 1984). In behaviouristic learning, reading and hearing about phenomena and reinforcing those stimuli was emphasised over the value of conscious experience in learning and directly being in touch

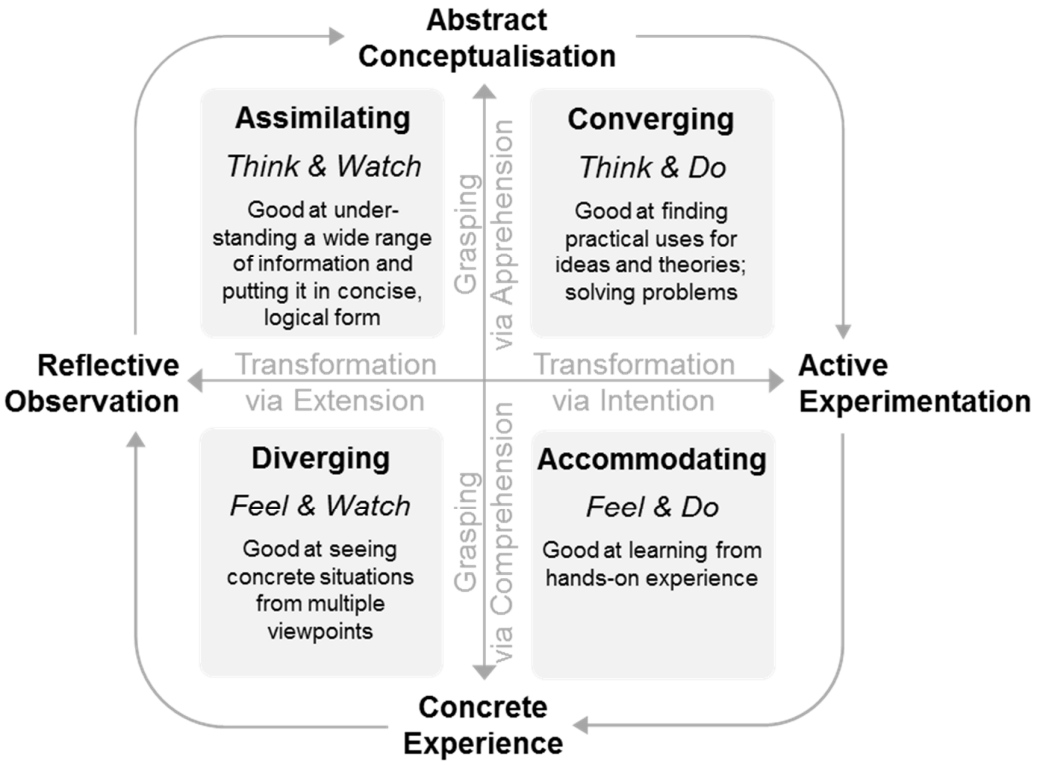
with reality (Kolb, 1984). Kolb and Kolb (2005b) explain that ELT builds on the following six propositions based on earlier research on human learning and development. First, learning should be thought of as a continuing process. Second, "[all] learning is *re*learning" (Kolb & Kolb, 2005b, p. 194). Third, learning depends on the resolution of conflict amongst contrasting approaches of coping with the world (this will be described in more detail in the next section). Fourth, learning should be thought of as a holistic process of adapting to the world. Fifth, learning happens when people interact with their environment. Sixth, learning is a constructivist activity and depends on the learners to create knowledge for themselves.

2.4.2. Kolb's Four Learning Styles

ELT argues that learning depends on the ability to choose between opposite modes of apprehension (or grasping information) and opposite modes of transforming stimuli, depending on the specific context where the learning experience occurs (Kolb, 1981). The two modes of grasping experience are concrete experience and abstract conceptualisation. The two modes of transforming experience are reflective observation and active experimentation (Kolb & Boyatzis, 2001). The opposing modes of grasping and transforming stimuli as well as the resulting learning styles are visualised in Figure 2.8.

Based on the different modes of thinking, the following four learning styles can be defined: (1) Assimilating, (2) Converging, (3) Accommodating, and (4) Diverging (Beckman & Barry, 2007). Lau et al. (2012) note that a fifth learning style might be described as Balanced, which applies if an individual has no strong preference for grasping and transforming information. Usually, individuals are able to grasp and transform knowledge in all four learning styles, but overall will favour one preferred learning style (Kolb & Kolb, 2005a). Individual learning style preferences are relatively fixed states (Corbett, 2005).

Figure 2.8: Kolb's Learning Styles Model



This figure is based on Beckman and Barry (2007, p. 28+47) and prior models by Kolb (1981; 1984, p. 235) with additional labels (transformation and grasping) adapted from Corbett (2005, p. 480).

Kolb's Learning Style Inventory (LSI) is the most broadly established learning style classification and has overall received strong empirical support from the research community (Manolis et al., 2013). However, some scholars have raised concerns about its construct validity (Metallidou & Platsidou, 2008), the use of categorical rather than continuous classifications (Manolis et al., 2013), and the overall approach from a modelling perspective (Bergsteiner et al., 2010).

2.4.3. Application in Innovation Projects

Beckman and Barry (2007) as well as Corbett (2005) are among a group of researchers who are actively discussing the links between Kolb's model and

innovation processes. These authors speculate that your primary learning style will influence innovation tasks in which individuals will excel. For example, if someone favours a diverging learning style, they will likely perform well in idea generation tasks. Individuals who favour an assimilating learning style tend to show a certain ability to take many different pieces of information and structure them into logical frameworks. Individuals who prefer a converging learning style usually exhibit a preference for technical tasks, while individuals who primarily employ an accommodating learning style will tend to excel in hands-on experimental tasks.

Both Beckman and Barry (2007) as well as Corbett (2005) discuss the perspective of viewing successful new product development projects as analogous to learning experiences, where innovation teams cycle through all four learning styles. A typical team-based innovation project would start in the diverging phase where the team engages in customer research, observations and an analysis of the context. The team would then assimilate the new information, look for insights and structure the information in logical frameworks. Afterwards, the team would move on to the convergent phase, in which the team frames clear points of view and starts to generate novel ideas to solve the identified problems. The new product development (NPD) cycle would finish with accommodating these novel ideas into concrete products or services. The cycle might be restarted by bringing these concrete products back into the diverging phase (the context or real world) to refine them by going through the different steps once more.

Kayes et al. (2005) have found that teams composed of individuals representing all four learning styles frequently outperform other teams in similar tasks. Their findings are backed up by Halstead and Martin (2002), who have specifically looked at the composition of engineering student teams and their performance. Beckman and Barry (2007) have therefore concluded that individuals with different learning style preferences must be matched to create high-performance innovation teams. Beckman and Joyce (2009) also reveal that, according to their experience in teaching design thinking to MBA students, high performance teams will rotate leadership positions according

to the preference of learning styles matched to the current task at hand within a project.

In research focusing specifically on graduate student's learning styles and NPD teams, Lau et al. (2012) discovered that the more convergent learning types are on a team, the poorer the overall team result will get. Similarly, Glen et al. (2015) argue that students with a converging learning style may find dealing with the inherent ambiguity and uncertainty within a design thinking project difficult (see Section 2.2.7). This contradicts research on undergraduate design student performance by Demirbas and Demirkan (2007) who have found that students with a converging learning style perform significantly better than those with a diverging learning style. As Carmel-Gilfilen (2012) indicate, the preference of learning styles tends to correlate with specific subjects students are studying. In their research study, the authors discovered that, for example, interior design and architecture students have a stronger preference for diverging and accommodating learning styles when compared to a normative dataset. Armstrong and Mahmud (2008) also argue that managers who are accommodators have significantly higher levels of accumulated managerial tacit knowledge.

2.5. The Five-Factor Model of Personality

In general, personality traits can be defined "as dispositions to exhibit a certain kind of response across various situations" (Rauch & Frese, 2007, p. 355). Personality traits summarise individual abilities, motives, attitudes, and characteristics of temperament (Brandstätter, 2011) in overarching response-schemas to external stimuli (Pervin & Cervone, 2010), which influence what individuals feel and think as well as how they behave (Brandstätter, 2011). Personality traits are considered consistent qualities with high degrees of longitudinal, cross-cultural, and cross-situational stability (Pervin & Cervone, 2010).

Such personality trait taxonomies enable researchers to distinguish human personality at a general level (Norman, 1963). This allows scholars to differentiate and segment individuals into distinct groups of people, which can

be compared and contrasted (McAdams & Pals, 2007), e.g. in terms of their general attitudes and behaviours.

In entrepreneurship research for example, entrepreneurs and corporate innovators are often depicted as noticeably different from e.g. managers or employees of large companies (Stewart & Roth, 2001, 2007; Zhao et al., 2010). Rauch and Frese (2007) characterise entrepreneurs as possessing a unique set of personality traits, such as tenacity, proactiveness, high self-efficacy and need for achievement. In comparison to managers, entrepreneurs show a higher risk propensity (Stewart & Roth, 2001) and a higher achievement motivation (Stewart & Roth, 2007). After comparing the entrepreneurial activity of 870 monozygotic and 857 same-sex dizygotic twins from the UK, Nicolaou et al. (2008) conclude that differences in personality traits and their effect on the propensity to become entrepreneurs can partly be explained by genetic factors.

Personality traits research has a long history within psychology and adjacent fields (McAdams & Pals, 2007). One of the most widely used personality traits models is the Five Factor model of personality (John & Srivastava, 2001; McCrae & John, 1992; Paunonen & Ashton, 2001). It measures the five traits of openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Due to their broad nature, these five traits are commonly referred to as the *Big Five* personality traits, a term coined by Goldberg (1981). As John and Srivastava (2001) note, this name does not imply that all differences of individual personalities can be accurately represented with only these five traits. The Big Five should rather be seen as an abstraction of more complex psychological concepts, where each broad trait summarises a number of lower-level facets.

The Five Factor Model of personality builds on the central assumption that all personality traits relevant for describing human personality are encoded in the natural human language. This assumption is called the lexical hypothesis (Allport & Odbert, 1936; Goldberg, 1981; John & Srivastava, 2001; Pervin & Cervone, 2010). For this reason, early personality traits researchers such as Klages (1932), Baumgarten (1933), and Allport and Odbert (1936) turned to

dictionaries as a comprehensive source for this encoded information. Allport and Odbert (1936) began classifying and clustering terms which were used to distinguish human behaviour within everyday common language and came up with a list of almost 18,000 terms which were drawn from English dictionaries (Goldberg, 1981). These terms were then classified and clustered into mutually exclusive categories, which could be used to differentiate human behaviour. In an effort to construct a multi-dimensional model of human personality, Cattell (1943) used factor analysis to further reduce these terms to 35 distinct categories. Almost 20 years later, several authors such as Tupes and Christal (1961, republished 1992) and Norman (1963) re-examined the statistical correlation of the available datasets and concluded that five factors were needed to distinguish human personality at a general level. Several assessment tools to measure these five traits and their corresponding facets were later developed, for example by Costa and McCrae (Costa & MacCrae, 1992; McCrae & Costa, 2004) and Goldberg et al. (Goldberg, 2011; Goldberg et al., 2006).

In adulthood, once a person's personality has fully formed, the Big Five personality traits model has been shown to have high levels of longitudinal stability (Digman, 1990; Marcati et al., 2008), cross-cultural stability (De Fruyt et al., 2004; John & Srivastava, 2001; Schmitt et al., 2008; Thompson, 2008) and cross-situational stability (Brandstätter, 2011). Gender differences in the Five Factor Model and their connection to entrepreneurial behaviour were identified in several different studies by authors such as Schmitt et al. (2008) and Zhang et al. (2009). In a study by Schmitt et al. (2008), women overall reported higher scores for neuroticism, extraversion, agreeableness and conscientiousness than men (n=17,637 from 55 nations). The authors conclude that "sex differences in personality traits seem to be rather robust, persistent across a diverse array of measures, data sources, ages, and cultures" (Schmitt et al., 2008, p. 169). According to Zhang et al. (2009), the genetic influence on the tendency of people to become entrepreneurs is significantly higher for females than males.

Entrepreneurship research has regained interest in the use of personality aspects and the Five Factor Model of personality through the publication of several meta-analyses linking personality traits with entrepreneurial predispositions and activities (Collins et al., 2004; Rauch & Frese, 2007; Stewart & Roth, 2001, 2007; Zhao & Seibert, 2006; Zhao et al., 2010). In a review of these meta-analyses, Brandstätter (2011) summarises that noticeable differences in personality traits exist between entrepreneurs and managers. Entrepreneurs were found to score higher on contentiousness, openness to experience as well as extraversion, whereas they score lower on neuroticism and agreeableness. Scoring high on conscientiousness, openness to experience, and extraversion as well as scoring low on neuroticism are also weak but significant predictors for both entrepreneurial intention as well as the entrepreneurs' performance. Zhao et al. (2010) explain that people who possess such a personality trait profile are more likely to be drawn to entrepreneurial careers. In a quantitative review of the literature on creative personalities, Feist (1998) concludes that creative people are generally more open to new experiences, self-confident, self-accepting, driven, ambitious, dominant, hostile and impulsive, as well as less conventional and conscientious. In another study, Kao (2016) reports that extraversion and openness to experience generally show a significant correlation with creative thinking. However, Kao (2016) also demonstrates that for students, raised in a Taiwanese cultural setting, agreeableness and conscientiousness have proven to exhibit a larger correlation with creative thinking. Kao (2016) argues that this finding may result from the desire to conform to the characteristics and habits expected of children raised in Taiwanese society.

2.6. Five Research Themes Based on the Literature Review

As several authors have pointed out, design thinking, especially in domains outside of traditional design remains under-researched (Carlgren et al., 2014; Dinar et al., 2015; Hobday et al., 2011; Johansson-Sköldberg et al., 2013; Kimbell, 2011; Liedtka, 2015; Razzouk & Shute, 2012). In their reviews of the available scholarly literature on design thinking, Razzouk and Shute (2012),

Carlgren et al. (2014) as well as Dinar et al. (2015) conclude that rigorous scholarly contributions are especially rare. This section therefore defines five research themes, with the intention of filling several gaps within the current literature on design thinking and therefore providing a contribution to knowledge within this field. These research themes form the nucleus of the empirical research study presented in later chapters.

The first research theme relates to design thinking as a multidisciplinary innovation methodology. In the literature, design thinking is predominantly portrayed as a team-based approach (Alves et al., 2006; Brown, 2009; Fischer, 2000; Kelley & Kelley, 2013; Kelley & Littman, 2006; Lojacono & Zaccai, 2004; von Thienen et al., 2011). As argued in Section 2.2.4, design thinking teams should exhibit high levels of diversity to produce significant output in design thinking tasks. Individual team members should be "T-shaped" and possess a solid foundation in at least one discipline, while also being open towards other perspectives (see Section 2.2.4).

> Theme 1: *How does the degree of diversity in a team affect the application of design thinking?*

The second theme relates to the concept of iteration within design thinking process models. As illustrated in Section 2.2.6, several authors have proposed different formalised process models of design thinking. Each model consists of various connected activities. What these models have in common, is that they are not intended to be applied in a strictly linear manner. It is possible to skip ahead to test a promising assumption or to move back to change the trajectory of a project. For the purpose of this study, this recursive movement was defined as iteration within the design thinking process. An accepted limitation to this measurement strategy was the fact that sideways iteration (e.g. iteration between different prototypes in the same process phase) could not be captured.

> Theme 2: *How do different design thinking teams incorporate the concept of iteration into their projects?*

The third research theme is concerned with the connection of individual learning styles (see Section 2.4) and their effect on design thinking teams. This line of thought was inspired by a conceptual paper by Beckman and Barry (2007). In their paper, the authors argue that there appear to be similarities between the processes of how individuals learn through experience (ELT) and how design thinking projects are sequenced.

> Theme 3: *How do individual learning styles influence teams during different phases of the design thinking process?*

The fourth research theme relates to the levels of feeling effective and at ease during a project. As Brown (2009, p. 64) notes, each phase and activity within a design thinking project "*feels"* different. In his book, Brown (2009, p. 65) proposes a U-shaped model of team confidence throughout a project, with confidence being high at the beginning, declining as the team struggles to discover insights and increasing again towards the end (see Section 2.2.7).

> Theme 4: *When do individuals in design thinking teams feel effective and at ease during a project?*

The fifth research theme is concerned with how multidisciplinary design thinking teams (see Section 2.2.4) collaborate, and what patterns of communication form during the collaboration. Radical collaboration is one of the key attitudes and behaviours inherent in design thinking (see Section 2.2.5). It encourages frequent exchanges of ideas, insights, and information among team members during the design process.

> Theme 5: *What patterns of communication are beneficial to teams during design thinking projects?*

All five research themes build on the fact that design thinking is an inherently applied methodology. Many design thinking projects are embedded in an organisational context (see Section 1.4 and Section 2.2.12), where project outcomes have to be aligned with the requirements of several stakeholders. Deadlines and other goals have to be met, which influences how design

thinking teams operate. Therefore, this research study is also concerned with the following additional question:

> *How do the underlying concepts of research theme 1 to 5 influence design thinking team performance?*

Later, in Section 3.2, the underlying constructs of the five research themes will be operationalised and subsequently developed into testable hypotheses.

2.7. Chapter Summary

Following the distinction proposed by Johansson-Sköldberg et al. (2013) between *designerly thinking*, i.e. how professional designers practice design and *design thinking*, i.e. using design practice and competences beyond the traditional design context, this literature review predominantly focussed on the still evolving domain of *design thinking* and the application of design in a wider context, such as entrepreneurship and innovation. This review intended to provide an extensive overview of the key themes currently discussed under the umbrella term *design thinking*. Although, several connections to the *designerly thinking* literature are drawn to underline key design principles, this literature could not be covered in its entirety. Several *designerly thinking* theories, such as associative theories (especially Gestalt theory) and creativity theories relating to the role of emotions, were therefore out of the scope of this dissertation.

In this literature review, several perspectives on design thinking were developed. In the current literature, design thinking is conceptualised as a collection of tools from the “designer’s toolkit”, leveraging the potential of multidisciplinary teams, a set of attitudes and behaviours, iterative process models, creative confidence as well as by its usefulness in approaching wicked problems. These different perspectives are not mutually exclusive, but rather show that design thinking has different meanings depending on the context where it is applied. Design thinking has also found its way into several university curricula and continues to receive a growing interest from the business community.

As the empirical research study described in the following sections was embedded in a university setting with a strong focus on entrepreneurship, additional background theory on entrepreneurship education, Kolb's learning styles and the Five Factor Model of personality was provided.

The literature review concluded with five research themes based on the critical discussion of the literature. These five themes form the nucleus for the research study presented in the following chapters.

3. Research Methodology and Methods

3.1. Chapter Introduction

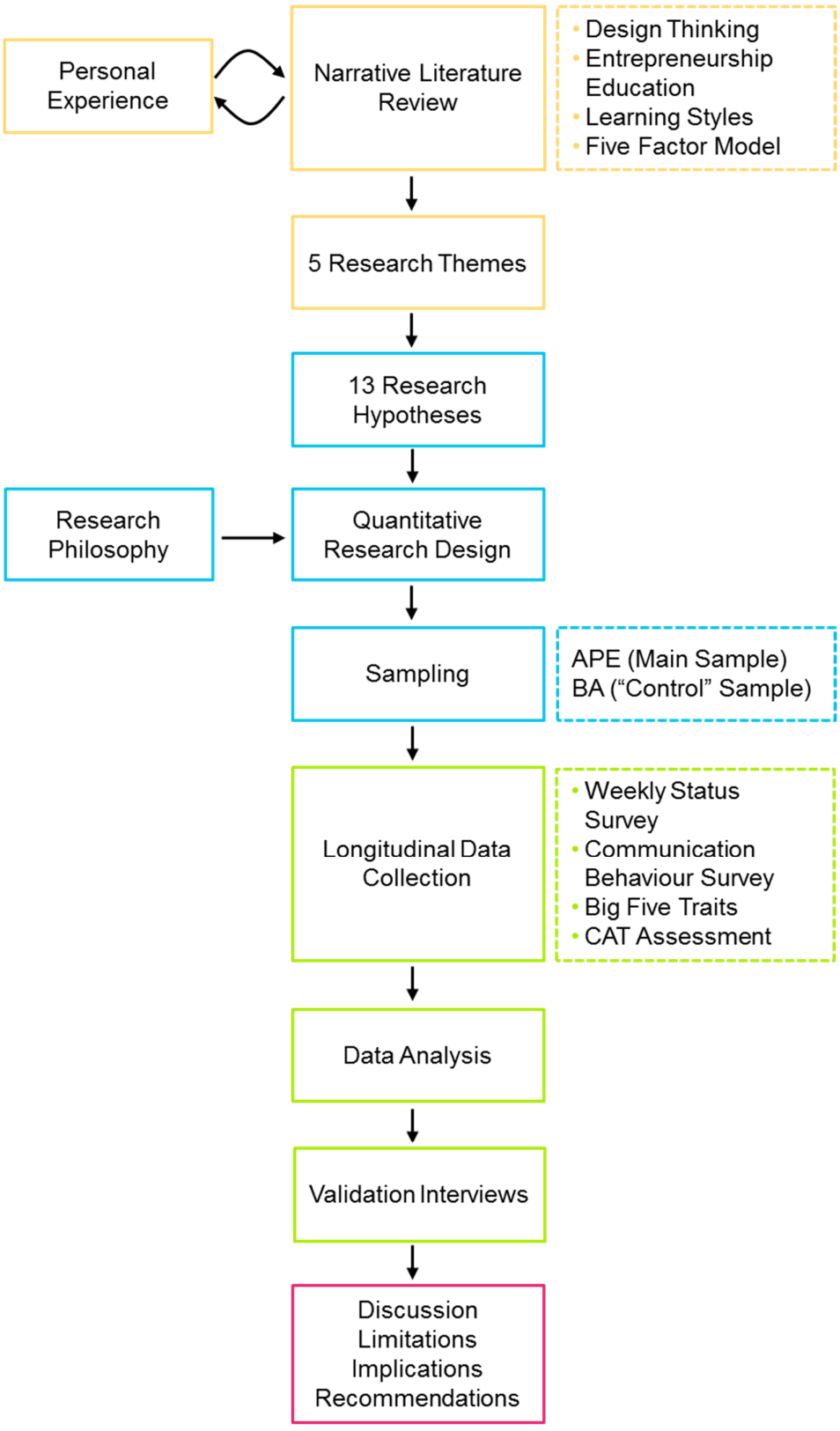
Described in this chapter are the research approach and the specific research methods which guided the empirical research study. Based on the broad research themes presented in Section 2.6, 13 falsifiable hypotheses are introduced. These hypotheses guided the overall research process.

In this chapter, the underlying philosophical assumptions of the researcher are laid out, before introducing the quantitative longitudinal study design. To provide the reader with a clearer understanding of the context of the research study, detailed background information on the different samples is provided. Ethical considerations as well as different criteria for trustworthy research are critically discussed and their implications for the underlying research design presented. Furthermore, details about the data collection procedures and how each research instrument was constructed are provided. A short account of a pilot study, which was conducted prior to the main study, rounds off this chapter.

Although this chapter is split into several sections, readers should keep in mind that good reflective research results from the interplay between these different perspectives (Holden & Lynch, 2004). Overall, this chapter can be considered a “blueprint” (Adams et al., 2007) of the underlying ten-month study presented in later chapters.

A visual flow-chart of the underlying research process is presented in the following Figure 3.1.

Figure 3.1: Flow-Chart of the Research Process



3.2. Research Hypotheses

The following section briefly reviews the five research themes presented at the end of the literature review (see Section 2.6) and introduces several research hypotheses for each theme. These hypotheses were formulated by the researcher after extensively immersing himself in the current literature on design thinking. Each hypothesis was built on a theoretical or empirical gap in the current body of knowledge. It is the intention of the researcher to propose a contribution to knowledge by offering methodologically sound evidence to narrow these theoretical gaps.

The hypotheses are being presented in five groups, corresponding to the five larger research themes. The hypothesis statements helped to direct the data exploration and analysis. To simplify this analysis chapter, the null-hypothesis (H_n) for each alternative hypothesis (H_a) is not explicitly stated (Adams et al., 2007). For each stated hypothesis it can therefore be assumed that the null-hypothesis states that there was no significant effect. Each hypothesis was devised to be testable, falsifiable, and verifiable by other researchers (Lorz et al., 2013).

Theme 1: Team Diversity

The first theme looked at how different degrees of team diversity affect the application of design thinking.

Many different authors have argued that design thinking is a multidisciplinary innovation methodology (see Section 2.2.4). Design thinking teams should therefore incorporate team members from various disciplinary backgrounds. Overall, this was expected to improve possible outcomes of design thinking project.

> Hypothesis 1a: *Multidisciplinary design thinking teams achieve a better final performance than single-discipline teams.*

Subsequently, the argument for team diversity was extended to include other measures of diversity, such as personality traits (see Section 2.5). Analogous to the previous hypothesis, teams with a high degree of diversity of

personality traits were expected to enrich design thinking activities with many different points of view. This was expected to result in better project outcomes.

> Hypothesis 1b: *Design thinking teams with a high degree of diversity of personality traits achieve a better final performance than those teams with a low degree of diversity.*

Theme 2: Iteration

The second theme examined how different design thinking teams incorporate the concept of iteration into their projects. For the purpose of this study, iteration has been conceptualised as recursive movement in the design thinking process.

It has previously been argued that, multidisciplinary teams are expected to more deeply engage with the problems and choices faced in design thinking projects. Multidisciplinary teams construct a rich shared mental model, which in turn results in more diverse points of view and a deeper reflective practice of design thinking (see Section 2.5). It was therefore expected that a more iterative approach concerning the several connected activities within the design thinking process is needed to explore and reconcile these multiple perspectives (see Section 2.2.6).

> Hypothesis 2a: *Multidisciplinary design thinking teams iterate more than single-discipline teams.*

Design thinking is generally described as an iterative methodology, despite existing linear formulations of the design thinking process (see Section 2.2.6). Over time, individuals are expected to grow more confident in the application of design thinking and develop are more elaborate and intuitive problem-solving strategies (see Section 2.2.7 and Section 2.2.10). It was therefore assumed that through experience, individuals are better able to appreciate iteration as a feedback and learning mechanism for their projects.

Hypothesis 2b: *More experienced design thinking team iterate more than novice teams.*

The concept of iteration is highlighted in multiple key publications on design thinking. It is described as an elementary principle of formalised design thinking process models (see Section 2.2.6). It was therefore assumed that the more a team iterates within a design thinking projects, the better it performs.

Hypothesis 2c: *More iteration during a design thinking project leads to a better final performance.*

Theme 3: Learning Styles

The third theme explored how different learning styles influence teams during the different phases of the design thinking process.

In Kolb's experiential learning styles model, individuals are expected to (repeatedly) cycle through four different modes of learning (see Section 2.4). Beckman and Barry (2007) have argued that there appear to be many similarities between how individuals learn through experience (ELT) and how design thinking projects are sequenced. It was therefore hypothesised that individuals in design thinking projects cycle through Kolb's learning styles in the suggested sequential order.

Hypothesis 3a: *Each member of a design thinking team cycles through Kolb's learning styles during a project.*

Experiential Learning Theory (ELT), and specifically Kolb's learning styles theory, argues that the utilisation of multiple learning styles leads to deeper learning, a quality also needed for successful design thinking innovation projects (Beckman & Barry, 2007). Achieving a balance of learning styles throughout a project, allows teams to constantly evaluate available information from multiple perspectives and potentially make better decisions. Hence, the author argued that this also influences the outcome of design thinking projects.

Hypothesis 3b: *Design thinking teams which demonstrate a balance of the four Kolb learning styles achieve a better final performance than those teams who do not.*

Theme 4: Perceived Effectiveness and Ease

The fourth theme studied the instances when individuals in design thinking teams feel effective and at ease during a project.

In his popular book on design thinking, Brown (2009) theoretically posits that creative confidence follows a U-shape throughout a project, with confidence being high at the beginning, declining as the team struggles to discover insights and increasing again towards the end (see Section 2.2.7). The author posited that how effective and how at ease one feels in the application of design thinking are two specific facets of the concept of creative confidence. Both variables were therefore expected to develop in a similar pattern.

Hypothesis 4a: *Perceived effectiveness and ease follows a U-shape throughout a project.*

Creative confidence and informed intuition in the application of design thinking develop over time (see Section 2.2.7). Hence, the author hypothesised that once these qualities are developed to a certain extent, they can be transferred to new projects and teams.

Hypothesis 4b: An *individual's perceived effectiveness and ease in the application of design thinking carries over to new projects and teams.*

In Section 2.2.11, it has been argued that the development of creative confidence is one of the most fundamental goals of design thinking education. Developing creative confidence allows innovators to trust their own problem-solving abilities and enables them to feel more comfortable with the inherent uncertainty and ambiguity of wicked problems in design thinking (see Section 2.2.7). It was therefore expected that higher levels of creative confidence within a team, and therefore higher levels of perceived

effectiveness and ease, positively influence the outcome of design thinking activities.

> Hypotheses 4c: *Teams comprised of individuals with high levels of perceived effectiveness and ease achieve a better final performance.*

Theme 5: Teams as Networks

The fifth theme investigated what patterns of communication are beneficial to design thinking teams from a network perspective. Social network analysis was used in the exploration of this theme. As Zenk et al. (2010) point out, most studies on networks and performance focus either on individuals or the organisational level. The exploration of this research theme was therefore focused on innovation teams as the unit of analysis.

The process of design thinking is best thought of as a set of connected activities (Brown, 2009). Each of these activities favours a slightly different skill-set. Based on their experience, Beckman and Barry (2007) suggest that good groups rotate leadership positions and specific roles within a team based on each team member's skill-set. When analysing design thinking team structures from a social network perspective, it was therefore expected that how important an individual is to his/her group changes throughout a design thinking project. Building on social network theory, individual importance within a team was conceptualised as a ranking order based on individual eigenvector centrality scores.

> Hypothesis 5a: *The relative importance of individuals changes throughout a design thinking project.*

Team cohesion is seen as a precondition to functioning innovation teams as it leads to more exploratory behaviour (Hülsheger et al., 2009). Radical collaboration and the frequent exchange of ideas and insights are thought to be one of the principles of design thinking (see Section 2.2.5). Teams who excel in both these behaviours were therefore expected to achieve superior performance in design thinking projects.

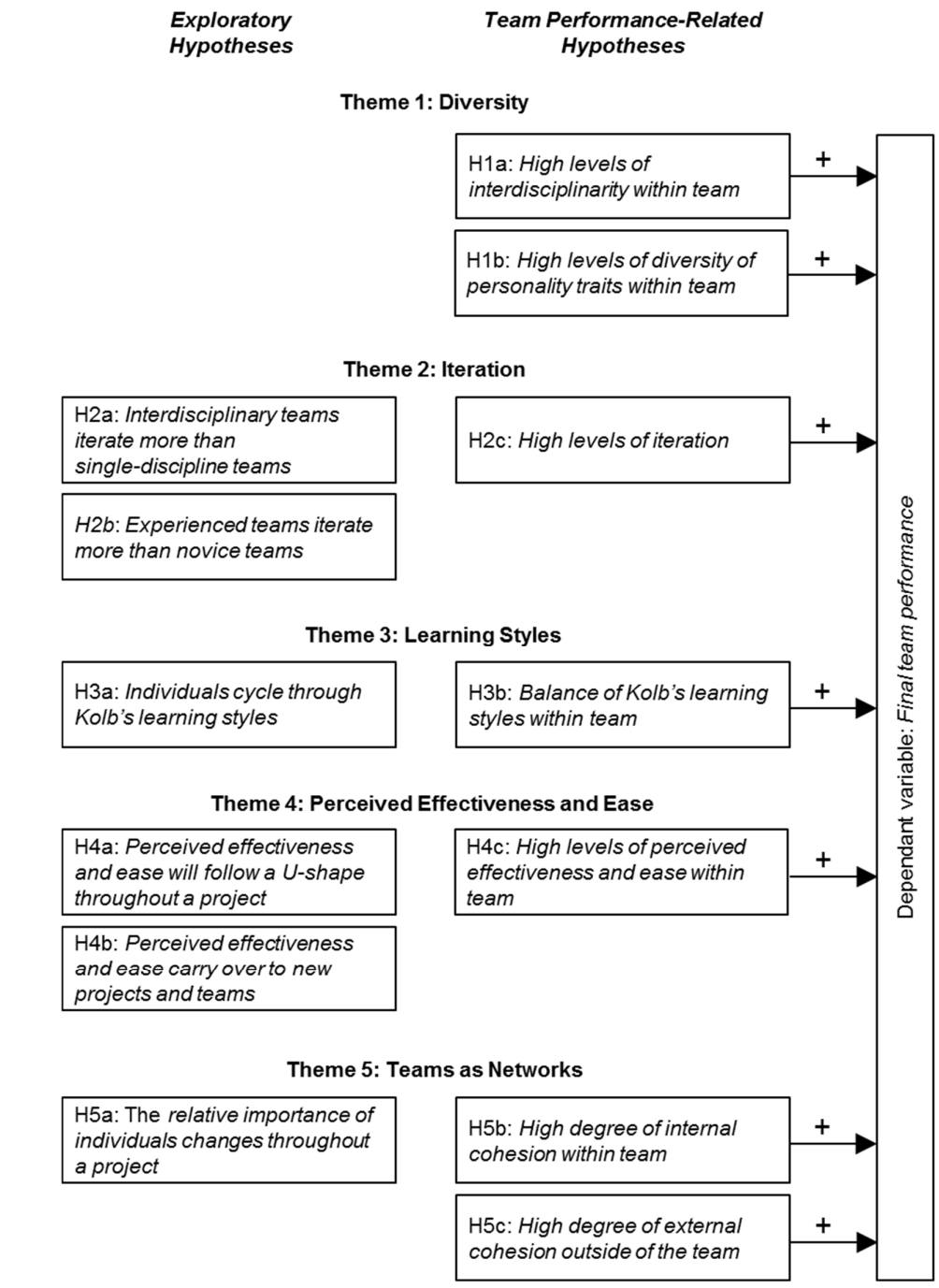
Hypothesis 5b: *Design thinking teams with a high degree of internal cohesion achieve a better final performance than teams with a low degree of internal cohesion.*

Similar to the previous Hypothesis 5b, radical collaboration and the frequent exchanges of ideas beyond one's own team were expected to enrich and inform the decision made within a team (see Section 2.2.5). External cohesion generally enables a design thinking team to benefit from outside perspectives and expertise. This allows a team to enrich its reflective practice and improve its internal decision-making. Teams with high external cohesion were therefore expected to achieve superior performance in design thinking projects.

Hypothesis 5c: *Design thinking teams with a high degree of external cohesion achieve a better final performance than teams with a low degree of external interaction.*

The five presented research themes and the corresponding 13 research hypotheses are further explored in the quantitative research study presented in Chapter 4. A visual summary of the themes and hypothesis is provided in the following Figure 3.2.

Figure 3.2: Summary of Research Hypotheses



3.3. Research Philosophy

Research philosophy describes the researchers' worldviews which they bring to their research (Creswell, 2013). As Holden and Lynch (2004) and Huff (2009) point out, one's personal stance on research philosophy should guide the choice of research design and specific research methods, not vice versa. Therefore, the author's own ontological and epistemological positions are discussed in the following sections, before continuing to describe this study's research design and specific research methods.

Ontology deals with the question of what exists (Gephart, 2004; Guba & Lincoln, 1994; Huff, 2009) and what we as people can actually know about the world. It is concerned with the nature of reality and debates if things can have an independent existence or whether reality is mainly constructed in peoples' minds (Holden & Lynch, 2004). This study was informed and guided by the author's realist ontological worldview. As a critical realist it is the authors belief that the social world exists independent of the labels and interpretations people assign to things and phenomena in it (Gephart, 2004; Guba & Lincoln, 1994; Huff, 2009).

Epistemology, on the other hand, deals with what human beings can know about what exists and how they can know it (Gephart, 2004; Guba & Lincoln, 1994; Huff, 2009). In other words, it discusses the nature of knowledge and how people might gain new knowledge about the world (Holden & Lynch, 2004). The author's own epistemological stance is that of "post"-positivism (Creswell, 2013; Gephart, 2004; Guba & Lincoln, 1994). In general, positivistic theory building follows a deductive approach (Bryman & Bell, 2011; Creswell, 2013; Huff, 2009). First, a theoretic statement is made about how variables or phenomena might interact with each other. Such a statement can be derived from gaps in the current body of knowledge or by logical deduction. Second, the theoretical statement is operationalised, so that it can be observed in a real-world setting. Third, tests are run to see if the observation proves or negates the theoretical statement. This then allows researchers to solidify or adjust existing theory or build new theory. Following Creswell (2013), Gephart (2004) as well as Guba and Lincoln (1994), the

approach of this research project can be described as “post”-positivism. Post-positivism stands for the thinking after traditional positivism, which was and generally still is the most common position in natural sciences. As Creswell (2013) explains, the post-positivist position was introduced to recognise that one cannot have absolute claims of knowledge when researching the actions and behaviour of people.

Through this description, the author attempted to isolate his personal philosophical position to more clearly articulate his own philosophical assumptions about research. Nonetheless the author also agrees with Holden and Lynch (2004) who note that, although philosophical positions are often clarified as extremes, most of the current business researchers use a more moderate position. They argue that only an intermediate stance between positivist and constructivist positions will allow researchers the possibility to conduct meaningful research in the fields of business and innovation.

3.4. Quantitative Research Design

Based on the author’s postpositivist research philosophy and the underlying research questions, a primarily quantitative research design was chosen for this study. Quantitative research, in general, aims to test objective theories through analysing relationships and connections among definable variables. These variables are operationalised by turning them into research instruments which are used to collect data, typically in the form of numbered data (Creswell, 2013). The overall research design is fully established before the data collection begins (Adams et al., 2007). According to Huff (2009), typical goals of quantitative research are to make inferences and predictions, to provide descriptions of patterns in larger datasets, to test hypotheses, as well as to expand the range of theoretic explanations. Collected data is analysed by means of statistical procedures (Huff, 2009). With a solid quantitative research design, researchers try to protect against several types of biases as well as control for alternate explanations to allow for the generalisation of the findings to a larger population than the underlying sample (Creswell, 2013).

Quantitative research can be contrasted with qualitative research (Adams et al., 2007). In qualitative research typical goals include offering explanations of how and why things happen, providing detail and depth for abstract theoretical concepts, connecting conceptual ideas to human experience, exploring a context to seek previously unacknowledged antecedents and finding new angles for future research (Huff, 2009). As has been pointed out by different researchers, these two approaches should not be seen as mutually exclusive (Bryman & Bell, 2011; Creswell, 2013). Research projects are usually either of a more qualitative or more quantitative nature.

Common critique of quantitative research includes its tendency to oversimplify phenomena (Huff, 2009), being reductionist (Adams et al., 2007), ignore subjectivity of definitions and procedures (Huff, 2009), and more generally, the fact that the success of positivist quantitative research in the natural sciences has so far not been able to be repeated in the social sciences (Holden & Lynch, 2004).

A quantitative research design based on a post-positivist would traditionally prescribe an outsider-perspective of the researcher with only minimal interaction with the research subjects. However, it cannot be denied that the "native" insider-approach of the researcher's during the study did not influence the interpretation of the collected data. However, as Brannick and Coghlan (2007) have highlighted, if it is carefully planned, a "native" insider-approach in academic research is commensurable with a positivist research philosophy and allows the researcher to use the often exclusive access and the pre-understanding of the research context to their advantage.

3.5. Longitudinal Research

A majority of the identified research themes in this focused on different phenomena of design thinking teams across time (see Section 3.2). Therefore, a longitudinal research design was chosen to allow the researcher to examine these phenomena in a comprehensive way.

Generally, longitudinal studies measure data over time (Ruspini, 2000). This means that data is collected from a cohort of research subjects or a similarly composed sample of subjects for a repeated number of times (Adams et al., 2007). This approach is especially helpful if researchers are interested in understanding changes in individuals and systems (Ployhart & Vandenberg, 2010). In contrast to cross-sectional research, longitudinal research produces a form of dynamic data which lends itself well to the analysis of dynamic processes (Ruspini, 2000). It also offers advantages in detecting causal orders between variables which might be left undetected in a cross-sectional study (Adams et al., 2007; Menard, 2008; Ruspini, 2000). The analysis of such data generally focuses on comparing cases across different points in time (Ployhart & Vandenberg, 2010).

As Ployhart and Vandenberg (2010) note, most theories in organisation sciences are explicitly or implicitly of a longitudinal nature, yet the vast majority of research employs cross-sectional designs. This can also be observed in the currently growing body of literature and empirical studies on design thinking. Besides a few interesting longitudinal studies (e.g. Beckman & Speer, 2006; Kröper et al., 2010) most researchers collect and analyse cross-sectional data. Ployhart and Vandenberg (2010) suspect that the lack of longitudinal studies in the management literature might be attributed to methodological uncertainty about how to properly conduct such studies. Ruspini (2000) also adds that such studies are usually very time-consuming and therefore not used very frequently.

For this study a prospective longitudinal research design was chosen, where a fixed cohort of participants is followed across time (Adams et al., 2007; Ruspini, 2000). This was considered a more rigorous approach than a retrospective longitudinal study, where participants from previous cohorts would have been asked to recount their experiences from their time in the programme. Other design options critical to longitudinal research such as the timeframe, which describes the spacing of the data collection intervals, were carefully considered and are described in more detail in later sections of this chapter. Attrition, the gradual decline of responses or respondents, which is a

critical factor in longitudinal research (Ployhart & Vandenberg, 2010) was not expected to be a serious issue in the research study, as participants in the pilot study had shown great willingness to participate in such research, even over a longer period of time.

3.6. Context and Research Setting

The research study described in the following chapters was embedded at the Strascheg Center for Entrepreneurship (SCE) of the Munich University of Applied Sciences (MUAS). The following section provides a "thorough description" (Lorz et al., 2013) of these institutions and the general context of the research to allow the reader to more accurately interpret the research findings presented in Chapter 4 through Chapter 6.

Strascheg Center for Entrepreneurship (SCE)

The SCE acts as a service centre for the 17,500 students, alumni and around 2,000 staff members of the Munich University of Applied Sciences, spread across the university's fourteen different schools. It was legally incorporated in 2002 as an independent academic institute. In 2011 the SCE and MUAS were jointly honoured for their efforts within the entrepreneurship community by the German Federal Ministry of Economy and Technology and were awarded the status of 'start-up university' [German: 'Gründerhochschule'] making it one of the first three higher education institutions in Germany to receive this honour (SCE, 2016).

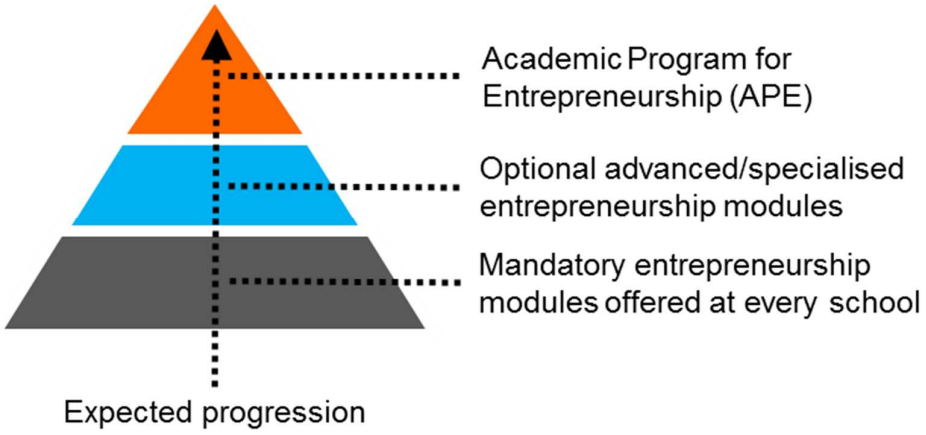
The core activities of the SCE can be grouped in three categories:

(1) **New venture consulting**: Several full-time mentors provide free consultations for (future) entrepreneurs and advise around 25 start-ups in a competitive accelerator programme. All SCE start-ups are eligible for free office space in the 700 m^2 SCE incubator which is situated in a separate building next to the main campus.

(2) **Entrepreneurship education**: The SCE offers entrepreneurship courses at all 14 schools of the MUAS. Many degree programmes at the MUAS include mandatory entrepreneurship modules. Motivated students are encouraged to sign up for additional advanced and specialised entrepreneurship modules offered by the SCE. For students and alumni with strong entrepreneurial intention, the Academic Program for Entrepreneurship (APE) is offered as a separate study programme (see Figure 3.3).

(3) **Entrepreneurship research**: The SCE conducts applied research in the fields of entrepreneurship and innovation.

Figure 3.3: Expected Progression of Entrepreneurship Education



This figure is based on internal SCE strategy documents.

The Academic Program for Entrepreneurship (APE)

The APE is the most advanced entrepreneurship education programme offered by the SCE. It was one of the first academic programmes to use design thinking as a methodology for developing entrepreneurial skills. Its main focus is to prepare its participants for careers as start-up entrepreneurs and entrepreneurial innovators within organisations. Close to 40 % of its alumni build their own start-up within five years of graduation. APE alumni have cofounded companies such as Freeletics (www.freeletics.com) and ProGlove (www.proglove.de), which were both ranked among the top 25 start-ups of 2015 by the business magazine Horizont (Horizont, 2015) as well as nearBees (www.nearbees.de) and Querfeld (www.querfeld.bio), which were both nominated for multiple social entrepreneurship awards.

Each year, 25 to 30 students, university alumni, and young professional are selected out of a large pool of applicants to take part in this 10-month programme. The APE has a total workload of around 600 hours, including both the time in class as well as the time spent on self-guided project work. The application process is open to all individuals who demonstrate high entrepreneurial motivation, a willingness to learn and the potential to strive as “t-shaped” innovators (see Section 2.2.4).

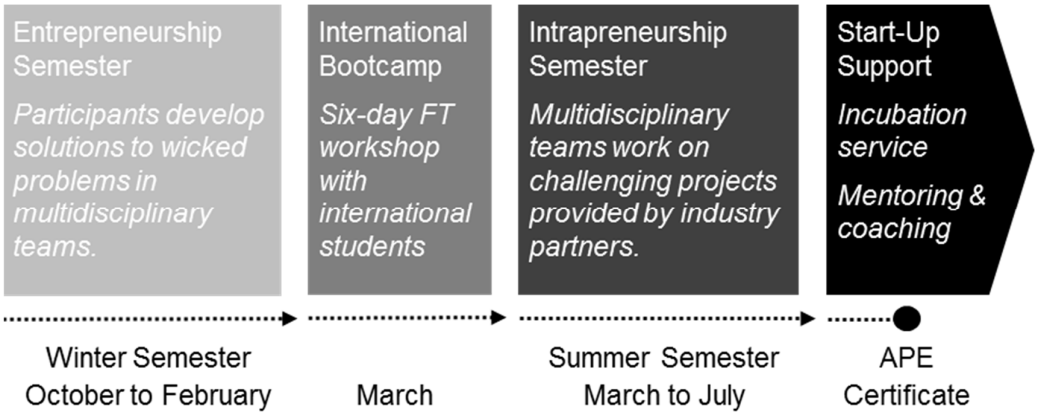
As shown in Figure 3.4, the programme is structured in three separate experiential learning projects (see Section 2.3.3). For each project, multidisciplinary teams of four to six participants are formed (see Section 2.2.4) to solve wicked innovation challenges (see Section 2.2.8) posed by either the team itself or by selected industry partners. These challenges are initially phrased as design briefs (see Section 2.2.6). These design briefs generally consist of a description of the strategic direction for the project and list the technical requirements as well as operational constraints, such as the budget and timeframe. Due to the nature of the “ill-defined” and “wicked” project challenges, these design briefs often evolve over time, to reflect the ongoing developments during a project. Formalised design thinking process models are used to iteratively guide each team from the initial team formation to a final concept pitch in front of a panel of external professionals and

investors (see Section 2.2.6). These process models are used to provide the necessary structure for each team's learning process, both from a macro and a micro perspective. This means that, at the end of the course, all teams will have gone through the process in its entirety (macro perspective) as well as having used these models to structure short sprints during individual teamwork activities to, for example, quickly go through a cycle of ideation, building prototypes as well as business models and testing key assumptions with potential users (micro perspective). Design thinking tools from the "designer's toolkit" (see Section 2.2.3) are introduced throughout the programme in short workshops, self-guided reflective learning exercises (see Figure 3.5) and through flipped-classroom teaching approaches.

The participant's learning process is facilitated by several experienced mentors from academia and industry. In this experiential learning-centred environment, the mentors' main focus is on engaging the participants' curiosity towards self-driven learning (see Section 2.3.3). Knowledge is co-produced between the individual learners, teams, and mentors. Regular team-based feedback loops engage the students in peer-learning across different disciplines. Together with design studio-like physical learning environments (see Section 2.2.9), this creates engaging learning spaces where each individual's creative confidence, informed intuition, and preparedness for ambiguous environments are fostered (see Section 2.2.7). Instead of grades, participants are provided with regular oral and written feedback in the form of design critiques from academic and industry professionals, start-up coaches and potential investors.

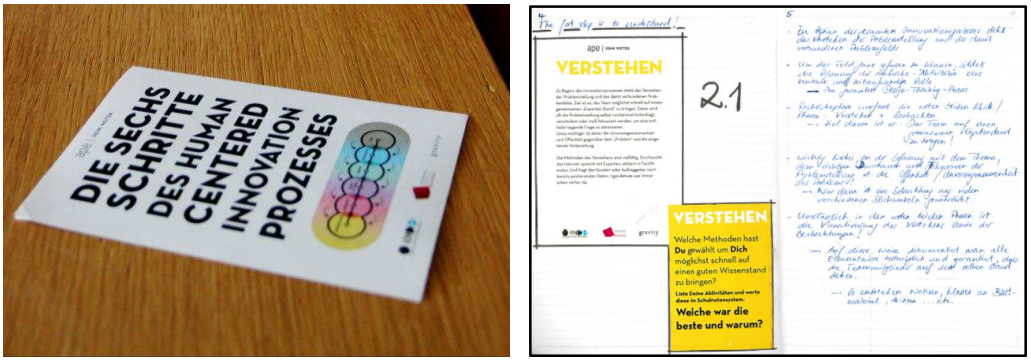
Some impressions of how this learning environment was set up at the SCE and how it is applied in the APE are provided in Figure 3.6.

Figure 3.4: APE Structure



During all three projects, design thinking process models, principles, and tools are introduced in short workshops and flipped-classroom approaches. Additional seminars on entrepreneurship-related topics supplement this practice-based learning process. Through continuous mentoring, these practices are reflected and refined. If participants chose to start a new venture after their participation in the APE, they are eligible for a space in the SCE incubator and will continue to receive mentoring in the SCE accelerator programme.

Figure 3.5: APE Teaching Tools



Core design thinking tools are provided in several formats. Short summaries and self-reflective assignments in the form of printed stickers allow the participants to discuss these concepts and tools in their groups (picture on the left). Participants are encouraged to use these materials to produce individual learning journals (picture on the right).

Figure 3.6: APE Impressions

Teaching Loft #1

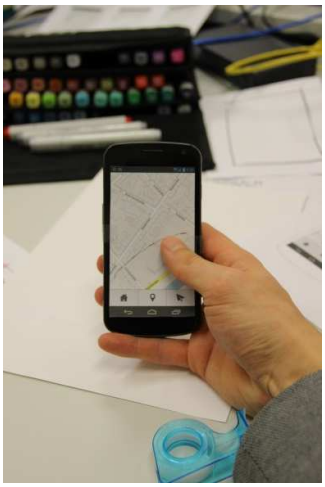
Teaching Loft #2

Teaching Loft #3

Teambuilding Workshop

Prototyping Workshop

Idea Generation



Wireframe Prototype

Mind-Mapping Seminar

3.7. Sampling Strategy and Unit of Analysis

Sampling describes the procedures used to select an adequate group of respondents (sample) for a research task from the overall population (Adams et al., 2007). The research study described in the following chapters utilised a non-probability convenience sample (Adams et al., 2007; Bryman & Bell, 2011).

The main sample for this study was comprised of all 25 participants from the 2013-2014 cohort of the APE (see previous section). A secondary sample of single-discipline novice design thinking teams was collected to contrast and compare findings from the multidisciplinary APE design thinking teams. This secondary sample consisted of 17 undergraduate business administration (BA) students enrolled at the MUAS during the winter semester 2013-2014. At the time of data collection, the BA students were in their third year of study which required them to participate in a mandatory entrepreneurship course. The BA students had the opportunity to select from seven different entrepreneurship courses. These different courses varied in both content and teaching pedagogy to offer a wide variety of options for students. For the following study, a new course was designed to mirror the APE in both the pedagogical approach and content. The same teaching facilities, teaching materials and lecturers were used for both the APE and BA course.

The dual role of being both researcher and studies director of the APE as well as lecturer for the BA course allowed the author a unique opportunity to plan and execute a quantitative longitudinal research design with weekly intervals between data collection points. Important to such a longitudinal study is to keep participant attrition to a minimum (Ployhart & Vandenberg, 2010). Therefore, all programme participants were asked to reaffirm their commitment to these courses before they started.

The small sample size, the non-probability sampling method and the fact that existing design thinking programmes all seem to be different in nature (Lewrick et al., 2012) limit the generalisability of the study's findings. Therefore, the author was careful not to draw unfounded generalising conclusions from the collected data. Arguably, this sampling strategy also

introduced a certain level of selection bias, as in both cases the participants self-selected into the study programmes, which indicates a pre-existing interest in design thinking and entrepreneurship. Nonetheless, these samples allowed the researcher to generate novel findings which may act as a springboard for further research (Bryman & Bell, 2011) in the field of design thinking, especially in contexts outside of traditional design.

Research on design thinking has so far focused on several different units of analysis:

- **Individuals who use design thinking** (e.g. Adams et al., 2011; Atman et al., 1999; Carmel-Gilfilen, 2012; Carmel-Gilfilen & Portillo, 2010; Cross, 2004; Goldschmidt & Rodgers, 2013; Gonçalves et al., 2014; Ho, 2001; Liedtka, 2011; Liedtka & Ogilvie, 2011; Liedtka & Parmar, 2012)
- **Design thinking teams** (e.g. Du et al., 2012; Hey et al., 2008; Lau et al., 2012; Seidel & Fixson, 2013)
- **The design thinking process** (e.g. Du et al., 2012; Noweski et al., 2009; Teal, 2010)
- **The role of design thinking within organisations** (e.g. Carr et al., 2010; Holloway, 2009; Liedtka, 2010; Liedtka & Mintzberg, 2006; Liedtka & Ogilvie, 2011; Martin, 2004, 2005; Simons et al., 2011)
- **The nature of design thinking** (e.g. Bjögvinsson et al., 2012; Dorst, 2011; Johansson-Sköldberg et al., 2013; Kimbell, 2011, 2012; Razzouk & Shute, 2012; Stewart, 2011).

For the following study, design thinking teams were chosen as main the unit of analysis due to the fact that many authors have portrayed design thinking as an inherently team-based innovation methodology (see Section 2.2.4). Team-based innovation approaches are also in line with the general teaching philosophy of other programmes and courses offered by the SCE (Turgut-Dao et al., 2015). In addition, demographic and individual-level data was collected to allow a richer description of the individual actors within the design thinking teams. However, with this choice of teams as the unit of analysis, the author does not intend to undermine the existence of individual creativity and design practice.

3.8. Sample Demographics

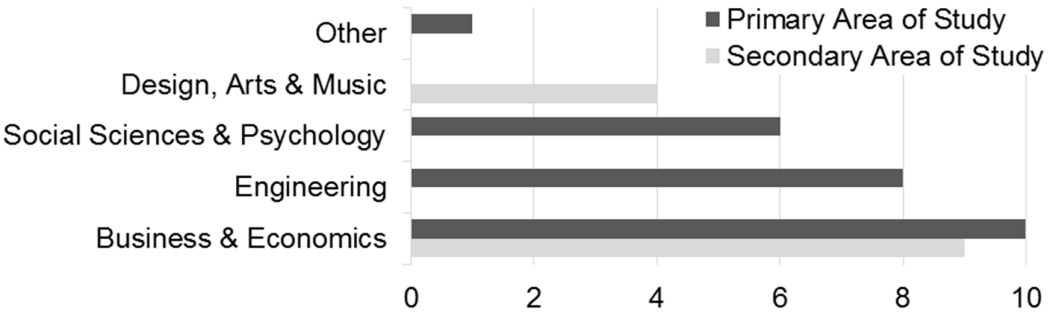
This section introduces a more detailed description of both the APE and BA samples to allow the readers a more nuanced interpretation of this study's findings. Please note that to ensure anonymity, nicknames from the Star Trek universe were assigned to all research participants in the research study (also see Section 3.9 on ethical considerations and data protection).

The APE sample consisted of a total of 25 participants who formed the 2013-2014 cohort of the APE. Within this programme, participants worked on a total of three different projects. For each project, the participants were re-grouped into new teams. Teams working on their first project were considered design thinking novices (APE_n). No data was collected for the second project during the International Bootcamp, as the timeframe was too limited (see Figure 3.4). After having spent more than 300 hours on the previous two projects, participants working on their third and last project within the programme were considered experienced design thinkers (APE_e). Overall, there was only minimal attrition between the APE_n and APE_e projects. Two participants (Tuvok and William) could only complete the first project and had to leave the programme due to personal reasons. One participant (Phlox) re-joined the programme for the third project after having had to put his studies on hold for the previous year. Of the 25 people included in the APE sample, 72 % were male. With 54 %, the majority of the group had graduated or was about to graduate with a bachelor's degree at the start of the data collection. Others had graduated or were working towards a master's degree (29 %), a German Diploma degree (13 %), which is a four to five year degree and roughly equivalent to a master's degree, or a PhD (8 %).

The 2013-2014 APE cohort was comprised of several disciplines as shown in Figure 3.7. Many participants had a primary background in business studies. Secondary areas of study are also indicated within this figure, as many participants came from dual-degree or interdisciplinary degree programmes, such as e.g. engineering design or music management with cultural studies. One of the open questions in the weekly survey asked the participants for their reasons for joining the APE. All responses indicated intrinsic reasons for

joining the programme (e.g. learning something new) while none stated extrinsic reasons (e.g. new career opportunities).

Figure 3.7: APE Sample Split by Subject Groups



Many participants were enrolled in dual-degree or interdisciplinary programs, In this figure, the primary area of study indicates the main discipline of their degree, while the secondary area of study indicates secondary disciplines.

The BA sample formed a “control group” of three single-discipline novice teams. Of the 17 students in this group 64 % were male. Most of the students were majoring in finance (29 %) or logistics (23 %).

On average, APE participants reported 3.81 years of previous full-time equivalent work experience (SD = 2.75 years). The average full-time work experience reported by the BA group was 4 years, although this was greatly influenced by one student with a previous industry career of 15 years. Excluding this participant lowered the average full-time work experience for the BA group to 2.24 years (SD = 1.58 years).

Two other weekly survey questions explored the participant’s prior exposure to entrepreneurship-related courses and their entrepreneurial environment. One third of the APE sample reported no prior participation in entrepreneurship courses, whereas the rest stated that they had previously participated in some entrepreneurship seminars and workshops. Within the BA sample, no prior exposure to entrepreneurship education was reported.

64 % of participants within the APE sample indicated that at least one of their parents, relatives or close friends are entrepreneurs themselves, whereas none of the participants from the BA sample reported any close connection to entrepreneurs within their immediate environment.

3.9. Ethical Considerations & Data Protection

While planning and executing research, potential ethical consequences both to individuals as well as to society have to be considered (Adams et al., 2007). This study's design and implementation were guided by Edinburgh Napier University's *Code of Practice on Research Integrity*. It describes the guiding principles for research at Edinburgh Napier University. Those principles are honesty, rigour, transparency and open communication, care and respect, as well as accountability (Edinburgh Napier University, 2013).

Following the university's guidelines, informed consent was obtained in written form from all research participants prior to the start of data collection. The corresponding participation consent form can be found in Appendix E. The information contained on this form was repeated to the participants in person during the initial class of each course, where research participants also had the opportunity to ask for additional information before they signed up for the study (Edinburgh Napier University, 2013, p. 4). The consent form also assured potential participants of the confidentiality of the collected data and guaranteed them anonymity (Adams et al., 2007; Edinburgh Napier University, 2013, p. 9). The collection and use of data was informed by Edinburgh Napier University's *Data Protection Code of Practice* (Edinburgh Napier University, 2012).

The dual role of the author as both the lecturer for the APE and BA courses as well as a researcher collecting data from the course participants was carefully considered. The *Code of Practice on Research Integrity* states that participants should be free from coercion and not be pressured in a study (Edinburgh Napier University, 2013, p. 5). A positivist research paradigm also dictates that the researcher should be a neutral observer and refrain as much as possible from interfering in the research setting (Holden & Lynch, 2004;

Huff, 2009). Several measures were taken to address these issues. First, where grading of course participants' work was necessary, a panel with a minimum of seven members rated each team's submission. Therefore, participants were assured that grading did not depend on their willingness to participate in the study. Grading criteria were known to the participants prior to their assessment. Second, the distribution and collection of the paper-based surveys was undertaken by a research assistant. This allowed the researcher to distance himself from the research process. Third, participants were randomly grouped into teams. For the APE industry projects, partner companies were also randomly assigned. The decision who each participant worked with and which client they worked for therefore did not depend on their willingness to participate in the study.

Approval of the research project was granted by the *Edinburgh Napier University Business School Research Integrity Committee* on February 28, 2013.

3.10. Criteria for Trustworthy Research

According to Huff (2009, p. 31), "scholarship is a communal effort" and thus requires a certain level of trust. The following research project was guided by four criteria for trustworthy research as suggested by Huff (2009). These criteria are: Truth, generalisability, consistency, and neutrality. Also taken into consideration were issues concerning the longitudinal research setup of this project which offered additional challenges compared to cross-sectional research (Menard, 2008). Overall, the adherence to these criteria was influenced by the quality of the collected data (Adams et al., 2007).

Truth

The first criterion for trustworthy research is truth. Quantitative research generally aims for internal validity. Internal validity indicates if the employed research instruments actually measure what they are supposed to measure and if inferences are drawn from the collected data in appropriate ways (Adams et al., 2007; Bryman & Bell, 2011; Field, 2009; Huff, 2009). In

longitudinal research, longitudinal validity also needs to be taken into account. This means that, if participants are asked to participate in repeated measures using similar or identical instruments they should be answering each measure with the same conceptual frame (Ployhart & Vandenberg, 2010).

Therefore, all research instruments designed for this study were carefully developed according to this criterion. All instruments were designed as non-invasive self-report instruments, which generally provide very accurate measurements of human behaviour (Pervin & Cervone, 2010). Each instrument was built on a solid theoretical framework. Validated scales were used where possible. All main research instruments were tested in a pilot study prior to the main study (see section 3.14). As validity is also concerned with the strength of the conclusions, inferences, and propositions (Adams et al., 2007), a set of semi-structured validation interviews was conducted to further add trustworthiness to the interpretation of the collected data (see Chapter 5).

Generalisability

The second quality criterion is generalisability. For research to have broad impact, the probability of patterns observed in an analysed sample also being present in a larger population needs to be considered (Bryman & Bell, 2011; Field, 2009; Huff, 2009). This allows the research community and practitioners to benefit from the knowledge put forward in an individual research project (Adams et al., 2007).

For the research study described in the following chapters, the obvious limitation in regard to generalisability is the narrow focus on only one design thinking education programme. Due to the fact that so far, only a few structured design thinking education programmes exist, the generalisability of the findings remains limited for now. However, design thinking appears to be a growing phenomenon and therefore comparable education programmes will likely continue to emerge around the globe (Lewrick et al., 2012).

To generalise findings from this study, parallels can also be drawn between the APE and start-up accelerator programmes. Accelerator programmes are usually organised in a cohort structure, provide small pre-seed investments, focus on small teams and not individual founders, and offer mentoring and support during the acceleration process (Cohen & Hochberg, 2014; Miller & Bound, 2011). This setup shows similarities to how the APE is structured. Lennon (2013) estimates that in 2013, approximately 170 start-up accelerators were active worldwide, while Cohen and Hochberg (2014) even estimate that there are somewhere between 300 to more than 2000 active accelerators. Regmi et al. (2015) illustrate, that start-ups which successfully completed an accelerator programme, have a 23 % higher survival rate, compared to businesses which did not rely on this structured support mechanism.

Consistency

The third criterion for trustworthy research is consistency. Consistency indicates how reliable the empirical research is (Huff, 2009). For research to be judged as reliable, it needs to produce the same results across different occasions (Field, 2009). This allows other researchers to replicate a study and therefore strengthen conclusions and implications drawn from individual studies (Bryman & Bell, 2011).

For the following research project, the stability of the measurements were tested by comparing results from the main study to the pilot study (Adams et al., 2007). In addition, the data collection and analysis procedures were clearly laid out, so that they may be replicated by other researchers. The longitudinal research setup also strengthened the consistency of the research findings, as most measurements were collected at multiple points in time. Furthermore, for the personality assessment, the Big Five personality traits were chosen due to their track record of being a reliable and consistent classification system of human personality with high longitudinal and cross-situational stability (see Section2.5). Similarly, Kolb's model of learning styles has been used in a multitude of scientific studies over the last decades and has proven to be a reliable research framework (see Section 2.4.2).

Neutrality

The forth criterion is neutrality (or objectivity). In general, positivist researchers assume that their studies can be conducted independently of the phenomenon which is being observed (Huff, 2009). Their personal interests, values, and beliefs are thought to have no influence on what they study and how their studies are conducted (Holden & Lynch, 2004).

Neutrality was considered in multiple ways in designing this research project. First, a research assistant was trained to administer the various paper-based research instruments in class. This created distance between the ongoing research and the teaching activities of the researcher. Second, grades and performance assessments were decided by multiple people in a transparent format (see the description of the CAT team performance assessment tool in Section 3.12.4). This disconnected the researcher's interactions with participants from the formal assessment process. Third, specific content and advice was only given to participants upon request. This way, the effect of "steering" students into a certain direction was minimised. Forth, the grouping of the different teams was done randomly by the hired research assistant. Therefore, the researcher's personal bias did not influence the decision of who would work with whom.

3.11. Data Collection Procedures

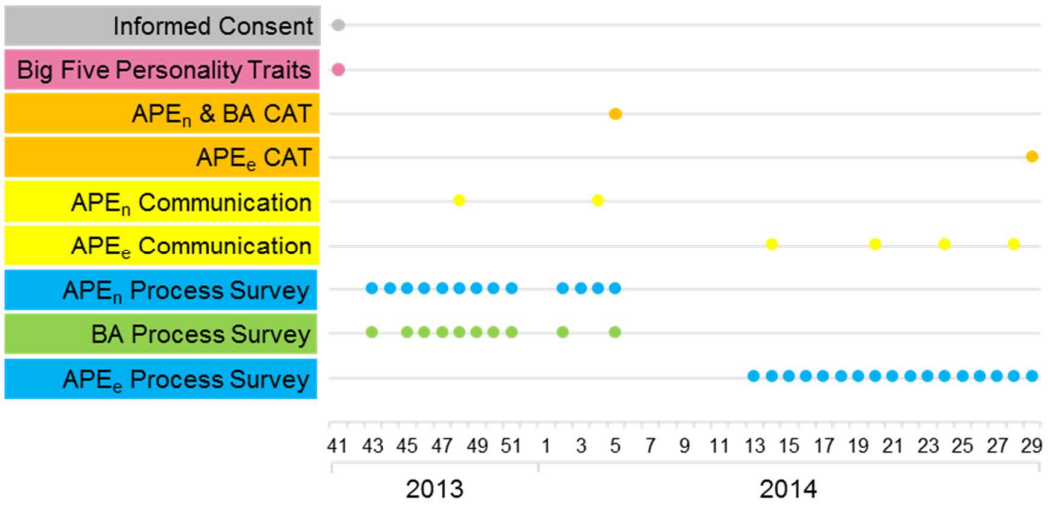
The data for the following longitudinal study was collected over a period of ten months, from early October 2013 to the end of July 2014. A detailed timeline of when each research instrument was administered is offered in Figure 3.8.

Missing data is almost unavoidable in longitudinal research (Menard, 2008). Nonetheless, great care was taken to minimise this effect in this study. All research instruments were paper-based surveys. These surveys were distributed at the beginning of each workshop and collected again, once each workshop had finished. Both the APE as well as the BA programmes were not traditional lecture-based teaching formats. Instead, participants received essential models, frameworks and tool at the beginning of each workshop

and through flipped-classroom teaching materials. In teams, the participants used the time during each workshop to learn by applying these concepts in actual innovation projects. Most participants completed the research surveys during the short breaks in-between the different workshop activities.

For the duration of the research project, a research assistant was hired and trained to assist with data collection. She was recruited from the previous APE-cohort, which guaranteed her familiarity with the overall research setting. She was trained in the use of the research instruments. During the data collection period, she distributed and collected the surveys. Following each workshop, she transferred the data from the paper-based surveys to a digital file via customised Excel templates. These templates allowed for easy monitoring of input errors and missing data.

Figure 3.8: Data Collection Timeline



In this figure the data collection process is illustrated. Each dot represents an administered research survey. The data collection lasted from the beginning of October 2013 to the end of July 2014. The x-axis represents individual weeks. Teaching was paused for the Christmas and Hogmanay holidays (weeks 51 and 1) and during the winter semester break (weeks 6 to 11). During the winter break, APE participants were engaged in a second project. They were then assigned into new teams and assumed their third and final design thinking project in week 12. Not included in this figure are the semi-structured validation interviews which were conducted in October and November 2015.

For longitudinal studies, determining the right frequency (how often data will be collected) and minimising attrition are crucial success factors (Ployhart & Vandenberg, 2010). After informed consent by all study participants was established in week 41, a questionnaire measuring the Big Five personality traits was administered (see Appendix C). The five personality traits of this model represent constructs with only very limited variability over time (see Section 2.5). Therefore, this survey was only administered once. All participants completed this survey (100 % completion rate). After this initial kick-off workshop, participants were grouped into teams and started to work on their projects at the beginning of week 42. The first weekly process survey (see Appendix A) was administered in week 43. For the APE sample, the overall completion rate of these weekly surveys was 81.8 %. The network communication surveys for the APE group (see Appendix B) were collected twice during their first project (once half-way through their project and once at the end) and four times during their third and final project (almost evenly spaced from the beginning of the project until the end). The completion rate for the communication surveys was 100 %. The team performance of each project team was measured by an panel of industry professionals at the end of each project via a customised performance assessment tool (see Appendix F). Not included in Figure 3.8 are the semi-structured validation interviews which were conducted in October and November 2015.

3.12. Research Methods

Research methods are the actual instruments used to collect data a research study (Creswell, 2013). Their design is heavily influenced by the underlying research questions (Adams et al., 2007). The following section provides a detailed account of how the different research methods for this study were constructed.

In the design of the different research instruments, common guidelines for survey research were followed (Adams et al., 2007; Bryman & Bell, 2011; Creswell, 2013). Questions were phrased in unambiguous and clear language and did not lead the respondents to certain biased responses (Adams et al., 2007).

Due to the quantitative research design, almost all questions in the different instruments for this study used a closed question format. This enabled a standardised and efficient process of entering the data from the paper-based surveys into an Excel template. It also kept the weekly survey instruments short enough to be filled out in class during a short break, which in turn led to higher completion rates. The instruments were designed as self-report measures which were completed by each participant individually. This allowed the researcher to collect a rich dataset in the given limited timeframe.

3.12.1. Weekly Process Survey

The weekly process survey in Appendix A was designed as a direct self-report instrument. It measured five different aspects of how participants coped with their current project. The aim of this weekly survey was to discover patterns in how teams dealt with the design thinking process and utilised the process model according to their needs. To guarantee high completion rates, it was important for this survey not to be disruptive to the flow of the workshops and the team projects. Therefore, it was kept very short and designed in a way so that it could be completed in less than three minutes, once participants were familiar with its structure.

For the first question, the participants were asked to assume that they had spent ten hours working on their team project during the previous week. Each participant then indicated how many hours they had spent on each of the six phases in the design thinking process model presented in Section 2.2.6. The forced choice of distributing exactly ten hours was deliberately introduced to balance the overemphasis on breakthrough (“eureka”) moments and the under-valuation of tedious work in design thinking teams. Aggregating this data to the team level allowed the researcher to analyse the recursive progression through the process and provided insights on when and how teams moved into different phases during their projects. For the purpose of this study, this recursive movement was defined as iteration within the design thinking process. An accepted limitation to this measurement strategy was the fact that sideways iteration (e.g. iteration between different prototypes in the same process phase) could not be captured.

The second question asked each participant about how much their activities during the previous week helped them to move their project along. Answers could be provided on a five-point Likert-scale ranging from “not at all” to “a lot”. The collected data from this question formed the metric of “perceived effectiveness”.

The third question asked participants about how at ease they felt with their project during the previous week. Answers were given on a five-point Likert-scale, ranging from “not at ease at all” to “very at ease”. This factor of “feeling at ease” was intended as an indicator for the ability to utilise the APE design thinking approach and move towards proficiency in it.

The fourth question asked participants about which of Kolb’s learning styles most closely matched their behaviour during the previous week (see Section 2.4). To indicate their answer, participants were provided with an adapted diagram which showed Kolb’s learning styles in a two-by-two matrix. Instead of labelling each quadrant according to Kolb’s nomenclature (converging, accommodating, diverging, and assimilating), more descriptive labels were presented (thinking & doing, feeling & doing, feeling & watching, and thinking & watching) to elicit intuitive responses (see adapted model in Section 2.4). This question aimed to explore, if certain modes of learning could be connected to the different phases within the design thinking process. It also explored the ability of individuals to switch between different learning styles, which, according to Experiential Learning Theory, represents an effective way to learn (Kolb & Kolb, 2005a; Krueger, 2007, 2009; Löbler, 2006; Neergaard et al., 2012).

The fifth part of this survey instrument was an open-ended question which changed from week to week. Responses were limited to two lines of text. Participants were asked to provide their responses as single-sentence statements, which simplified the analysis of the collected data. This question was used to gather additional background information from the participants. Many of these questions were inspired by a group discussion with several experienced international design thinking practitioners moderated by the author in March 2013 (see Appendix I for a visual documentation of the

discussion). The weekly open question also allowed the researcher to probe for possible explanations based on findings from the concurrent analysis of the collected data. For example, in the fourth week of project work, the researcher noticed several different approaches of how the teams collected, discussed, and stored their information. In the next week, he therefore posed the following question to them: “Do you feel that your group works in a ‘structured’ way, or is your approach more ‘chaotic’?” The individual answers to this question allowed the researcher to make sense of the observed phenomenon and initiated several follow-up questions. As these questions were mostly of an exploratory character, not every posed question was expected to directly elucidate to the more quantitative findings from the other research instruments. The following data analysis in Section 4.8 and discussion in Chapter 6 of these open-ended questions therefore only includes a sub-set of the provided answers, which the author interpreted as relevant in further explaining the observed phenomena.

3.12.2. Big Five Personality Traits Survey

The Big Five personality traits survey in Appendix C was designed to measure the five broad personality traits of openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. These five traits provided the researcher with a more detailed understanding and description of each study participant. It was designed as an indirect self-report survey (Paulhus & Vazire, 2007), in which the participants themselves took the role of the observer of their own behaviour (Pervin & Cervone, 2010). This enabled the researcher to explore distinctive privileged insights, which only the respondents themselves had access to (Craik, 2007). It consisted of 50 short statements; ten for each broad personality trait. Each statement described a facet of human behaviour. The statements were phrased in the first person. Participants rated each statement on a five-point Likert-scale ranging from “very inaccurate” to “very accurate”.

In the instructions to the survey, participants were being made aware that personality traits per se, are neither “good” nor “bad”. Therefore, there were no “right” or “wrong” answers for individual statements in this survey.

Participants were asked to describe themselves in an honest manner as they saw themselves then, and not as they wished to be seen in the future. Where points of reference to other people were needed to evaluate a statement, participants were instructed to compare themselves with other individuals they know, who were of the same sex and roughly of the same age.

The 50 statements, rating scales, and instructions were designed based on the International Personality Item Pool (IPIP) (Goldberg, 2011). This "collaboratory" is an open resource database which provides different measures of individual differences. All scales, items and coding schemes are in the public domain and can therefore be used without paying a licensing fee (Goldberg et al., 2006). The items, constructs and scales suggested for measuring the Big Five personality traits are modelled after the commonly used licenced NEO-PI-R inventory (Costa & MacCrae, 1992). The Big Five scales available from the IPIP are all highly correlated (between .85 and .92) with Costa and McCrae's (1992) licensed inventory (Goldberg, 2011). Using an established research instrument and validated scales for measuring human personality increased the trustworthiness and generalisability of the results (Paulhus & Vazire, 2007). For each of the five personality traits, half of the statements were positively keyed and half were negatively keyed to reduce the potential effects of unthoughtful responses and extreme response behaviour (Paulhus & Vazire, 2007).

During the pilot study, a few participants indicated that some of the statements might be misinterpreted by non-native English speakers. For these statements, German translations were amended. Participants were instructed to only refer to these translations, if the meaning of a statement would otherwise have been unclear to them.

An earlier version of this research instrument had previously been used by the researcher for a cross-sectional study for his MSc dissertation at Edinburgh Napier University.

3.12.3. Communication Behaviour Survey

The purpose of the communication behaviour survey shown in Appendix B was to better understand how individuals interacted within and across project teams. Data collected from these surveys was used to create visual network graphs and to apply social network analysis to the communication behaviour of the APE participants. This survey instrument was designed as a direct self-report instrument and measured the following three dimensions of communication:

(1) Communication about current **project issues**, including e.g. exchanging information from online and print sources as well as from personal interviews and observations
(2) Communication about **innovation methods**, like e.g. interview techniques, prototyping strategies and idea generation tools
(3) Communication about **private matters**, such as e.g. personal interests and what was going on in one's personal life at the moment

In the first section of this survey, each participant was asked to name all members of their current project team. Participants then rated the communication activities for each of those connections from their personal point of view. For each of the three dimensions of communication, participants indicated how frequently communication took place during the previous weeks and how helpful this communication was for their team project.

To give a sense of how strong the connection between two participants is, each participant was asked to rank each connection on a scale ranging from "1" (very little) to "5" (very much). If no communication took place, participants were instructed to indicate this by assigning a "0" (not at all). This data on the strength of each tie between two actors allowed the researcher to create weighted social network analysis metrics, which provided a more realistic image of the communication behaviour within the innovation teams (Opsahl & Panzarasa, 2009).

In the second section of the survey, this procedure was repeated for up to five other participants, who did not belong to the participant's own team. In the following data analysis, this information allowed the researcher to also create weighted social network analysis metrics which measure the level of inter-team communication.

In longitudinal research, it is crucial to carefully plan the intervals between the application of different research instruments (Ployhart & Vandenberg, 2010). In this research study, the communication behaviour survey was used to collect data at six different points in time throughout the APE programme. Data was collected twice during the first project (APE_n) and four times during the participants' last project (APE_e). For the first project, it was not deemed reasonable to administer this survey early in the project, as it required the participants to be fairly familiar with each other. Therefore, data was collected once, half-way into the first project, and a second time, just before the final performance assessment. The preliminary data analysis conducted after this first project (APE_n) suggested that the collected data showed a fair amount of variability across time. Therefore, the data collection intervals were adjusted for the final project (APE_e). In the final project, data was collected at the beginning of the project, twice during the project and again right before the final performance assessment.

For meaningful conclusions to be drawn from a quantitative network analysis of a small sample such as the group of APE participants, missing data points (actors in the network) should be kept to a minimum. Therefore, great care was taken to ensure that all participants completed this survey at the different points in time, which meant following up with them via e-mail and phone or during the next workshop. This led to a 100 % completion rate for all six instances where data was collected with this instrument.

3.12.4. Measuring Final Team Performance with the Consensual Assessment Technique

This section presents the assessment instrument which was created to measure each team's performance. This instrument was built on earlier

research by Amabile (1982, 1983, 1996), who proposes a new methodology for assessing creativity. Amabile argues that meaningful assessments of creativity should be based on subjective ratings from a panel of expert peers. This approach is referred to as the Consensual Assessment Technique (CAT). In her research, Amabile focuses on the conceptualisation of a tool, which can be used to assess creativity in real-world settings, rather than in experimental settings. The general idea of the CAT is that all assessments of real-world creativity are subjective (Amabile, 1982). Therefore, the CAT assumes that each relevant assessment of creative works should be based on the judgment of recognised expert peers within the same domain from which the creative work originated (Baer & McKool, 2009). Several subjective expert opinions combined, allow the development of a consensual assessment of the creative work (Amabile, 1982). Baer and McKool (2009) note that each expert should judge the work independently from the other experts. While rating the creative work, they should rely on their expert sense, which is largely based on their individual experiences. When explicit rating scales are provided, the experts should be asked to utilise the full scale to differentiate the various levels of creative work between the artefacts they are judging. In this process, different experts will arrive at different conclusions. Nonetheless, raters often show reasonable levels of inter-rater reliability (Baer & McKool, 2009), especially if the performed creative task is somewhat standardised (Kaufman et al., 2007) and if the jury consists of impartial objective raters (Petersen & Stevels, 2009).

During framing of the research design, the author also explored other potential assessment approaches of creative ability and personality, e.g. via self-report inventories such as Gough's Creative Personality Scale (Gough, 1979; Zampetakis, 2010). However, for the purpose of this study, the author chose to focus on measuring the final team performance via the CAT, as this approach provided the opportunity to rely on an external point of reference (i.e. experienced external evaluators) for the team performance assessment. Due to the fact that the analysed design thinking teams were embedded in real-world industry settings, where their abilities and performance are predominantly evaluated by external stakeholders such as clients or

investors, a CAT approach was deemed the most appropriate way of meaningfully measuring their performance in action.

The team performance evaluation tool, which was used for the following research study, was built on the CAT framework (see Appendix D). It consisted of a one page assessment tool which was provided to several industry professionals at the final public events, where all project teams presented the outcomes of their innovation projects. Each team was given eight minutes to present their concept. After all presentations had concluded, each team gathered around a booth, which they had previously set up. At each booth, additional information for each project was displayed and the team members made themselves available for follow-up discussions. Each team had previously been briefed about the exact procedure and the rating criteria of their final assessment.

In their verbal briefing as well as in the written instructions (see Appendix D), the industry professionals were advised to complete the assessment tool right after each presentation had finished. They were asked to assess all five assessment dimensions quickly and succinctly. They were also made aware that their assessment should be based on their intuition, experience and gut feeling. They were ensured that their ratings would not influence the students' grades and that they therefore should use the full range of the available scales for each rating dimension. Raters were also instructed not to interact with each other during the presentations.

The assessment consisted of the following five assessment dimensions:

(1) **Desirability**. Does the presented product or service address unmet/latent needs of the proposed target group(s)? Would customers buy this product?
(2) **Viability**. Do the key assumptions of the proposed business model and financial model make sense? Are they realistic?
(3) **Feasibility**. From a technology point of view, do you think that the product or service can be built by this team? (with/without external help)

(4) **Selling & team**. How well did the presenter(s) sell the concept to you? Do you think this team has what it takes to bring the product or service to market?
(5) **Investment intent**. Imagine you have 10,000 € in your pocket right now. You can put this money in a bank account to collect interest or invest (some of) it in the team. How much would you invest?

The first three dimensions of “desirability”, “viability” and “feasibility” were based on one of the more general definitions of potential outcomes of design thinking activities (see Section 2.2.2). These three categories were meant to assess the quality of the produced artefact, based on key principles of the underlying design thinking theory. The fourth dimension of “selling & team” was included to provide a measurement of how well the team convinced the audience of their capabilities to successfully bring their proposed product or service to market (Kawasaki, 2015). The fifth category was built on research by Morwitz et al. (2007) as well as Kornish and Ulrich (2012) who have identified purchase intention as a reliable predictor of later sales.

Raters were provided with a continuous scale, ranging from low (☹) to high (☺) for each of the five dimensions (see Appendix D). To indicate their answer, the professionals were asked to mark the continuous scale at the point which reflects their answer. The continuous scales were later converted into numerical rating between “.0” and “10.0” for each category. This answer format was a deliberate choice over a more common Likert-scale format, as it provoked fast assessments based on each professional’s intuition (Baer & McKool, 2009).

As Kaufman et al. (2007) point out, securing suitable expert judges is a time consuming endeavour. For both performance assessments, minimum requirements for desirable industry experts raters were defined. Invitations for the public presentations were then send out to selected individuals within the network of the SCE. For both assessments, a minimum of seven industry professionals were involved in the CAT performance assessment process. These included experienced professionals from target industries, current or

former venture capitalists, entrepreneurship professors, experienced design thinking practitioners as well as programme alumni now working in industry.

3.12.5. Semi-Structured Validation Interviews

Ten follow-up validation interviews were conducted in October and November 2015. In validation interviews, researchers usually present some of their research findings and conclusions to elicit feedback about the reliability and appropriateness of their interpretations (Adams et al., 2007). This strengthens the overall quality of the data analysis and helps to tailor research implications to specific target groups.

The interview guides for the conducted validation interviews shown in Appendix G and Appendix H were devised after the initial data analysis had been completed. The interview guide contained semi-structured interview questions as well as a list of statements which reflected the key findings of the research project. These questions were arranged to allow a certain flow throughout the interview (Bryman & Bell, 2011). Their main intention was to draw out the interviewee's personal point of view (Bryman & Bell, 2011) and to collect rich descriptions and accounts to supplement the interpretation of the quantitative data analysis. Deviation from this fixed order of the interview questions was expected during the interviewing process (Bryman & Bell, 2011). Therefore, new questions were added throughout the individual interviews to highlight and follow up on interesting points made during the conversation.

In total, five in-sample validation interviews and five external practitioner validation interviews were conducted. Participants for the in-sample validation interviews were selected from the list of participants of the main study. These participants formed a convenience sample which was mainly influenced by peoples' availability for the follow-up interviews. Interviewees for the external practitioner validation interviews were recruited through the professional network of the SCE and are therefore also considered a convenience sample. It was the aim of the researcher to have a diverse sample of experienced practitioners to enrich the findings and conclusions

drawn from the quantitative data from several different perspectives. Details on both samples can be found in Chapter 5.

Most interviews were conducted face-to-face, either at the facilities of the SCE or nearby public locations. Some external practitioner interviews had to be conducted via Skype. The interview guide was not provided before the interviews to elicit truthful and “on the spot” answers. All external validation interviews were conducted in English. All in-sample interviews were conducted in German, as the younger participants felt more comfortable with expressing themselves in their native language. All interviews were digitally recorded. The in-sample interviews were translated directly from the audio recordings by the researcher. The external practitioner interviews were loosely transcribed by the researcher. All interviews were edited for brevity to allow readers to quickly absorb the key points of each interview and easily compare the different answers and perspectives.

3.13. Software Packages for the Data Analysis

Several different software packages were used to store and analyse the data for this study. Raw data from every research instrument was stored in a large Excel file. Customised Excel templates were created to allow for easy data entry. The templates allowed for different custom sorting and search options to spot input errors. The raw data was entered each week after a survey instrument had been administered. The data entry was conducted by a research assistant hired for the duration of the research project. Her work was monitored on a monthly basis by the researcher. Necessary data transformations were conducted at the end of each semester/project. The Excel file was later modified to enable different data analysis options, such as a descriptive data analysis of the sample, the aggregation of collected data from individual to group level and the creation of several descriptive figures.

For more complex data analysis tasks, IBM SPSS Statistics 20 was used. SPSS is a widely used software package for complex statistical analysis (Field, 2009). Some of tables and figures generated in SPSS were exported back to Excel to edit them for better visual display.

Data for the social network analysis of the communication behaviour surveys was directly entered into Gephi (version 0.8.2 beta). Gephi is an open-source software package for graph and network analysis. It allows for the visual exploration and manipulation of network data in real-time which includes functions such as spatializing, filtering, navigating, manipulating and clustering network data (Bastian et al., 2009). Gephi was also used to compute several descriptive metrics relating to the different network structures, the project groups, and individual positions within the networks.

3.14. Pilot Study and Refinement of Research Methods

Many authors have highlighted the benefits of conducting a pilot study prior to a main study (Adams et al., 2007; Huff, 2009; Van Teijlingen & Hundley, 2001). The term “pilot study” is also sometimes referred to as “feasibility study” (Van Teijlingen & Hundley, 2001). The basic goal of a pilot study is to test underlying assumptions in the study design and instruments. As Van Teijlingen and Hundley (2001) have pointed out, even a pilot study cannot guarantee the success of a research project, but it will make it more likely. The authors have listed several compelling reasons in favour of conducting a pilot study. For example, with a pilot study the adequacy of the designed research instruments can be verified. Also, the recruitment process for the main study can be tested and adapted if needed. Furthermore, the proposed data analysis procedures can be tested on actual data to uncover flaws in the format and kind of data collected. Adams et al. (2007) add that a pilot study should also be used to estimate the response rates and the time it takes to complete each survey. If research instruments are administered in a language other than participant’s native language, a pilot study can be used to test if the items in each survey are understood in the way the researcher intends them to be understood (Adams et al., 2007).

For this research project, an extensive pilot study was conducted with the participants from the previous APE 2012-2013 cohort. This context provided a research setting similar to the main study and therefore allowed the researcher to fully test the intended research approach. Relying on a different group of people for the pilot study helped to avoid a contamination of the

main study with data from people already familiar with the research environment (Van Teijlingen & Hundley, 2001). During the pilot study, over 2,000 individual data points were collected. This dataset was not included in the main study.

During the pilot study, the research instruments intended for the main study were tested. While testing these instruments, participants were asked to underline phrases and words not familiar to them. The researcher also took notes while the participants were completing the different research instruments to highlight difficult and time-consuming section as well as to get a feel for the total time needed to complete each survey. Short follow-up interviews were conducted with several pilot study participants to clarify some of these observations. The indicated insights led to minor refinements of the different research instruments.

The following research instruments were tested and refined in the pilot study:

- Weekly team survey instrument (Appendix A)
- Communication behaviour survey (Appendix B)
- Big Five personality traits survey (Appendix C)
- CAT performance evaluation tool (Appendix E)

The collected data from the pilot study was also used to build templates for easier data entry into Excel spreadsheets. This dataset enabled the researcher to test some of the intended data analysis procedures in Excel and SPSS. Working with a comprehensive pilot study dataset also allowed the researcher to develop guidelines for training the research assistant who was hired to support the data collection during the main study.

Overall the pilot study and the refinements of the underlying research instruments greatly added to the quality of the collected data and therefore strengthened the research approach of the main study.

3.15. Chapter Summary

This chapter started out by presenting 13 testable research hypotheses which were based on the five more general research themes presented at the end of the literature review. Subsequently, the researcher's realist ontological position and post-positivist stance towards research were introduced and critically discussed. These positions lead to the adoption of a quantitative research design. The presented longitudinal research setup allowed the researcher to comprehensively study several aspects of design thinking innovation teams. Background information was provided on the two sample groups included in the research project. The main sample consisted of all 25 participants from the 2013-2014 cohort of the APE, whereas the second sample formed a "control" group consisting of 17 business administration students. This chapter also discussed potential ethical implications and different criteria for trustworthy research which guided the research process. Several different research instruments were introduced and their use in the data collection process explained. The chapter concluded with a summary of a pilot study, which had been conducted prior to the main study.

4. Data Analysis

4.1. Chapter Introduction

Presented in the following chapter is an analysis of the previously described research themes (see Section 2.6) and the resulting research hypotheses (see Section 3.2). Furthermore, this chapter provides detailed accounts of how each hypothesis was operationalised. As is recommended for longitudinal studies, descriptive statistics and visual explorations of the data are presented throughout this chapter before introducing more complex statistical procedures (Fitzmaurice, 2008).

The hypothesis statements helped to direct the data exploration and analysis. To simplify this analysis chapter, the null-hypothesis (H_n) for each alternative hypothesis (H_a) is not explicitly stated (Adams et al., 2007). For each stated hypothesis it can therefore be assumed that the null-hypothesis states that there was no significant effect. Each hypothesis was devised to be testable, falsifiable, and verifiable by other researchers (Lorz et al., 2013). For each hypothesis, a variety of statistical tests were conducted to determine if the underlying data allows for the null-hypothesis to be rejected at the pre-defined level of significance.

For each hypothesis, a brief discussion of the findings of the statistical tests is presented. These findings will be tied together and further examined in more detail in the final chapter of this thesis.

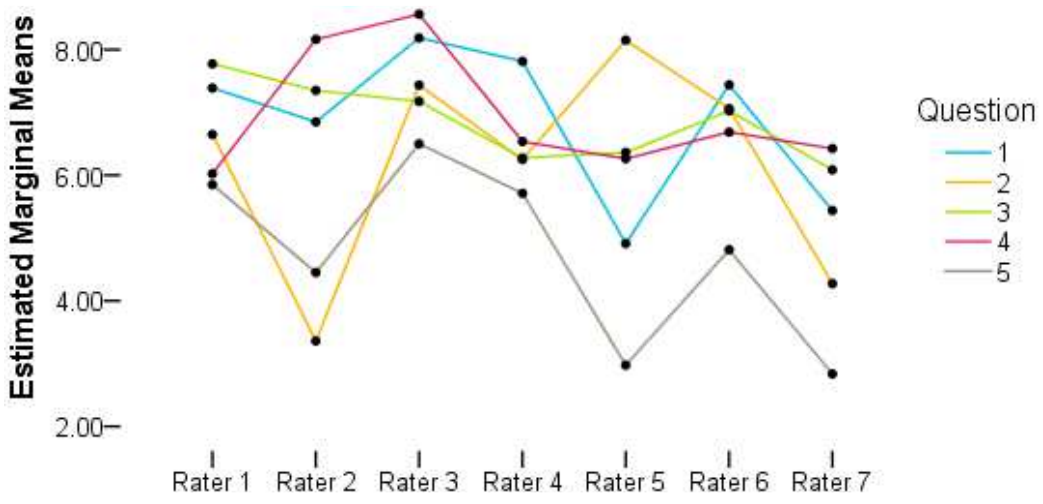
4.2. Accuracy of CAT Performance Assessment

The most important dependable variable in this research study was the final team performance assessed at the end of each project. Each team's performance was evaluated by a panel of industry professionals and experienced design thinking practitioners using a Consensual Assessment Technique (CAT) tool (see Section 3.12.4 and the survey instrument in Appendix E). As Baer and McKool (2009) suggest, if experts are recruited

from a wide range of fields and backgrounds, a CAT assessment should show good internal reliability.

A univariate analysis of variance of the performance scores for study 1 revealed that all raters seem to have used the CAT instrument in a consistent way. However, some raters appear to have evaluated the teams against a different baseline, resulting in a less accurate performance assessment (see Figure 4.1). Therefore, all performance scores for study 1 and study 2 were standardised by transforming them into z-scores. This allowed for a more precise expression of the final performance ratings for each team.

Figure 4.1: Estimated Marginal Means of Final Performance Study 1



Following this adjustment, the level of internal reliability was measured via the Cronbach's α test statistic. Study 1 (APE_n and BA sample) and study 2 (APE_e sample) were analysed separately, because the two assessment panels were made up of different industry professionals and experienced practitioners each time.

For study 1, if all seven raters were included, Cronbach's $\alpha = .660$, which just falls short of the suggested reliability cut-off criterion of .7 for exploratory research (Lance et al., 2006; Nunally & Bernstein, 1978). Further analysis

was conducted to see, if Cronbach's α could be improved by excluding one or more rater from the rating who might have scored inconsistently. Table 4.1 showed that excluding rater 2 would have increase Cronbach's α above the cut-off criterion to $\alpha = .708$. After taking a closer look at the profile of this rater, it was argued that his inconsistent scoring relative to the other raters might be attributed to a lack of insight into the technology used by the teams to build their prototypes (Arduino open-source hardware). Therefore, rater 2 was dropped from further analyses. Excluding other raters would not have significantly improved the reliability further.

Table 4.1: CAT Rater Reliability for Study 1

	Scale Variance if Item Deleted	Corrected Item Total Correlation	Cronbach's α if Item Deleted
Rater 1	13.545	.232	.664
Rater 2	14.760	.067	.708
Rater 3	11.928	.488	.589
Rater 4	12.159	.442	.603
Rater 5	13.806	.204	.671
Rater 6	11.291	.589	.556
Rater 7	11.075	.634	.542

Based on $n = 39$ cases (1 case listwise excluded)

This procedure was repeated for study 2, which was based on the smaller APE_e sample. With all ten raters included, Cronbach's α was reported as .686. As became evident from examining Table 4.2, the reliability could be greatly enhanced by excluding rater 8, resulting in $\alpha = .781$. The inconsistency of this rater's scores and the comments on his feedback surveys indicated a likely misunderstanding of the assessment instructions which were provided in English. Rater 8 was therefore dropped from further analyses. Dropping additional raters would not have improved Cronbach's α significantly.

Table 4.2: CAT Rater Reliability for Study 2

	Scale Variance if Item Deleted	Corrected Item Total Correlation	Cronbach's α if Item Deleted
Rater 1	24.526	.065	.712
Rater 2	20.203	.552	.624
Rater 3	22.260	.308	.670
Rater 4	21.856	.354	.662
Rater 5	19.461	.647	.605
Rater 6	19.092	.695	.595
Rater 7	21.466	.399	.653
Rater 8	29.467	-.396	.781
Rater 9	20.079	.568	.621
Rater 10	20.922	.464	.641

Based on all n = 20 cases

Discussion

The CAT team performance assessment tool showed adequate reliability with α = .708 for study 1 and α = .781 for study 2. Standardising the performance scores and dropping inconsistent raters further improved its validity. The author therefore gained confidence in using the standardised performance scores as a reliable measure in several of the following hypothesis tests.

4.3. Theme 1: Team Diversity

Research theme 1 looked at how the diversity of teams influenced their performance. As has been previously described in Section 3.8, the APE sample was made up of 25 participants from different disciplinary backgrounds. Both the novice APE_n teams as well as the experienced APE_e teams were comprised of participants from multiple backgrounds. The BA sample on the other hand, was entirely made up of business administration students in their final year. The resulting project teams were therefore considered single-discipline teams. Besides this, the biggest differences

between these two samples were the higher average work experience and the higher scores of openness as well as neuroticism for the APE sample (see Section 3.8).

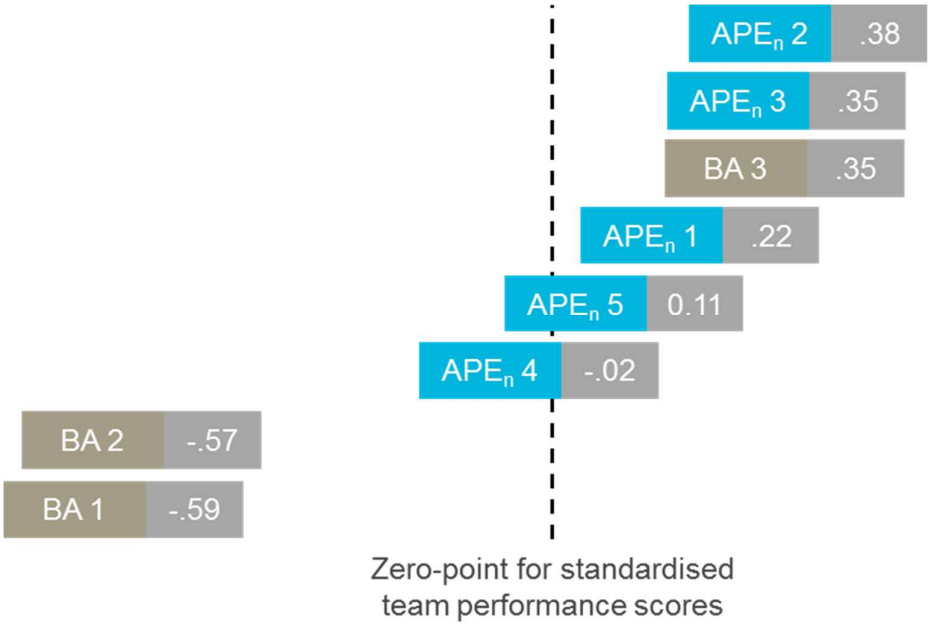
Hypothesis 1a

Multidisciplinary design thinking teams achieve a better final performance than single-discipline teams.

To explore the first hypothesis, two samples were analysed. Each team in the APE_n sample consisted of members trained in different disciplines (e.g. engineering, business management, arts/design, etc.). Therefore, the APE_n sample teams were classified as multidisciplinary. Teams in the BA sample on the other hand, were all made up exclusively of business administration students in their final year. Therefore, these teams were classified as single-discipline teams. All teams from both samples worked on the same task for roughly the same amount of time and in otherwise very similar conditions. The final performance of each team was assessed by the same panel of industry professionals and experienced design thinking practitioners (see Section 4.2).

A visual comparison of the performance of the teams in Figure 4.2 showed that on average, the five APE_n teams appear to have performed better than the three BA teams, with BA team 3 being an exception. A closer look at the team profile of BA team 3 revealed that it was an all-male team which was made up of five individuals with little prior work experience. Otherwise, no obvious differences compared to the other BA teams could be identified.

Figure 4.2: Standardised Mean Performance for APE_n and BA Teams



Standardised performance scales shows z-scores with M = 0 and SD = 1

An independent-samples *t*-test was conducted to see if the standardised final performance scores for the two independent samples are significantly different from each other. In general, the APE_n teams (M = .163, *n* = 25 cases) were scored higher than the BA teams (M = -.272, *n* = 15 cases) by the CAT panel. This difference in standardised final team performance was significant, $p < .05$ (1-tailed). It also appears that the APE_n teams (SD = .520) were scored more consistently than the BA teams (SD = .721).

Discussion

On average, APE_n teams achieved a significantly better final performance than the BA teams. Therefore, Hypothesis 1a, that multidisciplinary design thinking teams achieve a better final performance than single-discipline teams, was accepted. A limitation, which the research design could not control for, was the slightly higher average age and work experience of the APE_n group (see Section 3.8). This might offer an alternative explanation

besides multidisciplinarity, for why, on average, the APE_n teams performed significantly better.

Hypothesis 1b

Design thinking teams with a high degree of diversity of personality traits achieve a better final performance than those teams with a low degree of diversity.

In Table 4.3, the APE and BA samples were compared according to the Big Five personality traits (see Section 2.5). For both the openness to experience and the neuroticism traits, the APE sample scored considerably higher than the BA sample. The other three traits are fairly comparable between the two samples. Overall, women had higher scores for extraversion (+.02) and agreeableness (+.08) and lower scores for openness (-.05), conscientiousness (-.04), and neuroticism (-.02) compared to the men in both samples.

Table 4.3: APE and BA Big Five Personality Traits

	APE		BA	
	M	SD	M	SD
Openness	0.76	0.13	0.59	0.12
Conscientiousness	0.62	0.12	0.62	0.11
Extraversion	0.65	0.16	0.61	0.13
Agreeableness	0.77	0.11	0.71	0.10
Neuroticism	0.61	0.15	0.35	0.18

To investigate this hypothesis, the average Euclidian distance between the individual scores of each team member for the five personality traits was determined. The following analysis was based on all available samples, consisting of the APE_n (n = 5), BA (n = 3), and APE_e (n = 4) teams.

The Euclidean distance between the Big Five personality traits for each team member (m) and each colleague within the same team was given by:

$$D_{ij}^{m} = \sqrt{\sum_{k=1}^{5} \left(x_{ik} - x_{jk}\right)^2}$$

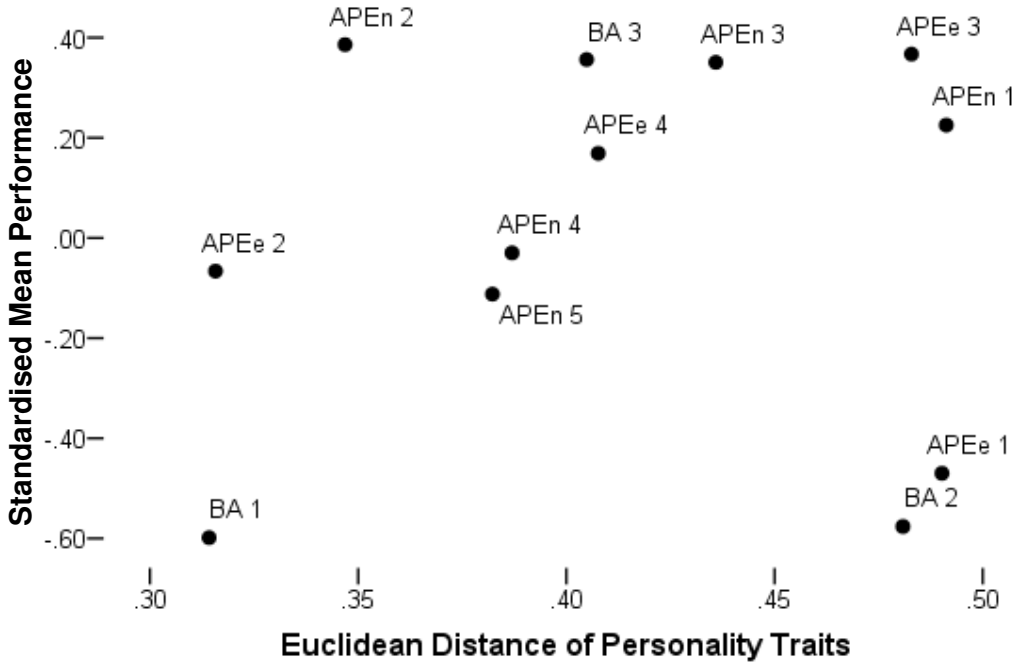
These distances were then averaged over the n teams to obtain the *average team personality distance* ($\overline{D}_t$) using:

$$\overline{D}_t = \frac{1}{n} \sum_{i=1, j>i}^{n} D_{ij}^{m}$$

The resulting scores per team were used as an indicator for the degree of diversity of the Big Five personality traits within each team.

Plotting the standardised mean performance per team against the average team personality distance did not reveal any close connection between the two variables (see Figure 4.3). A Pearson product-moment correlation confirmed that no significant relationship between the degree of diversity of the Big Five personality traits and standardised final team performance was present.

Figure 4.3: Scatter Plot of Standardised Mean Performance and the Euclidian Distance of Personality Traits per Team



Discussion

There does not appear to be a significant correlation between the degree of diversity of the Big Five personality traits within a team and the final team performance. Therefore, Hypothesis 1b, that teams with a high degree of diversity of personality traits achieve a better final performance than those teams with a low degree, was rejected.

4.4. Theme 2: Iteration

Research theme 2 explored the concept of iteration in design thinking. As illustrated in Section 2.2.6, authors have proposed various non-linear design thinking process models which consist of several connected activities. For the purpose of this study, iteration was defined as the recursive movement through the chosen design thinking process. An accepted limitation to this measurement strategy was the fact that sideways iteration (e.g. iteration between different prototypes in the same process phase) could not be captured.

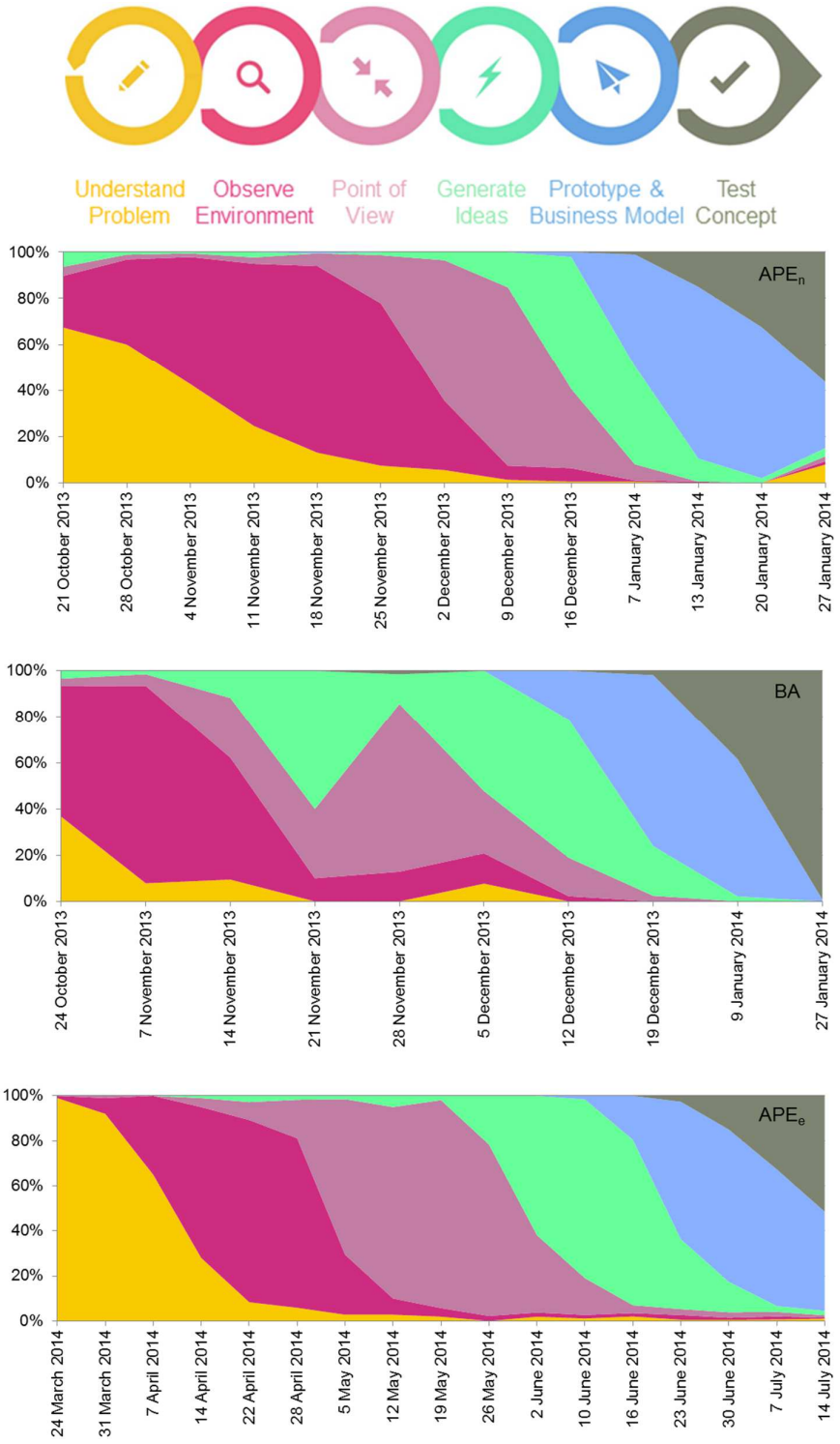
For every week of data collection, study participants were asked to indicate how they had spent their time working on their project during the previous week. Data was collected via the paper-based weekly survey instrument, which was administered at every face-to-face workshop (see Appendix A). To allow for a visual comparison of the iteration behaviour of the different sample groups, the collected data was illustrated as a stacked diagram in Figure 4.4. The colours in each diagram correspond to the individual steps of the design thinking process model (see Section 2.2.6).

A new metric was created to express how much each individual participant iterated from week to week (see Section 3.2). For the purpose of this study, iteration was defined as either moving forward or backwards in the design thinking process. For each week, the data was coded to indicate how many hours a participant has either remained in the same process phase, moved forward, or moved backwards. Remaining in the same phase was coded as “no iteration”. The resulting scores for moving forward and for moving backwards were added together to provide an iteration score for each participant during each week. Considering that the main focus of this research project is the study of teams, average iteration scores for each team were aggregated. These scores ranged from “0”, indicating no iteration, to “10”, indicating maximum iteration. The average team iteration scores for the different samples and weeks are shown in Figure 4.5. The thicker black lines indicate the average iteration scores for each sample group. The dotted line represents a linear regression model which was fit to the overall average

iteration scores. The coefficient of determination (R^2) in each diagram indicates the goodness of fit of the trend line and therefore how linearly each group approached the design thinking process. The coefficient of the slope was significant at the .05 level for the APE_n group and not significant for the BA and APE_e groups.

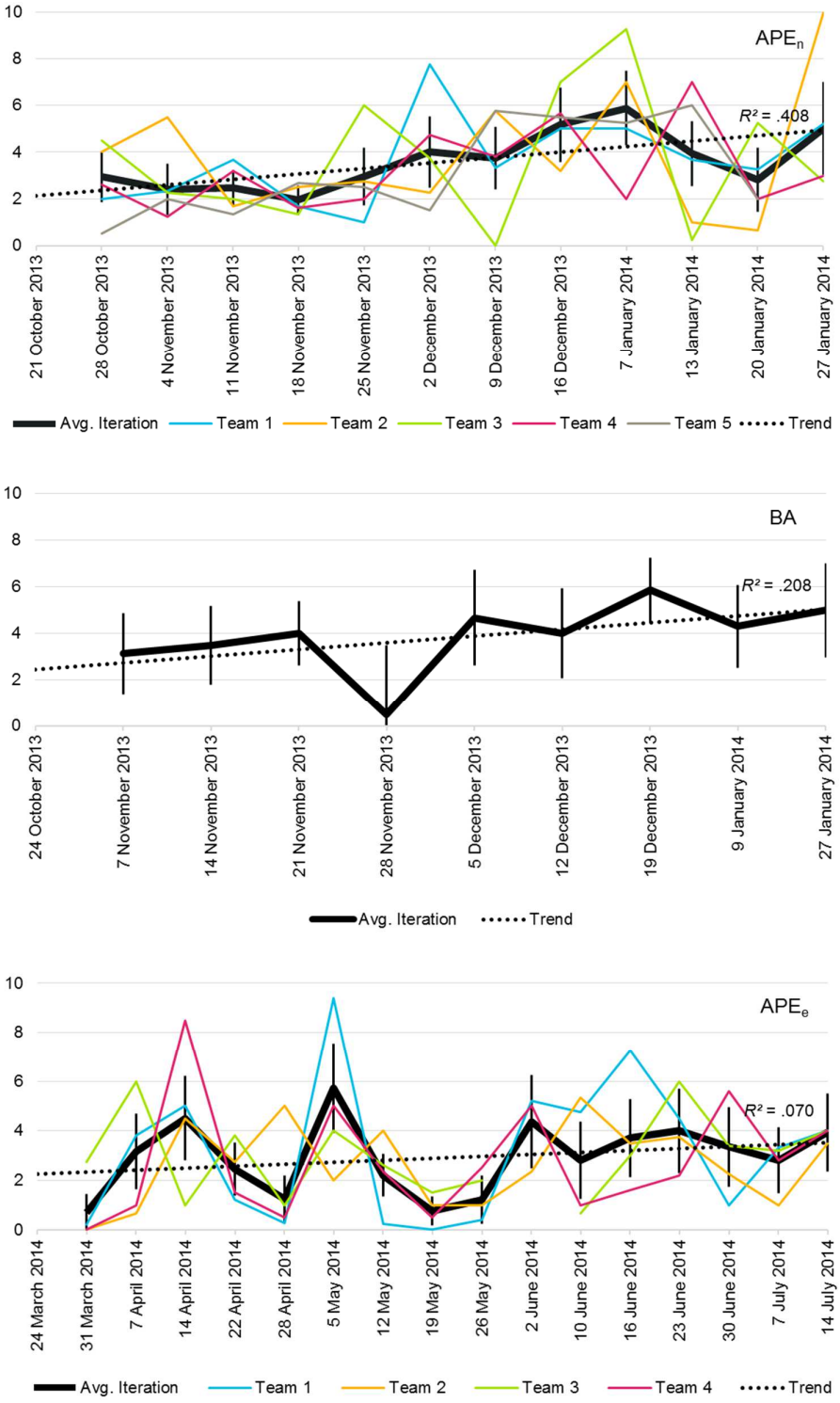
To spot more global patterns in the data, the time periods were also sliced into quarters as shown in Figure 4.6. This mirrors the insight drawn from the previous Figure 4.5 that the APE_n group seem to have iterated significantly more in the third quarter. Applying one-way analysis of variance indicated that there are significant differences between the four quarters, $p < .01$ (2-tailed). On the other hand, for the APE_e groups the average iteration scores seem to have increased steadily from quarter to quarter. However, these quarterly increases were not significant.

Figure 4.4: Stacked Diagram of Time Distribution in Projects



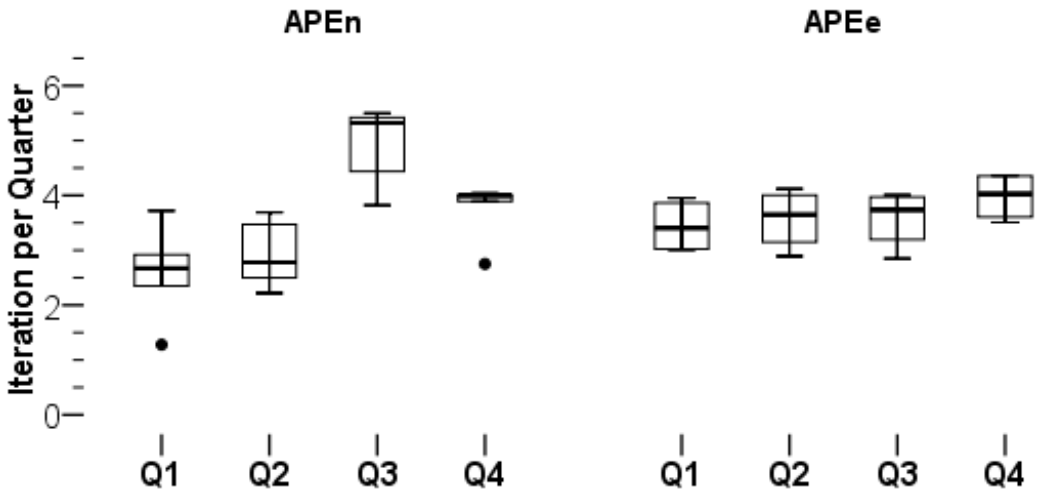
The colours in each stacked diagram correspond to the colours in the design thinking process model used for both programmes (see Section 2.2.6). The more vertically separated the colour blocks are, the more linearly the teams structured their projects.

Figure 4.5: Average Iteration in Design Thinking Projects per Team



This figure shows the average amount of iteration per sample (min. = 0, max. = 10). Error bars indicate the 95 % confidence intervals. R^2 indicates the fit of the trend line for average iteration. For the BA group, insufficient data was available to provide a break-down per team.

Figure 4.6: Box Plot of Aggregated Iteration per Quarter



This figure shows the iteration scores in aggregated form per project quarter. For the APE_n group each quarter represents three weeks. For the APE_e group the first quarter represents five weeks, while the other quarters represent four weeks each. Error bars indicate the 95 % confidence intervals.

Hypothesis 2a

Multidisciplinary design thinking teams iterate more than single-discipline teams.

To test Hypothesis 2a, the APE_n (multidisciplinary) and BA (single-discipline) teams were compared. Figure 4.4 provides a visual comparison of how the different sample groups allocated their project time within the six phases of the design thinking process model. While examining this figure it became apparent that the BA teams spent less time in the "understand problem" phase of the model than the APE_n teams. It seems that the BA teams also had one larger iteration loop, when they moved back from generating ideas (21 November) to working on their "point of view" (28 November). The corresponding Figure 4.5 shows the average amount of iteration per week for each sample group. Both APE_n and BA groups overall seem to have increased the amount they iterated over time, as indicated by the trend line.

An independent-samples *t*-test revealed that the total amount of iteration of the two compared sample groups is not significantly different from each other at the .05 level (1-tailed). On average, the APE_n teams (M = 3.600, *n* = 5 teams) seem to have iterated slightly more than the BA teams (M = 2.406, *n* = 3 teams). The APE_n teams (SD = .449) also seem to have been more consistent than the BA teams (SD = 1.340) in how much they iterated.

Discussion

Overall, the APE_n teams seem to have iterated slightly more than the BA teams. However, this difference is not significant. Therefore, Hypothesis 2a, that multidisciplinary design thinking team iterate more than single-discipline teams, was rejected in favour of the null-hypothesis. The power of the statistical test was limited by the amount of cases which could be included in the analysis (*n* = 8 teams).

Hypothesis 2b

More experienced design thinking teams iterate more than novice teams.

This hypothesis was tested by comparing the novice APE_n teams and the experienced APE_e teams. Figure 4.4 provides a visual comparison of how both sample groups had allocated their time during the design thinking project. It appears that the APE_e teams approached the different steps in the design thinking process model more sequentially. They also seem to have assigned less time for the two initial research phases of “understand problem” and “observe environment” in favour of spending more time making sense of the collected data in the “point of view” phase. An examination of Figure 4.5 revealed that the APE_e teams tended to iterate in small iteration loops rather than evenly spread throughout the project. This was confirmed by comparing the R^2 coefficients of determination for the regression models which indicated that a linear model only provides a poor fit for the behaviour of the APE_e sample group (R^2 = 6.9 %) when trying to explain their iteration behaviour

throughout their project. Also, the coefficient of the slope in the linear regression model is not significant for the APE_e sample group, whereas it is significant for the APE_n group, $p < .05$.

An independent-samples *t*-test revealed that the total amount of iteration of the two contrasted sample groups is not significantly different from each other at the .05 level (1-tailed). When comparing the means for average iteration per group, there seems to be a slight indication that the opposite of the stated hypothesis is actually true. The experienced APE_e teams (M = 2.875, $n = 4$ teams) overall seem to have iterated less than the novice APE_n teams (M = 3.600, $n = 5$ teams). The APE_e (SD = .780) group's iteration behaviour was slightly less consistent than that of the APE_n group (SD = .449).

Discussion

The previous analysis showed that the observed experienced design thinking teams did not iterate more than the novice design thinking teams. In fact, the data provided some evidence that the opposite might be true. Research Hypothesis 2b, that more experienced design thinking teams iterate more than novice design thinking teams, was therefore rejected in favour of the null-hypothesis. A possible explanation for this behaviour might be found by linking this phenomenon with the research theme on perceived effectiveness and ease (see Section 4.6). Higher levels of experience, which coincides with higher levels of perceived effectiveness and ease, might make experienced teams feel better able to foresee how a project could progress. This, in turn, might lead them to structure design thinking projects more linearly than novice teams.

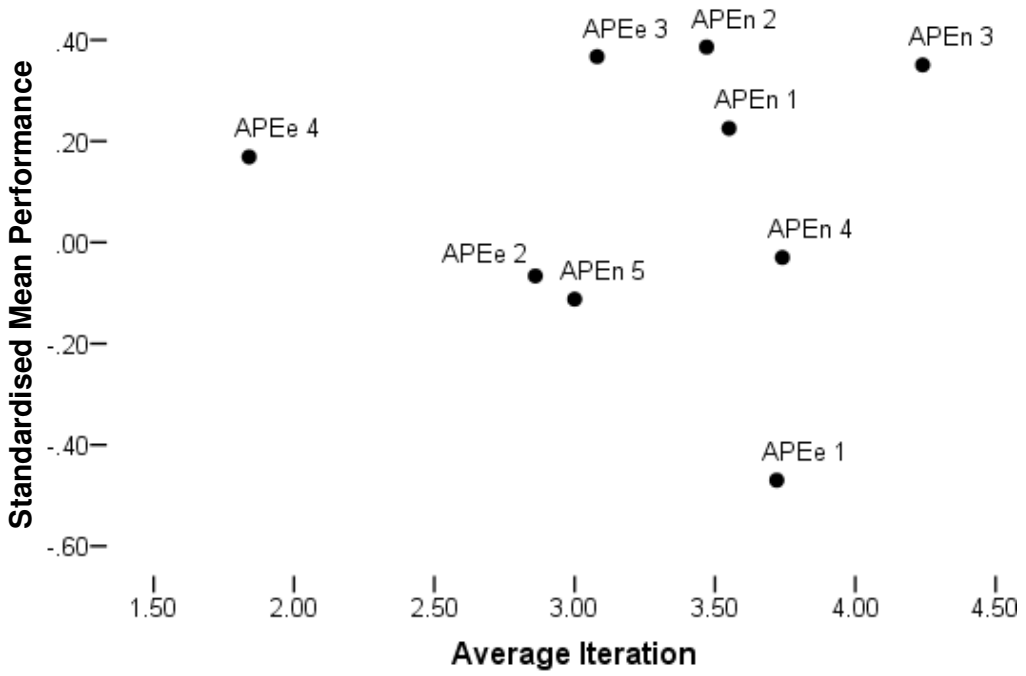
Hypothesis 2c

More iteration during a design thinking project leads to a better final performance.

To test Hypothesis 2c, the APE_n and APE_e groups were jointly analysed. A scatter plot, with the standardised mean performance plotted against the

mean total average iteration, did not reveal a direct correlation between these two factors (see Figure 4.7).

Figure 4.7: Scatter Plot of Standardised Mean Performance and Total Average Iteration per Team



A Pearson product-moment correlation analysis for the nine APE teams confirmed that there is no significant correlation between these two variables. Repeating this analysis separately for the APE_n and APE_e groups to account for the different levels of experience, resulted in similar findings.

The analysis was extended to investigate the correlation of the standardised mean performance and the average amount of iteration for each week. The Pearson product-moment correlation analysis was conducted separately for the APE_n and APE_e groups due to the different length of their respective projects. For the APE_n group, only the week starting from 7 January showed a significant effect. For this week the amount of iteration showed a strong significant negative correlation of $r = .944$, $p < .05$ (2-tailed). During this week

teams were mostly prototyping and business modelling while moving out of the idea generation and slowly advancing towards testing their prototypes (see Figure 4.4). For the APE_e group no specific weeks could be flagged as significant in the correlation analysis of standardised mean performance and average iteration per week.

Discussion

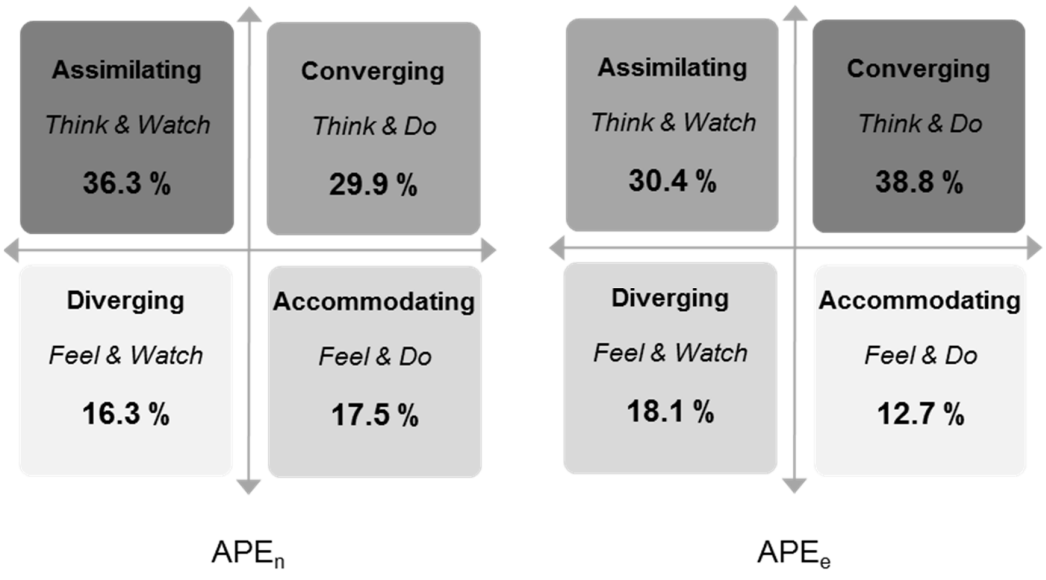
Overall, no significant correlation between the standardised mean performance and the average amount of iteration per team, as measured by the amount of recursive movement in the design thinking process, was found. Therefore, Hypothesis 2c, that more iteration during a design thinking project leads to a better final performance, was rejected in favour of the null-hypothesis. Once the analysis was broken down week-by-week, only one week showed a significant correlation between iteration per team and final team performance for the novice APE_n group. This week signalled the point at which the teams had locked into a specific idea and move on into prototyping, business modelling, and the initial testing of the idea. At this point, higher levels of iteration seem to have a negative effect on final team performance. This might suggest that, once projects are in their final stages before being presented to clients or investors, teams should fully commit to their current idea and direction. They should focus their efforts on finalising that idea rather than iterating within the design thinking process model.

4.5. Theme 3: Learning Styles

Theme 3 examined how learning styles influence design thinking teams throughout a project. At every face-to-face meeting during the period of data collection, participants were asked to indicate which of Kolb's learning styles best described their learning process during the previous week (see Section 2.4 and the survey instrument in Appendix A). This enabled the researcher to identify which learning styles were dominant during the observed design thinking projects and how this changed over time.

In Figure 4.8 the dominant learning styles for the APE_n and APE_e sample groups are visualised. Overall, participants indicated that they were grasping new information predominantly through abstract conceptualising, resulting in a dominance of assimilating and converging learning styles. For the novice teams (APE_n), the dominant learning style was the assimilating learning style, whereas the more experienced teams (APE_e) showed a preference for the converging learning style.

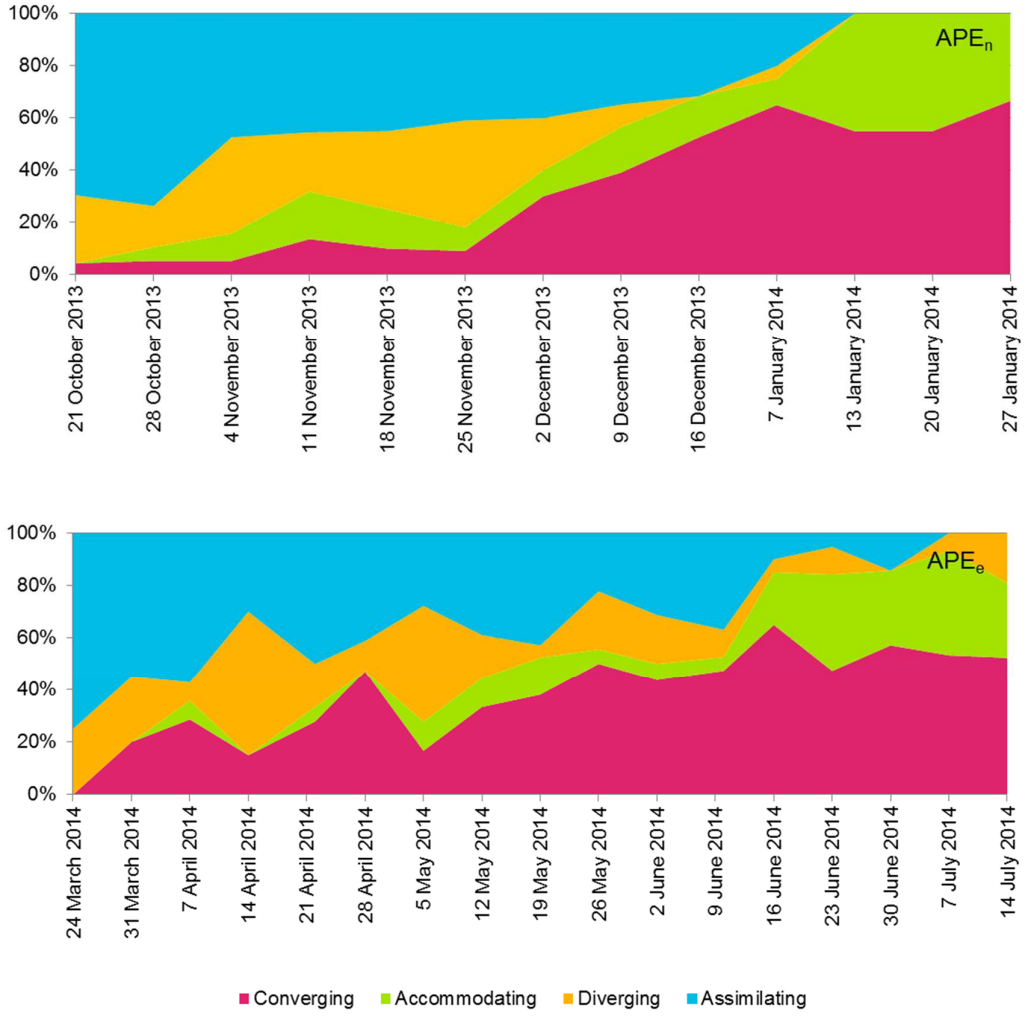
Figure 4.8: Heat Map of Dominant Learning Styles



This figure shows the average time spent in each of the four Kolb learning styles split by sample group.

An overview of how the use of learning styles of the APE_n and APE_e sample groups changed over time is shown below in Figure 4.9. The assimilating learning style dominated during the early phases of the design thinking projects and then gradually lost importance over time. The converging learning style on the other hand, grew in relevance during the projects and dominated the final stages of the design thinking projects.

Figure 4.9: Stacked Diagram of the Use of Learning Styles over Time



This figure shows how the use of the four different Kolb learning styles changed over time.

Hypothesis 3a

Each member of a design thinking team cycles through Kolb's learning styles during a project.

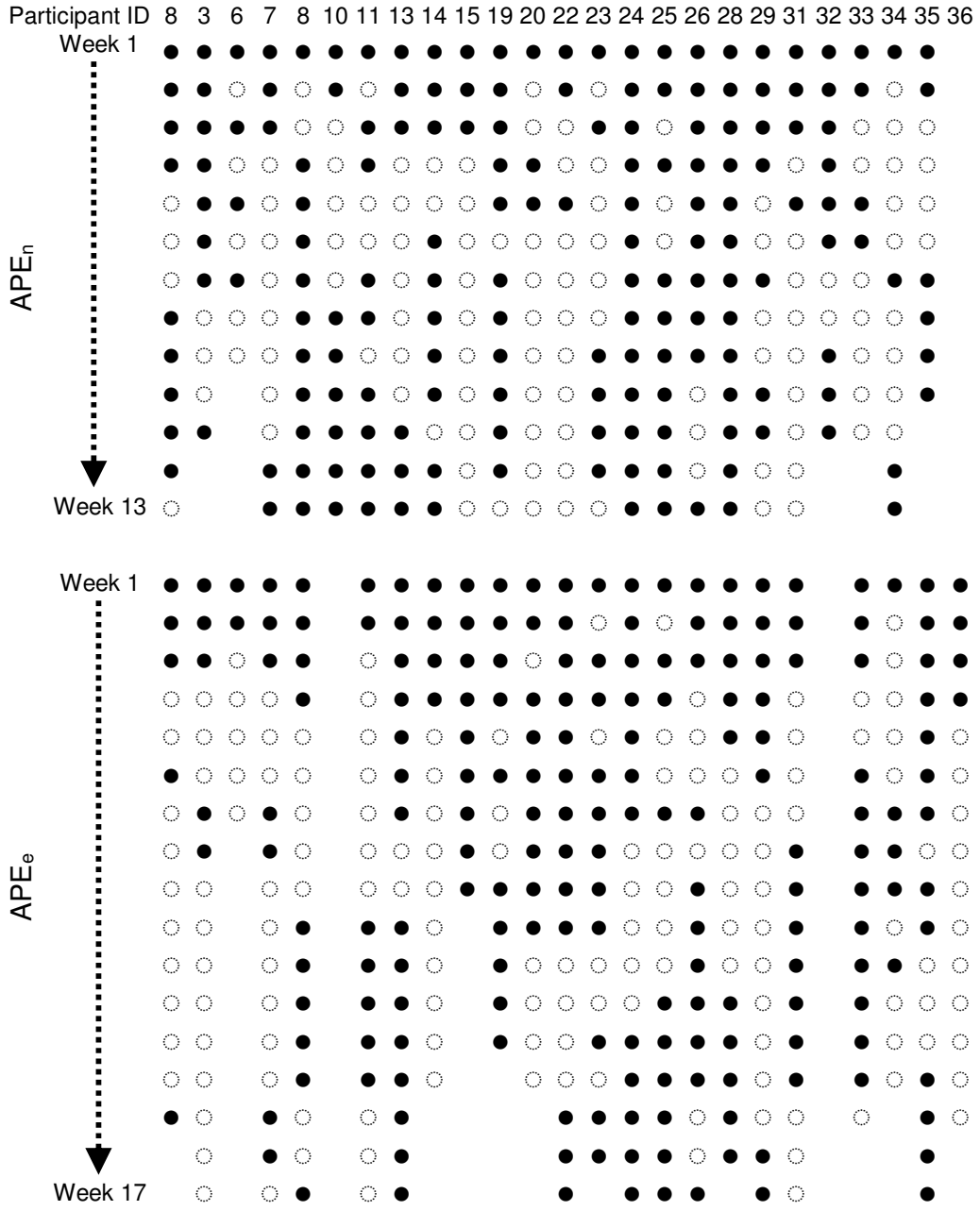
As previously described in Section 2.4, the effects of learning can be maximised by cycling through all four of Kolb's learning styles. It was the aim of this hypothesis to test if this phenomenon could also be observed while individuals worked on design thinking projects in multidisciplinary teams.

A non-parametric runs test (Mendenhall et al., 1993) was conducted separately for the APE_n and APE_e groups to test for randomness in the choice of participant's learning styles. In this case, the test measured to what extent individuals adhered to the proposed process logic of Kolb's model by comparing the number of actual runs to the number of possible runs for each case. A run was defined as a single sequence of learning styles per participant in which the process logic was not violated, i.e. the participant remained in the same learning style or moved on to the next learning style, as proposed by Kolb's model (see Figure 2.8 for the proposed sequential order). Every time a participant violated the process logic, a new run was initiated.

For this test to work, the collected data was recoded into binary form as shown in Figure 4.10. Each vertical row represents one APE participant. As the quality of the runs test increases with the number of available cases, the researcher chose to fill gaps of up to one week with inferred values, if closing the gap allowed connecting an otherwise continuous cycle. Gaps of more than one week were excluded from the analysis, resulting in different column lengths for some cases. If two similar dots follow each other within a column, then the inherent process logic within Kolb's model is being adhered to, i.e. a person stayed within the same learning style or moved on to the next learning style as proposed by Kolb's model. If the dots change from one week to the next, then that individual has violated the process logic, i.e. a person moved to a different learning style which breaks a learning loop in Kolb's model.

For the APE_n sample group, the runs test indicated that five cases out of the total of 24 participants are significantly non-random at the .05 level (2-tailed). For the APE_e group a total of 10 out of 23 cases were flagged as significantly non-random, $p < .05$ (2-tailed). One likely reason for the higher amount of significant cases within the APE_e sample group is the availability of more data points per participant. The BA sample group was excluded from this analysis, as its dataset was too fragmented to produce reliable results in a non-parametric runs test.

Figure 4.10: Learning Styles Runs Test Binary Coding



This figure shows the runs logic of the Kolb learning styles for each APE participant (x-axis) and for each week of the project (y-axis) in binary form. Every time the runs logic was violated, the binary code switches. Gaps in the data of up to one week were filled with inferred values. Gaps of more than one week were not filled, hence the different column lengths for some cases.

Discussion

There seems to be some systematic evidence that individuals in design thinking teams do indeed follow the circular sequential logic proposed by Kolb's learning styles model. However, in the current dataset the non-parametric runs test only flagged between 20 % and 41 % of cases as significantly non-random. This can likely be attributed to the low number of available cases, which greatly limited the power of this statistical test. For now, Hypothesis 3a, that each member of a design thinking team cycles through Kolb's learning styles during a project, was therefore rejected in favour of the null-hypothesis.

Hypothesis 3b

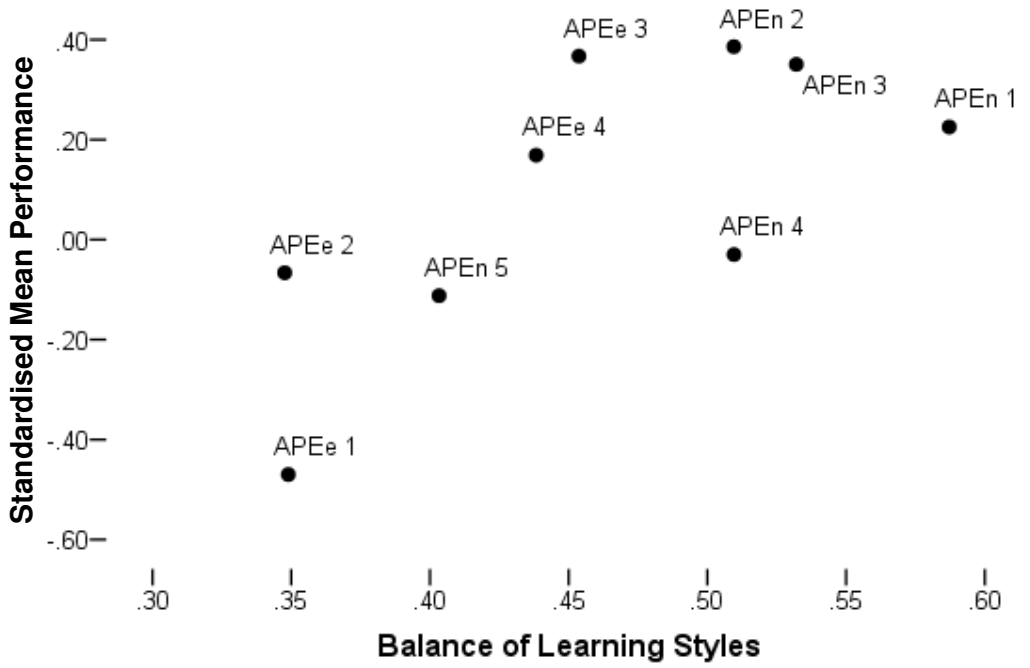
Design thinking teams which demonstrate a balance of the four Kolb learning styles achieve a better final performance than those teams who do not.

To test this hypothesis, a custom metric for the degree of balance of the four Kolb learning styles needed to be created. For this purpose, balance was defined as having spent 25 % of the total project working time in each of the four learning styles. Subsequently, an analysis was conducted to see how much each individual deviated from this "optimal" balance during the span of each project. The resulting individual scores were aggregated to provide an overall score of balance of learning styles for each team. On the resulting scale, "1" equals a perfect balance of learning styles, while "0" indicates maximum imbalance. This analysis included both the APE_n and APE_e teams.

The analysis of the scatter plot shown in Figure 4.11 suggested a positive correlation between the balance of learning styles and the standardised mean performance.

A Pearson product-moment correlation confirmed a positive significant correlation of $r = .701$ between the standardised mean performance and the balance of learning styles at the .05 level (1-tailed).

Figure 4.11: Scatter Plot of Standardised Mean Performance and Balance of Learning Styles per Team



Discussion

Overall, the balance of learning styles within a team correlated significantly with standardised mean performance. Therefore, Hypothesis 3b, that design thinking teams which demonstrate a balance of the four Kolb learning styles achieve a better final performance than those teams who do not, was accepted. In conclusion, it appears that utilising different learning styles to analyse a project from different angles has a positive effect on a team's performance.

4.6. Theme 4: Perceived Effectiveness and Ease

Theme 4 investigated perceived effectiveness and ease in design thinking project teams. Both variables relate to the concepts of creative confidence and informed intuition, as discussed in Section 2.2.7. Initially, the variables of perceived effectiveness and perceived ease were treated as separate

variables. However, a closer examination of the collected data revealed that feeling effective and feeling at ease in the application of design thinking are highly correlated. The visual analysis of the data displayed in Figure 4.12 suggested a positive correlation between how effective and how at ease individuals in design thinking teams feel during projects. A Pearson product-moment correlation for these variables supported this conclusion. Both variables are significantly correlated, $r = .673$, $p < .05$.

To further investigate the correlation between these two variables, the average values of “feeling effective” and “feeling at ease” for each data collection interval were visualised in Figure 4.13. In this longitudinal view, both factors again showed a clear correlation pattern. Due to this strong correlation, both variables were merged into the single variable “perceived effectiveness and ease” for the subsequent statistical tests.

Figure 4.12: Scatter Plot of Average Perceived Effectiveness and Ease per Team

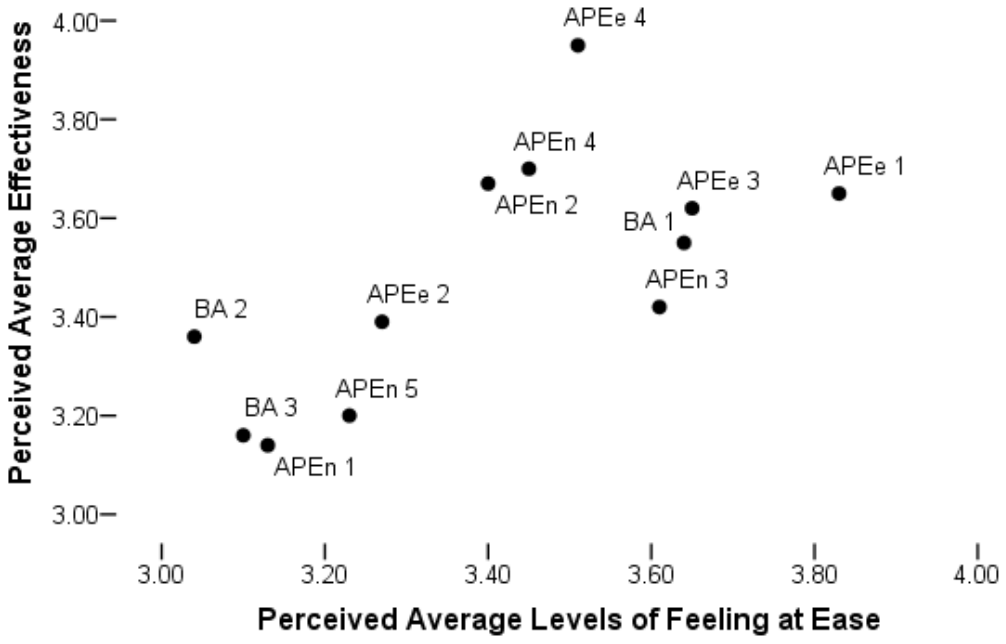
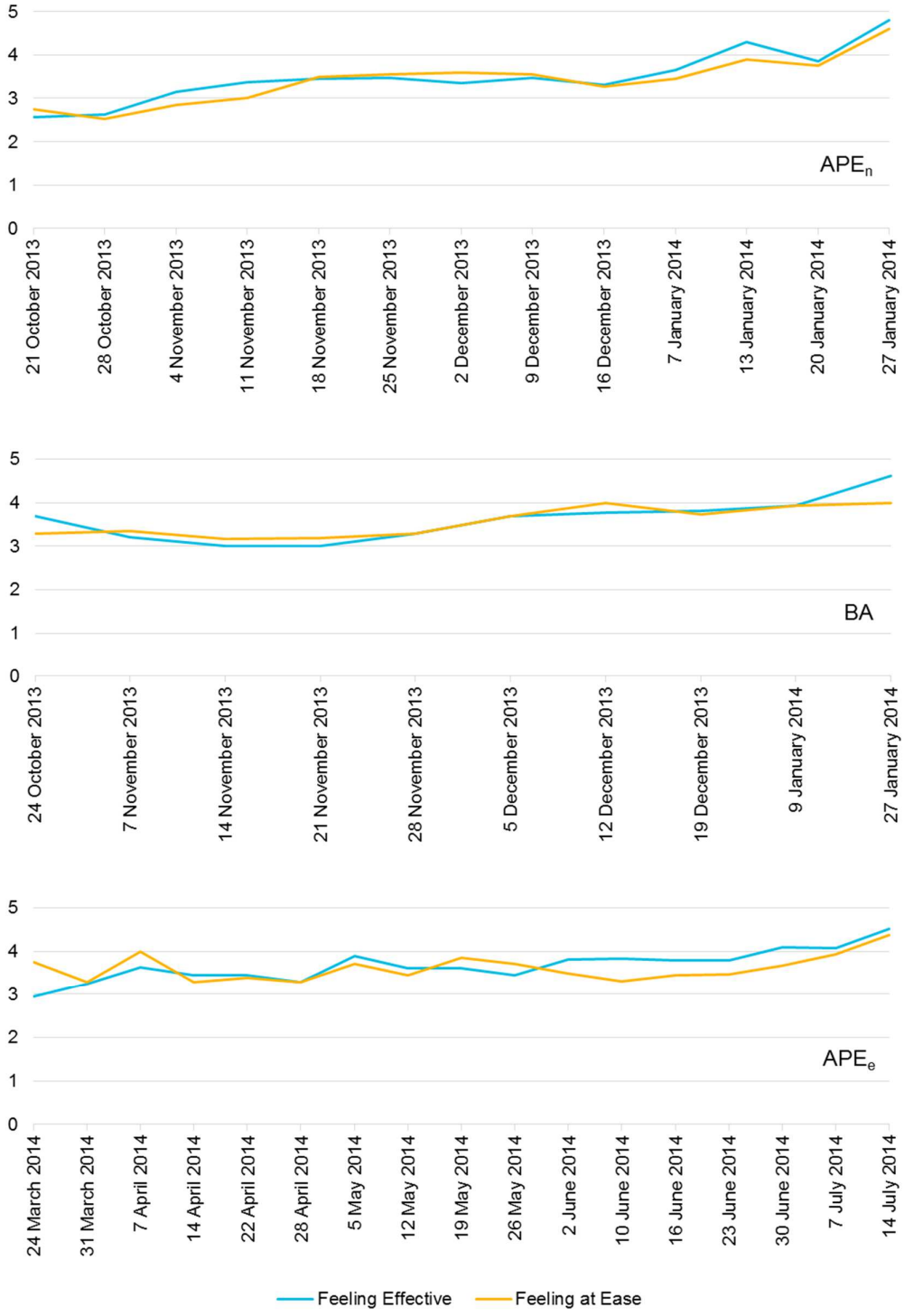


Figure 4.13: Correlation of Perceived Effectiveness and Ease over Time



These figures show the levels of feeling effective and feeling at ease (scale min. = 0, max. = 5) for each sample group. Both variables are highly correlated.

Hypothesis 4a

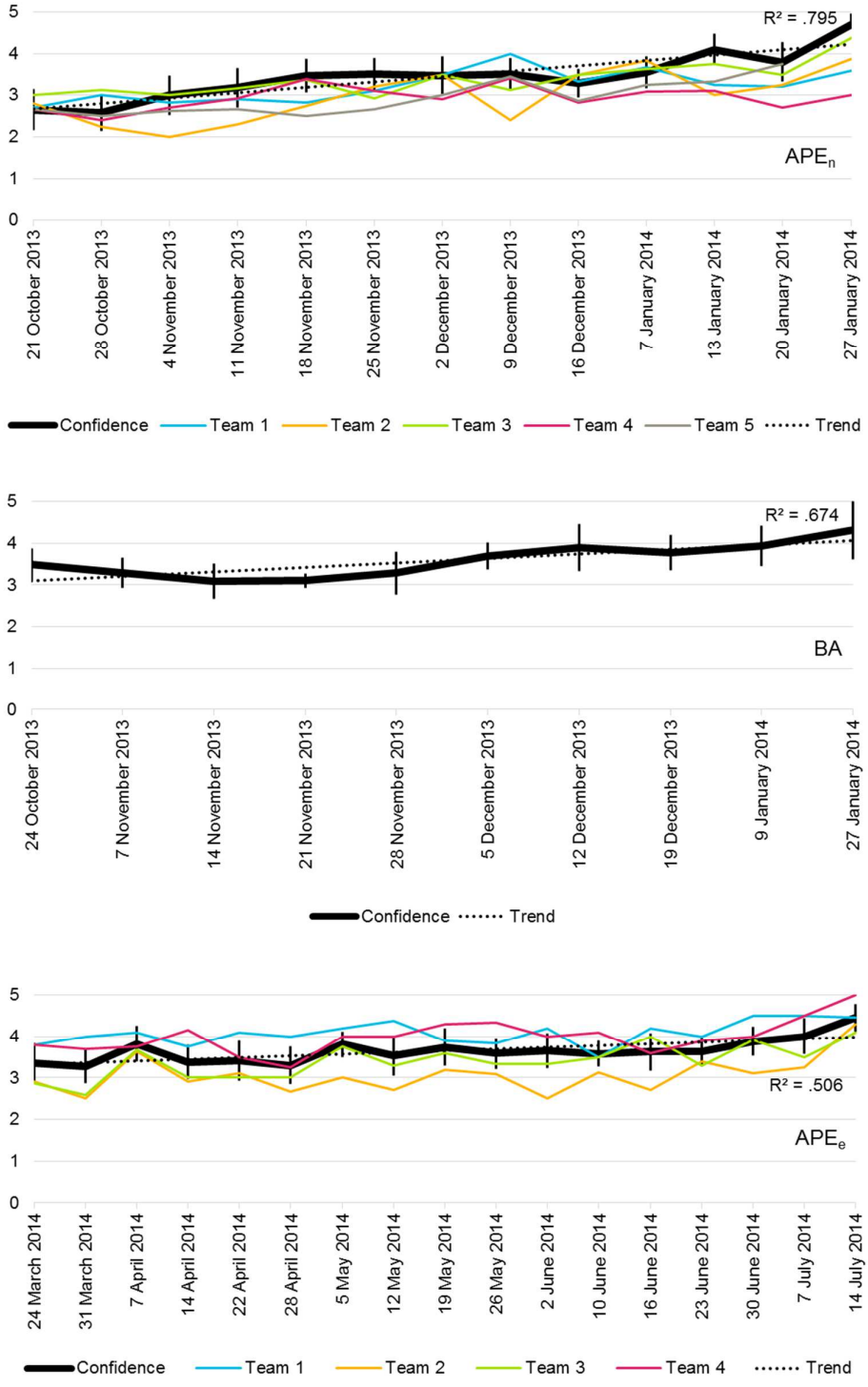
Perceived effectiveness and ease follows a U-shape throughout a project.

As previously described in the literature review, Brown (2009) posits that a team's level of creative confidence is high at the beginning of the project, significantly decreases towards the middle, and then increases again towards the end. In other words, he expects creative confidence to follow a U-shape throughout a project. As both perceived effectiveness as well perceived ease in the application of design thinking were thought to be facets of creative confidence, they were expected to show a similar pattern of development throughout a project.

The first step in testing this hypothesis was to conduct a visual analysis of how the joint measure of perceived effectiveness and ease developed over time. Figure 4.14 presents the corresponding data for each of the three sample groups. For the APE_n and APE_e groups, enough data was available to analyse each team separately. In Figure 4.14, the thick black line represents each sample group's average level of perceived effectiveness and ease. At first glance, perceived effectiveness and ease seem to have increased fairly linearly during the design thinking projects. No distinguishable U-shape could be detected.

As a second step, a linear regression model was fitted to the variable of perceived effectiveness and ease in Figure 4.14. The R^2 values > .5 for all three samples indicated that a linear model offers a good representation of the underlying data. For the APE_n and APE_e groups, the coefficient of the slope was significant at the .001 level. For the BA group, it was significant at the .01 level.

Figure 4.14: Perceived Effectiveness and Ease per Sample Group



This figure shows the level of perceived effectiveness and ease per sample (scale min. = 0, max. = 5). Each sample group average is shown as a thick black line. Error bars indicate the 95 % confidence intervals. R^2 indicates the fit of the trend line for sample group average of perceived effectiveness and ease.

Discussion

Based on the collected data, perceived effectiveness and ease seems to have slowly and linearly increased over the course of the design thinking projects. Hypothesis 4a, that perceived effectiveness and ease follows a U-shape throughout a project, was therefore rejected in favour of the null-hypothesis. Perceived effectiveness and ease actually appears to be mainly influenced by the amount of time a team spends working on a design thinking project.

Hypothesis 4b

An individual's perceived effectiveness and ease in the application of design thinking carries over to new projects and teams.

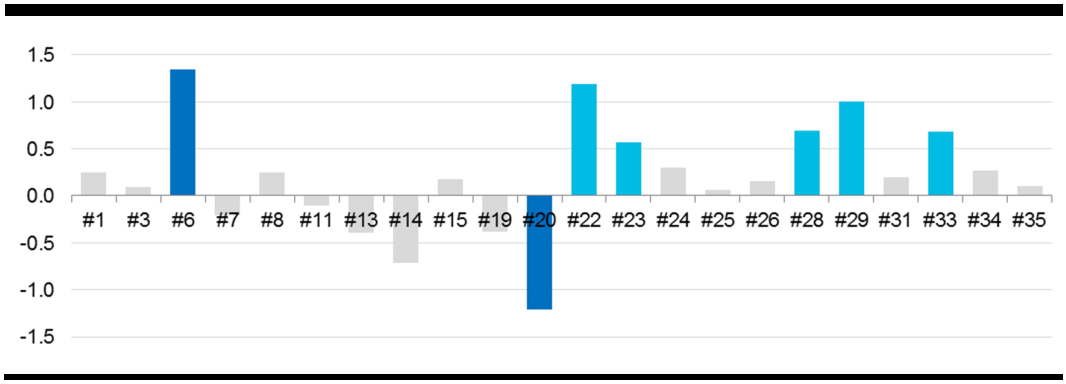
To analyse Hypothesis 4b, individuals in the APE_n and APE_e sample groups were compared. It was assumed that during the first design thinking project, (APE_n) novice participants had developed their perceived effectiveness and ease to some extent. It could subsequently be assumed that the participants exhibited higher levels of creative confidence during their final design thinking project (APE_e).

In the previous Figure 4.14, the average levels of perceived effectiveness and ease for both the APE_n and APE_e groups were represented by the thick black line. As has been described in the previous section relating to Hypothesis 4a, perceived effectiveness and ease in the application of design thinking seems to have increased linearly throughout a project. In Figure 4.14, the experienced sample group (APE_e) seems to have started off with a slightly higher base level of perceived effectiveness and ease compared to the novice sample group (APE_n). The slope of the fitted trend line for the experienced group therefore appears less steep than that of the novice group.

Figure 4.15 shows a visual comparison of the individual differences of means for the joint perceived effectiveness and ease measure. Individual-level data for both the novice and the experienced project were needed for this statistical comparison, which left a total of 22 cases to be analysed. An

examination of Figure 4.15 uncovered that for 16 out of the 22 participants, the level of perceived effectiveness and ease was higher for the APE_e project than the APE_n project. An independent samples *t*-test revealed that in five of these instances, this difference was significant at the .05 level (2-tailed). In one case it was significant at the .01 level (2-tailed). A closer examination of these significant cases revealed that the disciplinary background of all these participants is in management-related subjects. For the remaining six cases, the level of the average perceived effectiveness and ease seemed to have declined for the APE_e project. In one case (participant #20) this difference was significant at the .01 level (2-tailed). The disciplinary background of Kathryn (participant #20) is in business and music.

Figure 4.15: Differences in Average Perceived Effectiveness and Ease of Experienced and Novice Design Thinkers



The bars represent the differences in perceived effectiveness and ease between experienced and novice design thinkers (APE_e *minus* APE_n). Continuous data was available for 22 cases. Bars highlighted in light blue represent significant differences at the .05 level (2-tailed). Bars highlighted in dark blue represent significant differences at the .01 level (2-tailed).

Discussion

Overall, there appears to be some evidence that at least parts of individual perceived effectiveness and ease in the application of design thinking carries over to new projects and teams. However, in the current dataset, only six out of 22 cases showed a significantly higher level of perceived effectiveness

and ease in their final design thinking project. Therefore, Hypothesis 4b, that an individual's perceived effectiveness and ease in the application of design thinking carries over to new projects and teams, was rejected in favour of the null-hypothesis. In six out of 22 cases, perceived effectiveness and ease had decreased from the first to the last project. One potential reason for this might be a form of over-confidence in some novices, which resulted in a drop of perceived effectiveness and ease between the first and the final project, once they had adjusted their level of confidence in relation to the other participants.

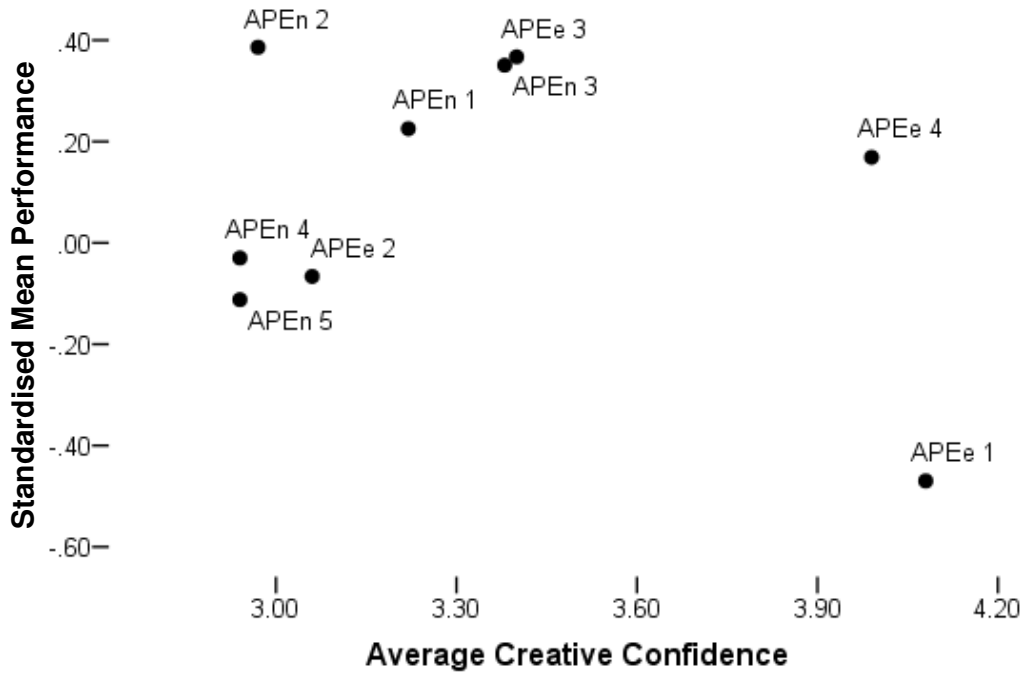
Hypothesis 4c

Teams comprised of individuals with high levels of perceived effectiveness and ease achieve a better final performance.

To test Hypothesis 4c, the joint variable of perceived effectiveness and ease was plotted against the standardised mean performance of the APE_n and APE_e teams in Figure 4.16. The scatter plot did not reveal any obvious linear correlation.

A Pearson product-moment correlation analysis confirmed that there is no significant linear correlation between the average perceived effectiveness and ease per team and its standardised mean performance. It should be noted that the joint variable of perceived effectiveness and ease did not show great variation across the different teams ($M = 3.331$, $SD = .436$).

Figure 4.16: Scatter Plot of Standardised Mean Performance and Perceived Effectiveness and Ease per Team



The analysis was extended to see if the levels of perceived effectiveness and ease during specific weeks correlate with the final team performance. This allowed the researcher to identify specific points in time during the observed design thinking project in which perceived effectiveness and ease might have had a stronger impact on the final performance than others. For the APE_n sample group, three weeks were identified as showing a significant correlation between these two variables. The levels of perceived effectiveness and ease for week 7 (2 Dec, $r = .924$, $p < .05$), week 9 (16 Dec, $r = .980$, $p < .01$), and week 10 (7 Jan, $r = .918$, $p < .05$) all show a high significant correlation with standardised mean performance. For the APE_e sample group on the other hand, no specific weeks were identified to show a significant correlation with final team performance.

Discussion

No significant linear correlation between the joint variable of perceived effectiveness and ease and final performance could be identified. Therefore, Hypothesis 4c, that teams comprised of individuals with high levels of perceived effectiveness and ease achieve a better final performance, was rejected in favour of the null-hypothesis. For the APE_n group, three individual weeks were shown to significantly correlate with final performance. These three weeks seem to coincide with the peak in the amount of iteration per week (refer to Figure 4.5 in Section 0). It should also be noted that the joint variable of perceived effectiveness and ease did not show great variation between the individual teams. This indicates that overall, teams exhibited fairly similar average levels of perceived effectiveness and ease, independent of their final performance.

4.7. Theme 5: Teams as Communication Networks

Individual and team communication in real-world projects is multi-faceted. This research study offered the rare opportunity to go beyond the analysis of individual cases and look at communication behaviour from a social network perspective. Furthermore, the longitudinal research design allowed the researcher to track changes in these networks across time. As previously described in Section 3.12.3, three different dimensions of communication were measured. The first dimension looked at how much APE participants communicated about the project they were currently undertaking and how helpful these exchanges were for moving that project along. This included the exchange of different forms of factual information (articles, studies, online sources, etc.), primary data from interviews, new product ideas, insights from testing prototypes with potential users, as well as other information relating to the ongoing project. The second dimension investigated how much APE participants communicated about innovation methods and how helpful this was for making progress within their projects. For example, this dimension included activities such as talking about how to apply the design thinking process, how to do desk research, how to conduct user interviews, how to come up with new ideas and how to build prototypes. The third dimension

measured how much APE participants communicated about private matters and how helpful this was for advancing their projects. This included all communication within and outside of the classroom which was not directly connected to the ongoing project and the employed innovation methods.

The completion rate for all surveys tracking the communication behaviour (see Appendix B) was 100 %, which enabled the researcher to compile complete and accurate visual network graphs for the different points in time. Figure 4.17 to Figure 4.20 show these network graphs as “small multiples”, which allow for visual comparisons of the different datasets (Tufte, 1997, 2001). These graphs leverage the human perceptual abilities to visually extract patterns from larger datasets (Bastian et al., 2009). The corresponding summaries in Table 4.4 to Table 4.7 further add descriptive network indicators, which supplement the interpretation of each network graph.

In general, a social network is comprised of a number of actors (nodes), which can be arbitrary entities, and one of several types of relationships (edges or vertices) which connect these actors (Brandes, 2001). When studying social networks, a simple but meaningful first indicator of how influential certain nodes are within a network is to see with how many other nodes they are connected to. In directed networks, two types of connection can be distinguished: In-degree and out-degree. In the current study in-degree indicates how many other APE participants wanted to talk to an individual person at each point in time. Hence, out-degree indicates with how many other participants an individual was engaged in. In a directed network, it is possible for two individuals to be connected in only one direction, in the sense that person A indicates that he/she frequently has meaningful exchanges with person B, but person B does not feel the same way and therefore does not indicate person A as a valuable communication partner. This is different to, for example, being friends on Facebook, where friendships are always bi-directional, in the sense that if a friendship request is accepted, person A is as much a friend to person B as person B is to person A. For this study, weighted degree metrics were used to see how

strong each connection was. Such weighted networks offer a much richer description of the story behind the data, especially when nodes represent individual people (Opsahl & Panzarasa, 2009). In the following Figure 4.17 to Figure 4.20, the total weighted in-degree for each APE participant is indicated by the size of their node. The researcher chose to display this indirect metric rather than total average degree, as it greatly reduced the risk of working with skewed network graphs due to biased self-reported data in which people over-estimate their own influence. The weight of each edge represents the strength of the connection between two participants.

Table 4.4 to Table 4.7 provide further metrics to describe the topology of each network. The average path length states the average number of steps needed to connect each node with every other node along the shortest possible path within a network. This robust metric can be interpreted as the efficiency of information diffusion within a network (Albert & Barabási, 2002). Another measure introduced in the summary tables is the average clustering coefficient which was built on research by Watts and Strogatz (1998) on small worlds networks. On an individual level, the clustering coefficient measures how complete the neighbourhood of an individual node is. The average clustering coefficient therefore describes the average of all individual clustering coefficients within each APE network. Lastly, graph density describes how close each graph is to being perfectly connected. Theoretically, this metric ranges from “0” (none of the nodes are connected) to “1” (every node is connected to all other possible nodes). For each graph, edges with a weight of 0 are excluded from the statistical analysis.

Data for the APE_n sample group was collected twice during their project. From the graphs in Figure 4.17 and the network topology metrics in Table 4.4 it was concluded that the connection between individuals have overall become stronger, as indicated by an increase in the average weighted degree and graph density. It was also concluded that out of the three measured dimensions of communications, the APE_n participants talked extensively more about the ongoing project, than about innovation methods or private matters.

For the APE_e sample group, data was collected at four different instances throughout the project. This data is displayed in Figure 4.18 to Figure 4.20 and Table 4.5 to Table 4.7. Again, it was concluded that overall, the connections between individuals seem to have increased over time. Like in the APE_n group, participants seemed to have communicated more about the ongoing project, than about innovation methods or private matters.

Table 4.4: Summary of APE_n Communication Networks

	Figure 4.17.1	Figure 4.17.2	Figure 4.17.3	Figure 4.17.4	Figure 4.17.5	Figure 4.17.6
Number of Edges	131	124	111	121	103	107
Avg. Weighted Degree	2.277	2.838	1.358	1.672	1.325	1.487
Avg. Path Length	2.138	2.342	2.259	2.387	2.321	2.541
Avg. Clustering Coefficient	.574	.511	.518	.502	.533	.476
Graph Density	.237	.245	.201	.239	.187	.211
Edge Weight = 0 in %	1.53	1.59	15.27	3.97	21.37	15.08

Figure 4.17: Communication Networks for APE$_n$ Teams

Figure 4.17.1 and Figure 4.17.2: Communication about the Ongoing Project

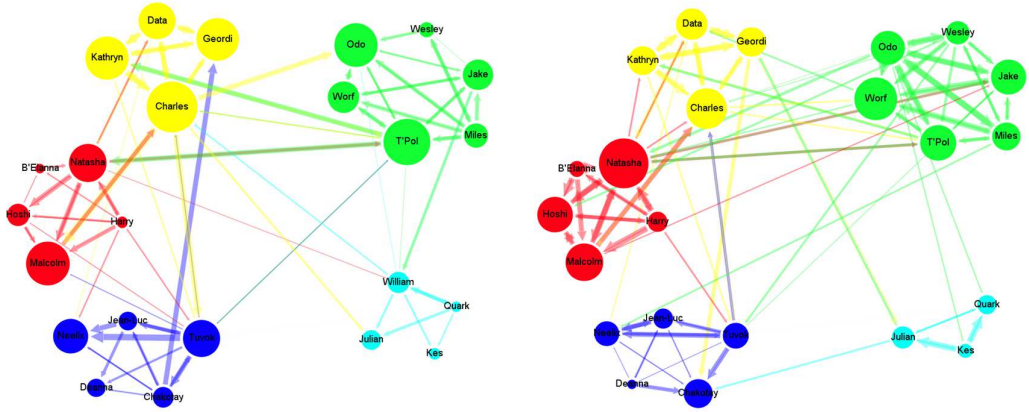


Figure 4.17.3 and Figure 4.17.4: Communication about Innovation Methods

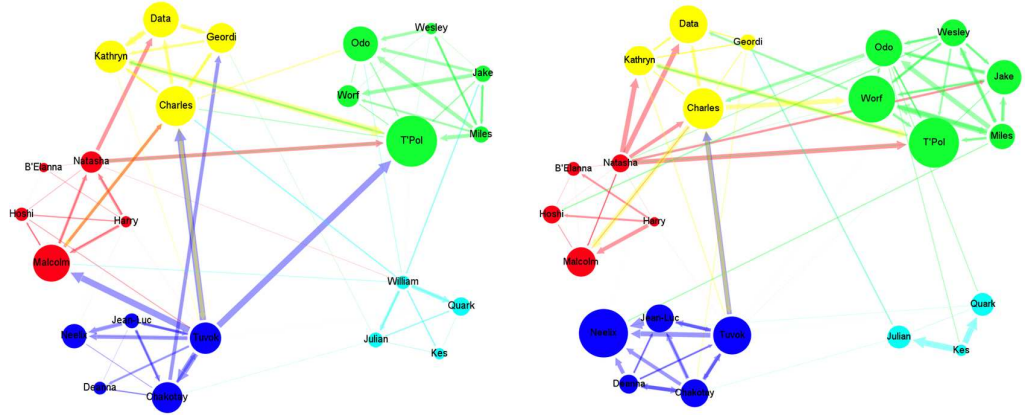
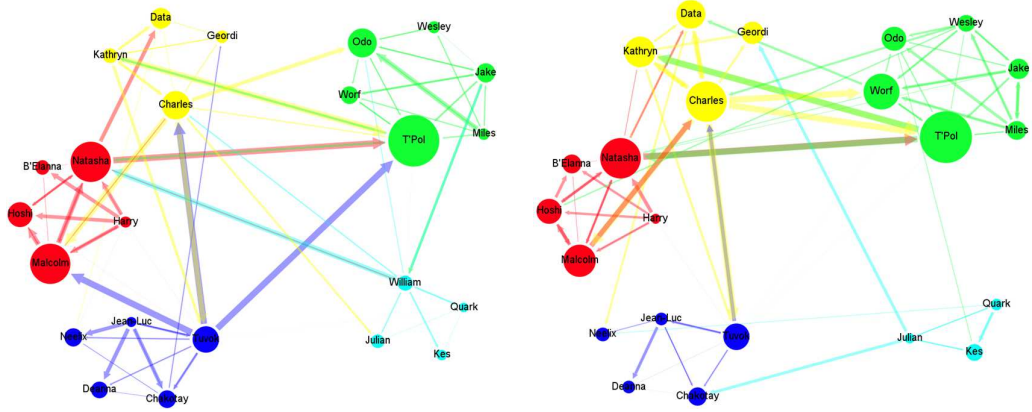


Figure 4.17.5 and Figure 4.17.6: Communication about Private Matters

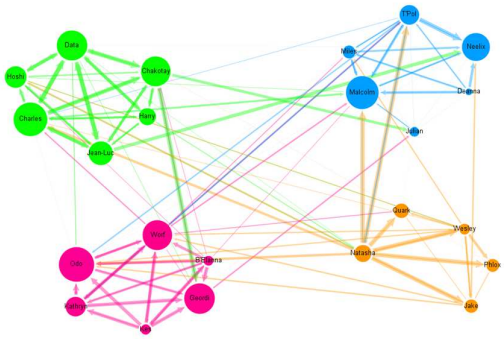


During Project: Week 6/7 End of Project: Week 12/13

The size of each node was determined by the weighed in-degree of that person. Edge weight was determined by how frequently communication took place and how helpful this was for the ongoing project. This figure is based on $n = 23$ nodes.

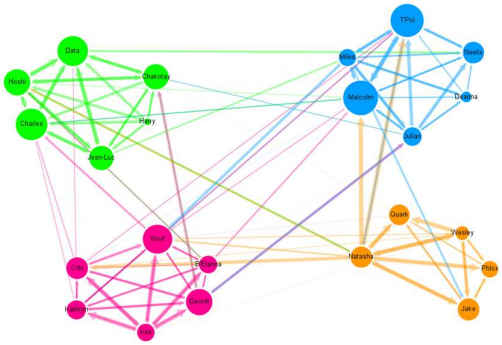
Figure 4.18: APE$_e$ Team Communication about the Ongoing Project

Figure 4.18.1



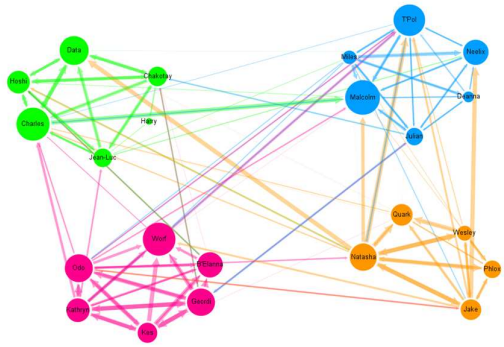
Beginning of Project: Week 1

Figure 4.18.2



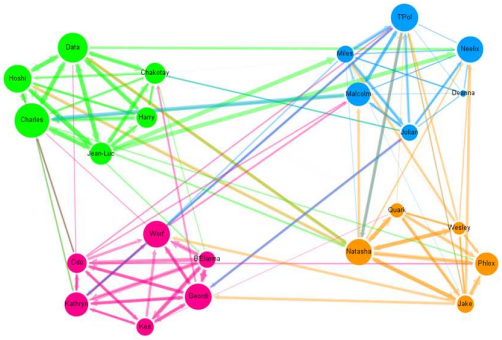
During Project: Week 6/7

Figure 4.18.3



During Project: Week 11/12

Figure 4.18.4



End of Project: Week 17

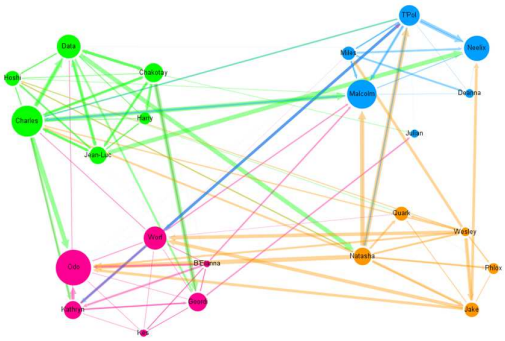
The size of each node was determined by the weighed in-degree of that person. Edge weight was determined by how frequently communication took place and how helpful this was for the ongoing project. This figure is based on n = 23 nodes.

Table 4.5: Summary of APE$_e$ Communication about the Ongoing Project

	Figure 4.18.1	Figure 4.18.2	Figure 4.18.3	Figure 4.18.4
Number of Edges	153	151	153	161
Avg. Weighted Degree	2.774	3.143	3.261	3.823
Avg. Path Length	1.889	1.933	1.886	1.825
Avg. Clustering Coefficient	.485	.526	.490	.505
Graph Density	.302	.298	.302	.318
Edge Weight = 0 in %	6.13	5.62	2.55	1.23

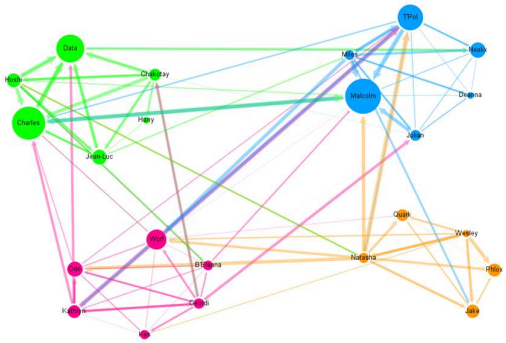
Figure 4.19: APE$_e$ Team Communication about Innovation Methods

Figure 4.19.1



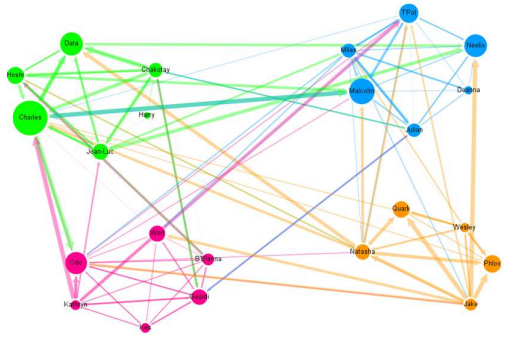
Beginning of Project: Week 1

Figure 4.19.2



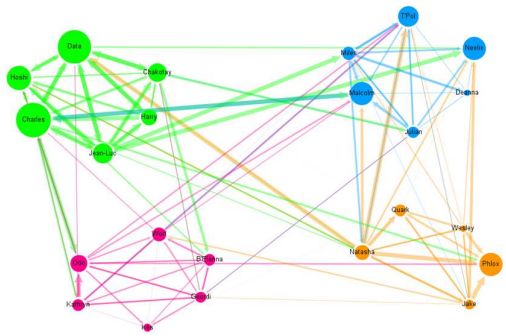
During Project: Week 6/7

Figure 4.19.3



During Project: Week 11/12

Figure 4.19.4



End of Project: Week 17

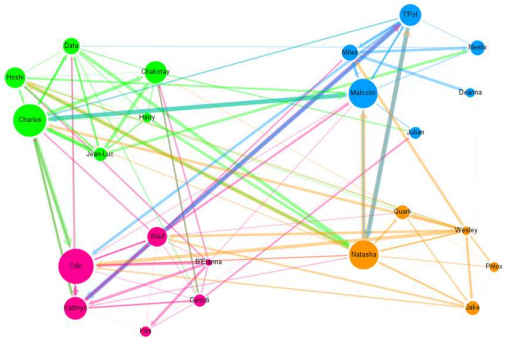
The size of each node was determined by the weighed in-degree of that person. Edge weight was determined by how frequently communication took place and how helpful this was for the ongoing project. This figure is based on n = 23 nodes.

Table 4.6: Summary of APE$_e$ Communication about Innovation Methods

	Figure 4.19.1	Figure 4.19.2	Figure 4.19.3	Figure 4.19.4
Number of Edges	134	141	147	147
Avg. Weighted Degree	2.134	2.134	2.323	2.718
Avg. Path Length	2.047	2.047	1.913	1.907
Avg. Clustering Coefficient	.496	.496	.478	.462
Graph Density	.279	.279	.291	.291
Edge Weight = 0 in %	11.88	11.88	6.37	9.82

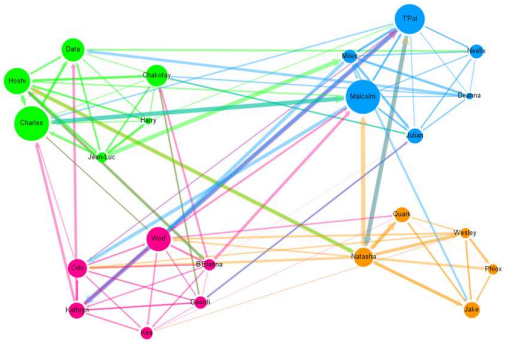
Figure 4.20: APE$_e$ Team Communication about Private Matters

Figure 4.20.1



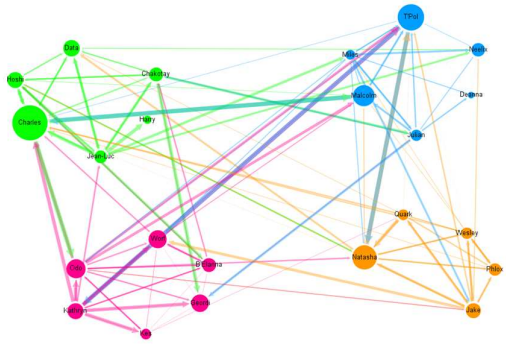
Beginning of Project: Week 1

Figure 4.20.2



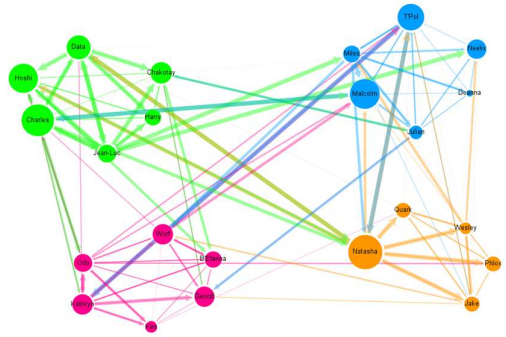
During Project: Week 6/7

Figure 4.20.3



During Project: Week 11/12

Figure 4.20.4



End of Project: Week 17

The size of each node was determined by the weighed in-degree of that person. Edge weight was determined by how frequently communication took place and how helpful this was for the ongoing project. This figure is based on *n* = 23 nodes.

Table 4.7: Summary of APE$_e$ Communication about Private Matters

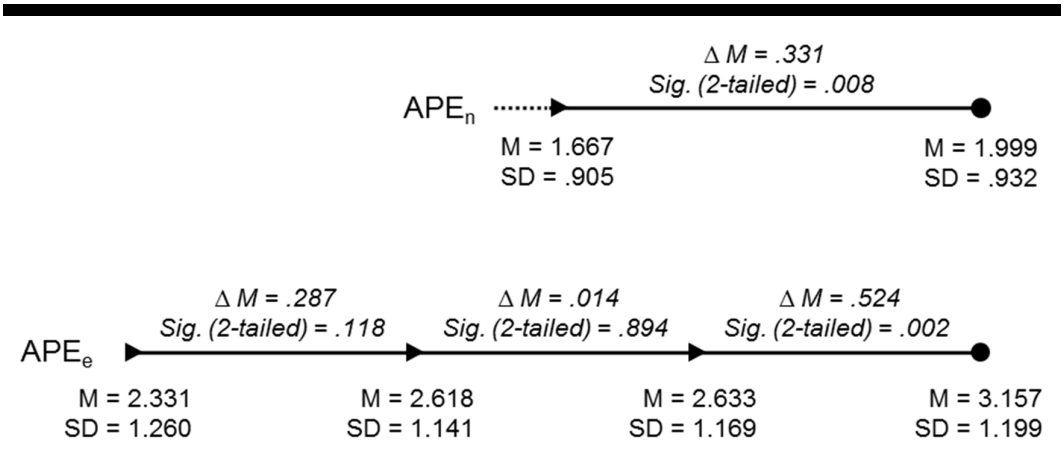
	Figure 4.20.1	Figure 4.20.2	Figure 4.20.3	Figure 4.20.4
Number of Edges	139	153	144	157
Avg. Weighted Degree	2.143	2.579	2.315	2.932
Avg. Path Length	1.911	1.933	1.898	1.862
Avg. Clustering Coefficient	.451	.506	.457	.486
Graph Density	.275	.302	.285	.310
Edge Weight = 0 in %	14.72	4.38	8.28	3.68

Hypothesis 5a

The relative importance of individuals changes throughout a design thinking project.

To facilitate statistical testing, the three measured dimensions of communication were aggregated into one single dataset. In Figure 4.17 to Figure 4.20, the node size within each network graph represents each participant's weighted in-degree centrality. Overall, the measure of weighted in-degree centrality increased over time. This indicates that stronger connections were formed, the longer the teams had worked together. There appeared to be some individual cases for which distinct changes in in-degree centrality between the different points in time could be observed. Applying a paired samples *t*-tests revealed mixed findings, as illustrated in Figure 4.21. For the individual APE_n participants overall, a significant difference at the 1 %-level was discovered for the two available points in time. For the APE_e participants, only the comparison of the last two available points in time revealed a significant difference in the change of the individual weighted in-degree at the 1 %-level.

Figure 4.21: Change of Average Weighted In-Degree over Time



For the APE_n (n = 23) sample group, the communication behaviour was measured once during the middle of the project and once at the end. For the APE_e (n = 23) sample group, four data points were available, one at the start of the project, one at the end, and two in-between.

However, the weighted in-degree measure only provided a rudimentary perspective on the importance of individuals within the team networks and the overall programme network structure. Therefore, the eigenvector centrality of each individual person within the analysed social network was calculated to provide a more comprehensive measure of individual importance. In general, centrality measures classify the actors by their prominence in a given social network (Brandes, 2001). Social network theory suggests that individuals with a high centrality within a network are more powerful than others (Bonacich, 2007). In contrast to less complex centrality measures such as in-degree, out-degree, betweenness, or closeness, the eigenvector centrality measure used for the subsequent analysis does not solely rely on the centrality of each individual node, but also takes into account the centrality of neighbouring nodes (Bonacich, 1987, 2007). This means that high-degree nodes, in this case APE participants, became more powerful, the more they were connected to low degree nodes in their local network. Vice versa, low degree nodes become more powerful, if they were connected to high degree nodes. This eigenvector centrality measure was deemed an appropriate way to express the relative importance of individuals within the APE cohort.

To test Hypothesis 5a, “relative importance” was operationalised by assigning ranks to each member of a team according to their individual eigenvector centrality score. Changes in the ranking order within a team across two consecutive time intervals therefore signalled a change of the relative importance of the individual team members. The ranking order for each APE_n and APE_e team across the measured time periods is presented in Figure 4.22 and Figure 4.23. The columns marked in light grey indicate the changes between consecutive intervals. For each team, a percentage value expresses how many of the team members changed ranks between these intervals.

For the APE_n group, data about the communication behaviour was only collected for two intervals. Between the halfway point (week 6/7) and the end of the project (week 12/13), an average of 51 % of team members changed

their rank within in their team. This phenomenon appears to vary across teams. Within Team 1 (Red), four out of five team members changed ranks, no rank changes were reported for Team 3 (Yellow).

For the APE_e sample group, data was collected four times, almost evenly spread from the beginning to the end of the project. During the first few weeks of the project, an average of 78 % of team members moved to a different rank within their team. This percentage declined to 60 % for the following weeks. On average, only 29 % of individuals changed their rank during the last few weeks of the project. This indicates that changes in individual importance tend to occur more often during the early phases of a project. However, large differences between the teams become apparent during these last few weeks. While no changes in ranks were reported for Team 1 (Green) and Team 4 (Orange), the analysis for Team 2 (Pink) revealed that within this team, five out of six team members moved to a different position within the ranking order.

Figure 4.22: APE_n Changes in Individual Importance per Team According to Eigenvector Centrality Ranks

		t1		t2		Δ t1 → t2	
	Within Team Rank	Participant (ID) Ranked	Eigenvector Centrality	Participant (ID) Ranked	Eigenvector Centrality	Δ Eigenvector Centrality	% Rank Changes
Team 1	1	#34	0.55	#34	0.89	0.33	
(Red)	2	#24	0.50	#8	0.59	0.13	
	3	#13	0.49	#15	0.43	0.12	
	4	#8	0.46	#24	0.41	-0.09	
	5	#15	0.31	#13	0.37	-0.12	
							80%
Team 2	1	#7	0.88	#7	0.88	0.00	
(Blue)	2	#10	0.33	#11	0.36	0.14	
	3	#26	0.30	#26	0.33	0.03	
	4	#11	0.22	#22	0.14	-0.04	
	5	#22	0.18	#10	0.10	-0.24	
							60%
Team 3	1	#33	0.91	#33	0.91	0.00	
(Yellow)	2	#3	0.51	#3	0.62	0.11	
	3	#1	0.50	#1	0.46	-0.04	
	4	#20	0.36	#20	0.36	0.00	
							0%
Team 4	1	#23	0.82	#31	0.67	0.08	
(Green)	2	#31	0.59	#23	0.56	-0.26	
	3	#35	0.53	#35	0.56	0.03	
	4	#25	0.36	#6	0.44	0.14	
	5	#6	0.30	#25	0.31	-0.05	
	6	#29	0.18	#29	0.11	-0.06	
							66%
Team 5	1	#14	0.86	#14	0.79	-0.07	
(Turquoise)	2	#28	0.63	#32	0.68	0.17	
	3	#32	0.51	#28	0.50	-0.14	
	4	#11	0.50	#11	0.00	-0.50	
							50%
M			0.49		0.48	-0.01	
SD			0.21		0.25	0.17	
% Rank Changes							**51%**

Figure 4.23: APE_e Changes in Individual Importance per Team According to Eigenvector Centrality Ranks

		t1		t2		Δ t1 → t2		t3		Δ t2 → t3		t4		Δ t3 → t4	
	Within Team Rank	Participant (ID) Ranked	Eigenvector Centrality	Participant (ID) Ranked	Eigenvector Centrality	Δ Eigenvector Centrality	% Rank Changes	Participant (ID) Ranked	Eigenvector Centrality	Δ Eigenvector Centrality	% Rank Changes	Participant (ID) Ranked	Eigenvector Centrality	Δ Eigenvector Centrality	% Rank Changes
Team 1	1	#24	0.75	#33	0.78	0.39		#1	0.49	-0.11		#1	0.79	0.30	
(Green)	2	#1	0.63	#7	0.76	0.41		#7	0.51	-0.25		#7	0.69	0.19	
	3	#22	0.59	#22	0.74	0.15		#15	0.22	0.02		#15	0.29	0.07	
	4	#33	0.39	#1	0.60	-0.03		#22	0.56	-0.19		#22	0.80	0.25	
	5	#7	0.35	#24	0.34	-0.41		#24	0.53	0.19		#24	0.80	0.27	
	6	#15	0.28	#15	0.20	-0.08		#33	0.59	-0.19		#33	0.66	0.07	
							66%				66%				0%
Team 2	1	#35	0.49	#25	0.67	0.21		#20	0.65	0.03		#20	0.89	0.24	
(Pink)	2	#20	0.48	#3	0.64	0.50		#35	0.46	-0.01		#25	0.71	0.25	
	3	#25	0.46	#20	0.61	0.13		#25	0.46	-0.21		#3	0.67	0.24	
	4	#14	0.44	#13	0.60	0.44		#3	0.43	-0.21		#14	0.55	0.27	
	5	#13	0.15	#35	0.47	-0.01		#13	0.31	-0.29		#35	0.55	0.09	
	6	#3	0.14	#14	0.40	-0.04		#14	0.28	-0.12		#13	0.39	0.08	
							100%				83%				83%
Team 3	1	#23	0.83	#11	0.83	0.21		#11	0.74	-0.09		#11	0.88	0.14	
(Blue)	2	#11	0.62	#23	0.82	0.00		#23	0.61	-0.22		#19	0.73	0.20	
	3	#19	0.51	#19	0.60	0.09		#19	0.53	-0.07		#23	0.54	-0.07	
	4	#31	0.40	#26	0.39	0.07		#34	0.36	0.10		#34	0.47	0.11	
	5	#26	0.32	#31	0.33	-0.07		#26	0.27	-0.11		#26	0.39	0.12	
	6	#34	0.27	#34	0.26	-0.01		#31	0.25	-0.08		#31	0.34	0.09	
							66%				50%				33%
Team 4	1	#8	0.99	#28	0.99	0.17		#8	0.99	0.01		#8	0.92	-0.08	
(Orange)	2	#28	0.82	#8	0.98	-0.01		#28	0.88	-0.10		#28	0.89	0.00	
	3	#6	0.51	#29	0.91	0.47		#29	0.60	-0.32		#29	0.72	0.12	
	4	#29	0.44	#6	0.60	0.08		#6	0.46	-0.13		#6	0.50	0.04	
	5	#36	0.27	#36	0.18	-0.09		#36	0.22	0.04		#36	0.50	0.28	
							80%				40%				0%
M			0.48		0.60	0.11			0.50	-0.10			0.64	0.14	
SD			0.21		0.24	0.22			0.20	0.13			0.19	0.11	
% Rank Changes							**78%**				**60%**				**29%**

Discussion

Overall, individual team members and the APE cohort as a whole formed stronger connections with each other, the longer they had worked together on a specific project. Ranking all members of each team by their individual eigenvector centrality scores at the different points in time revealed that significant changes in the ranking order within most teams took place. This indicated that individual importance within the observed teams changed significantly over the course of a design thinking project. Hypothesis 5a, that the relative importance of individuals changes throughout a design thinking project, was therefore accepted. These changes in importance appear to have been more distinct during the early phases of the projects and tended to decline, the longer a team had worked together.

Hypothesis 5b

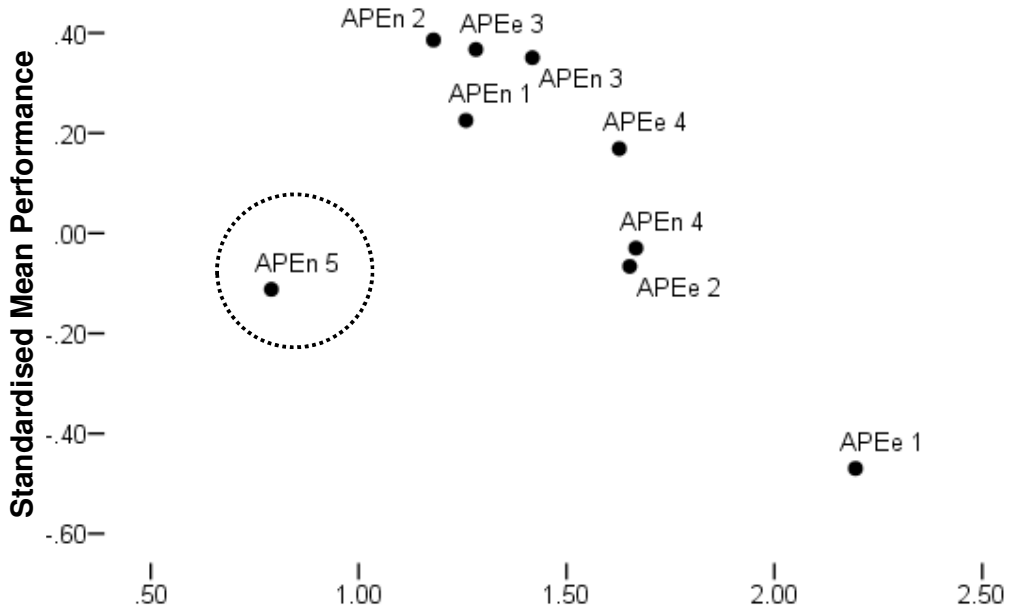
Design thinking teams with a high degree of internal cohesion achieve a better final performance than teams with a low degree of internal cohesion.

To test Hypothesis 5b, team cohesion was operationalised as the total average weighted degree of all ties within a team across the different points in time. This took into account the number of connection within each team and the strengths of each of these connections. Using the average scores of each team controlled for the different team sizes. Using the averages also allowed for the APE_n and APE_e to be analysed together. To ensure that both groups could be analysed together, an independent samples *t*-test was conducted. The test showed no significant differences between the two groups for both the total average weighted degree and the standardised mean performance. The total average weighted degree of the APE_e group ($M = 1.689$, $SD = .377$) was only slightly higher than that of the APE_n group ($M = 1.262$, $SD = .323$). This was to be expected, as the APE_e group had already known each other from the previous APE_n projects. The total average weighted degree ranged from .787 for APE_n Team 5 to 2.195 for APE_e Team 1. The difference in standardised mean performance between the

APE_n sample group (M = .164, SD = .224) and the APE_e sample group (M = 0.000, SD = .359) were minimal. Therefore, both sample groups could subsequently be analysed together.

A scatter plot of the two variables showed a clear correlation pattern for most teams, except for APE_n Team 5 (see Figure 4.24). A closer look this outlier revealed that this team had lost two team members during their project. Each of the two team members left at a critical stage of the project. This had a great impact on the team's overall motivation and cohesion and made the team experience less comparable to the other teams. The researcher therefore decided not to include Team 5 in further analyses regarding internal team cohesion.

Figure 4.24: Scatter Plot of Standardised Mean Performance and Average Weighted Degree Within Team (Internal Cohesion)



The highlighted APE_n Team 5 represented an outlier which was excluded from further analysis regarding internal team cohesion.

A Pearson product-moment correlation was conducted for the remaining eight teams. It revealed a very strong significant negative correlation of $r = -.947$ between the total average weighted degree and standardised mean performance at the .001 level (1-tailed) as shown in Table 4.8. This finding points to a significant reverse effect of internal cohesion and standardised mean performance compared to the initial hypothesis.

Table 4.8: Pearson Correlations of Standardised Mean Performance and the Different Dimensions of Internal Team Cohesion

	Cohesion Total	Cohesion Project	Cohesion Methods	Cohesion Private
Standardised Mean Performance	-.947***	-.869**	-.695*	-.845**

* Correlation is significant at the .05 level (1-tailed). ** Correlation is significant at the .01 level (1-tailed). *** Correlation is significant at the .001 level (1-tailed).

The analysis is extended to look at the three different dimensions of communication separately. The first dimension captured how much individuals in the APE_n and APE_e groups communicated about the specifics of the projects they were working on and how helpful this was for their project. As shown in Table 4.8, team cohesion for this dimension of communication showed a significant negative correlation with standardised mean performance, $r = -.869$, $p < .01$ (1-tailed). The second communication dimensions looked at how much participants communicated about innovation methods in general and how helpful this was for their project. This type of communication also had a significant negative effect on the final performance of teams at the .05 level (1-tailed). The third dimension of communication dealt with how much individuals communicated about private matters and how helpful this was for their project. This dimension also showed a significant negative correlation between internal team cohesion and standardised mean performance, $r = -.845$, $p < .01$ (1-tailed).

Discussion

A strong significant negative correlation of $r = .947$ exists between the average degree of internal team cohesion and the final performance of the observed teams. Therefore, Hypothesis 5b, that design thinking teams with a high degree of internal cohesion achieve a better final performance than teams with a low degree of internal cohesion, was rejected. In fact, the opposite of the research hypothesis seems to be true. Teams with a lower degree of internal cohesion showed a significantly better final team performance than those with a higher degree of cohesion. This effect was observable for all three dimensions of communication analysed in this study. One possible explanation for this effect might be that teams with high internal cohesion form a joint group opinion (i.e. groupthink) early on in the process and therefore do not benefit from the multiple points of view enabled by the different disciplinary backgrounds present in a team (compare Section 4.3).

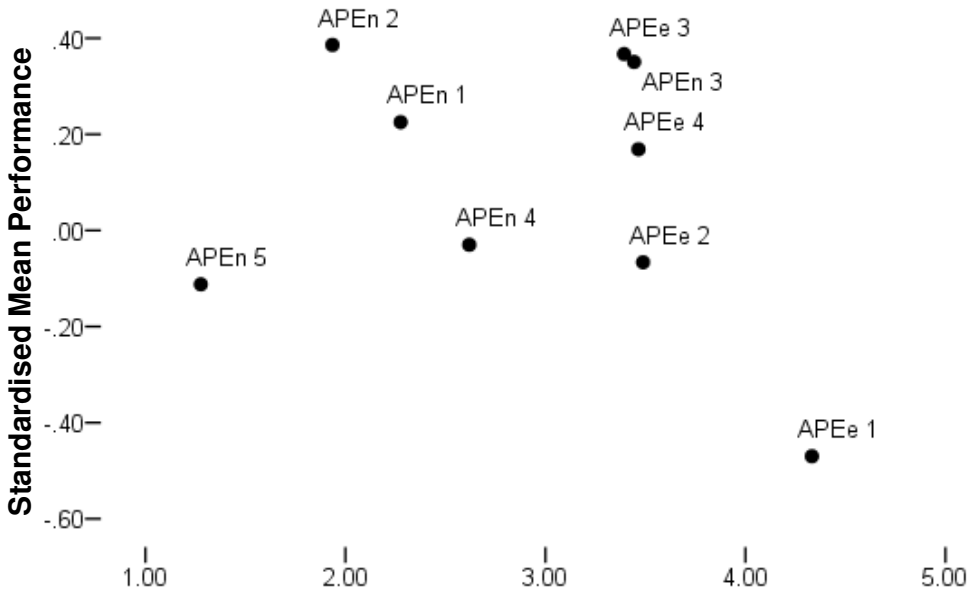
Hypothesis 5c

Design thinking teams with a high degree of external cohesion achieve a better final performance than those teams with a low degree of external cohesion.

Building on the previously tested Hypothesis 5b, an analogous logic was applied to Hypothesis 5c to investigate, if the degree of external cohesion with other project team members outside one's own team influenced the final team performance. The sample was again comprised of both the APE_n and APE_e teams.

A scatter plot was produced to allow for an initial visual assessment of the data (see Figure 4.25). No distinguishable correlation patterns could be discovered between the average weighted degree outside of a team (external cohesion) and the standardised mean performance.

Figure 4.25: Scatter Plot of Standardised Mean Performance and Average Weighted Degree Outside of Team (External Cohesion)



A Pearson product-moment correlation also revealed no significant correlation between the average weighted degree outside of a team (external cohesion) and the standardised mean performance. Analogues to the analysis conducted for the previous Hypothesis 5b, external cohesion was subsequently broken down into the three sub-dimensions of communication. No significant correlations between any of the three dimensions and standardised mean performance were identified for Hypothesis 5c.

Discussion

No significant correlation between the average weighted degree outside of a team (external cohesion) and the standardised mean performance became apparent from the collected data. Hypothesis 5c, that design thinking teams with a high degree of external cohesion achieve a better final performance than those teams with a low degree of external cohesion, was therefore rejected in favour of the null-hypothesis. Breaking down external cohesion into different sub-dimensions of communication also did not yield a significant

correlation pattern with final team performance. It therefore seems that design thinking project teams are not significantly influenced by other teams they work alongside with.

4.8. Summary of Findings from Weekly Open Questions

In the following section, attention is briefly drawn to selected findings from the weekly open questions posed to the participants via the weekly team survey instrument (see Appendix A). As previously described, these open-ended questions were mostly of an exploratory character. Therefore, not every posed question was expected to directly connect to the more quantitative findings from the other research instruments. Presented in this section is a sub-set of the collected qualitative survey responses, which the author interpreted as either clarifying, explaining, or extending the quantitative observations and findings presented in this chapter.

This discussion deepened the overall understanding and interpretation of the collected data. The findings were summarised and edited for brevity. Selected verbatim quotes are presented together with the narrative summary to better illustrate individual participant opinions.

Novice APE Sample Group (APE_n)

At the start of the project, most APE_n participants reported a fairly high level of initial confidence about solving the innovation challenge which was posed to them. Overall, participants indicated that, although they did not yet know the direction they were taking their projects in, they nonetheless felt confident about achieving satisfactory results. The participant Quark explained this as following: "*I know I will create a great product. I just don't know what it is going to be.*" When participants were asked the following week if they felt that they had all the necessary skills within their team to successfully complete their current project, the responses were more varied. Whereas some noted that within their team they possessed a sufficient skill-set for finishing their project, others indicated slight doubts about their team's abilities.

Another set of questions, posed to the participants in the middle of their project, allowed the researcher to gain further understanding about the different approaches the teams were taking. For example, in Week 5 participants were asked if they believed that their group had chosen a "structured" or a "chaotic" approach for solving their innovation challenge. About half of the participants stated that they worked in a structured way, whereas the other half of the participants indicated they their groups worked in a more chaotic way. Deanna explained that the design thinking process model provided some overall structure for their project, but that within each phase of the process, her team had taken a more chaotic approach. Odo ascribed a certain level of chaos within his team to bad time management, but also explained that his team seemed to have become more structured, the longer they had worked together. When participants were asked in Week 7, if they had assigned specific roles within their team, all participants indicated that they did not think that this was necessary. Data justified this choice as following: "*I don't see the value in specific roles within the design thinking process*." Chakotey's answer hinted to a more flexible approach, when it comes to team roles. He explained that his team did not need permanent fixed roles. Instead, his team assigned certain roles when they became necessary and then frequently switched the owner of that role.

In Week 8, participants were asked about how they were trying to incorporate the technical limitations of their challenge into their concept development process (Note: Prototypes for the projects had to be built using 3D-printing). Interestingly, APE participants did not think about these technical restrictions within their projects, until they were at the "generate ideas" and "prototyping" stage. In general, teams seemed to rely on the engineers within a team to have the necessary skills to quickly take their ideas into production at the end of the project.

The last two questions of the novice APE project were targeted towards finding out how the participants themselves thought their projects had progressed. When asked about, what each participant would do differently if they could start over with their project, six out of 19 participants indicated that

they would shift their focus more towards the last two steps of the design thinking process. Geordi for example commented that he would plan for shorter “understand problem” and “observe environment” phases in the process. Kathryn indicated that she would spend less time on ideation and concept selection, while Natasha said that she would plan for more prototyping and testing towards the end of the project. Participants generally seemed to have followed up on this insight, as becomes obvious when comparing the project time distribution of the APE_n and APE_e groups in Figure 4.4 (see Section 0). Interestingly, when asked how satisfied participants were with their final results, all participants expressed a very high level of satisfaction. One example was Hoshi. She explained that, “*[I am] very satisfied, confident and proud of our product!*”

BA Sample Group

A similar set of weekly open questions was posed to the BA teams which worked on their project in parallel to the APE_n group. In general, their answers were very similar to those given by the APE participants. Like the APE group, the BA students started their project with a moderately high level of confidence about achieving a satisfactory project outcome (compare Figure 4.14). Interestingly, similar to the APE_n group, all BA participants stated in Week 2 that they thought that they had all necessary skills to complete the project, although each team was made up entirely of business administration students with no formal engineering training.

The BA teams tended to be more specific about assigning fixed roles within their teams early on. Like the APE group, they did not spend great consideration on the technical restrictions imposed by the 3D-printing component of their innovation challenge early on in the project. Five out of eight respondents indicated that they would rely on outside help for producing the 3D-printed prototypes needed for their projects.

Similar to the APE participants, the BA students indicated a very high level of overall satisfaction at the end of their projects.

Experienced APE Sample Group (APE_e)

For the APE_e sample group some questions from the APE_n weekly surveys were repeated, while additional reflective questions were added to explore how the participants' previous experiences influenced their approach and thought processes. Similar to the novice APE_n group, all participants indicated a high initial levels of confidence about producing a satisfactory project outcome.

When again asked if the participants perceived the organisation within their team as "structured" or "chaotic", 13 out of 22 participants indicated a relatively structured approach towards the different team projects. Some of these participants also stated that, with their additional experience since the APE_n project, they tended to structure their projects even more than before. Although, a small amount of "chaos" in fact seemed to be a good thing, as Jean-Luc pointed out when he commented: "*I think we have structured project management. Sometimes it feels chaotic, but in a positive way.*" Malcolm however, was more critical of the structured approach his team had chosen when he noted: "*I think we're chaotic people who try to work in a structured way.*"

Near the end of the projects, participants were also asked two questions relating to their experience with multidisciplinary teamwork. Ten out of 18 responses indicated that participants generally thought that working in multidisciplinary teams adds value. They highlighted several advantages of multidisciplinary teamwork, but also hinted to the fact that the process of working together with people from different disciplinary backgrounds tended to be more challenging. Natasha explained this as following: "*You've got various opinions and views and are challenged to work with all of them.*" Data expressed a similar point of view and stated that in multidisciplinary teams it was easier to come up with novel ideas, but harder to communicate a novel idea to other team members. The key to successful multidisciplinary projects seemed to depend largely on how well a team actively managed the process of overcoming disciplinary differences, as both Hoshi and Jake have pointed out.

Finally, APE_e participants were again asked to rate their level of satisfaction with the final project outcome toward the end of the project. All APE_e participants reported very high satisfaction rates, with only minimal differences between the four projects teams.

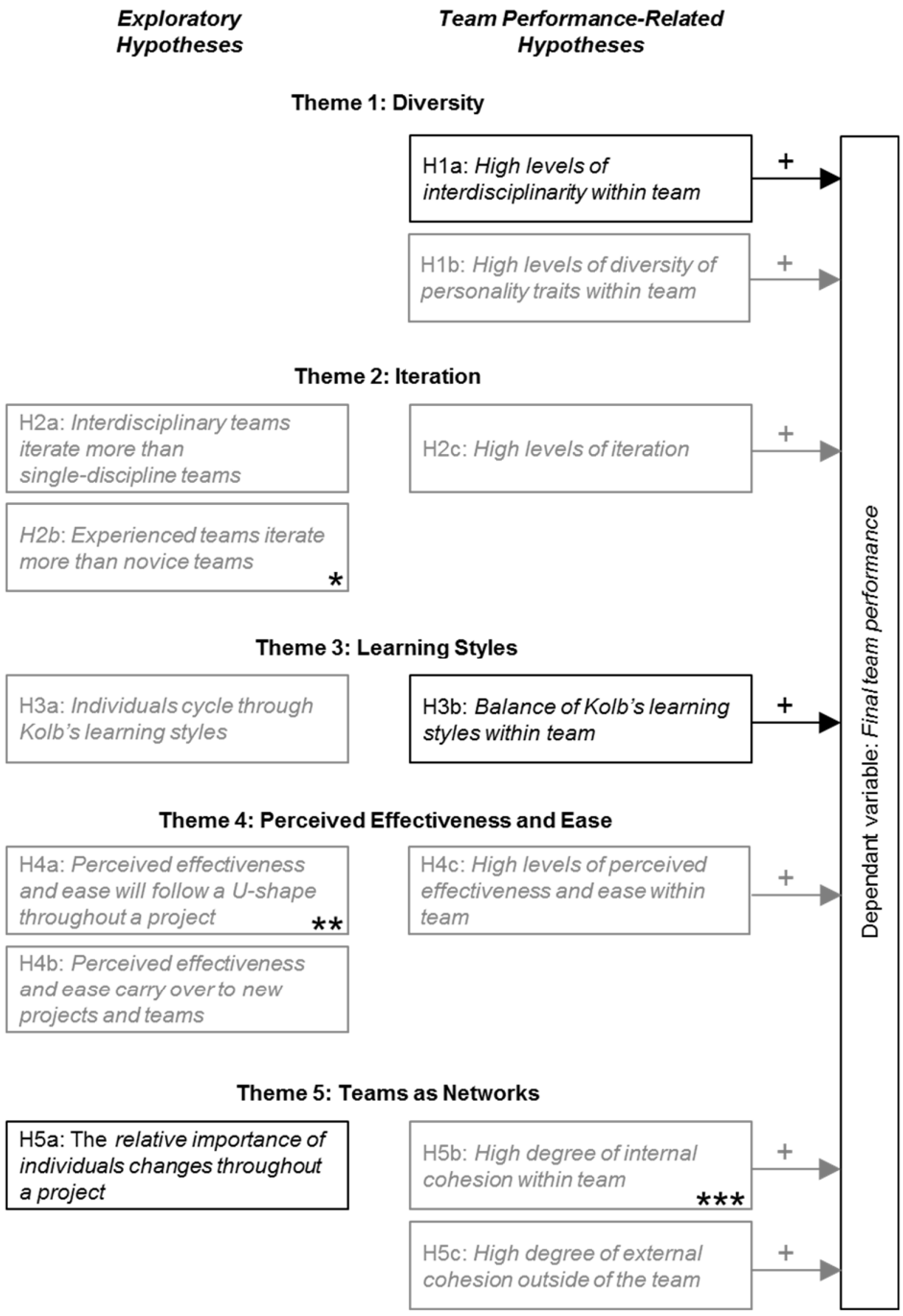
4.9. Chapter Summary

Presented in this chapter was a thorough empirical analysis of the underlying research themes and hypotheses. The chapter started out by scrutinising the variable of “final team performance”, as it forms the dependable variable for many of the following research hypotheses. After standardising the rater assessments and dropping inconsistent panel members, the internal consistency of the CAT assessment tool was found to be satisfactory.

Subsequently, different hypotheses for each of the five previously introduced research themes (see Section 3.2) were scrutinised by applying various statistical methods. The thorough data analysis also revealed some significant effects which lead the researcher to adjust previous assumptions. For Hypothesis 5b, significant evidence was found to reverse the previously assumed direction of the proposed effect. Whereas it was previously assumed that a high level of internal cohesion would have a positive effect on final team performance, in fact, a significant negative correlation between the two variables was identified. For Hypothesis 4a, significant evidence was found to support an alternative effect. Based on the popular book by Brown (2009), it was assumed that creative confidence, as conceptualise by the levels of perceived effectiveness and ease, would follow a U-shape throughout a project. However, the analysis of the available data revealed significant evidence that perceived effectiveness and ease in the application of design thinking actually build up linearly throughout a project.

Shown in the following Figure 4.26 is a visual summary of the findings from this chapter. For hypotheses displayed in black font, sufficient evidence was found to accept these hypotheses. For hypotheses displayed in grey font, no significant supporting evidence was found. In case of Hypothesis 3a, this was likely due to the limited amount of available data for the chosen statistical test.

Figure 4.26: Summary of Findings



Hypotheses for which no significant evidence was found are set in grey colour. Comments:
H2a (*): Weak evidence suggests that the opposite effect might be true, i.e. experienced teams iterate less than novice teams, although this effect was not significant.
H4a (**): Perceived effectiveness and ease in fact developped linearly over time.
H5b (***): Significant evidence was found to suggest the opposite effect, i.e. a high degree of internal cohesion within a team actually has a negative effect on final team performance.

5. Validation of Research Findings

5.1. Chapter Introduction

In this chapter, an analysis of a series of follow-up interviews is presented. These interviews were conducted with the aim of validating the conclusions drawn from the empirical research study and extending the interpretation of its key findings. The interview sample group was comprised of five participants of the main study described in Chapters 3 and 4 as well as five experienced external design thinking practitioners and coaches.

The validation interviews were conducted in a semi-structured format. The corresponding interview guides presented in Appendix G and H consist of three sections each. In the first section, additional demographic information for each interviewee was collected. The second section introduced statements based on the interpretation of the data from the empirical study. Interviewees were asked to comment on each statement, based on their personal experience. The third section engaged the interviewees in a broader discussion of the presented findings and the value of design thinking.

Each interview was recorded. The individual answers were edited for brevity by the researcher and are presented in a discussion format. The level of agreement with each statement is indicated in short summary tables. Each provided comment was ranked as either "✓✓" (strongly agree), "✓" (agree), "✘" (disagree), or "✘✘" (strongly disagree). In cases where interviewees did not provide direct comments to a statement, this is indicated by "–".

5.2. In-Sample Validation

The following in-sample validation interviews with study participants were conducted in German. This ensured that the interviewees felt comfortable during the interviews and allowed them to express their opinions accurately. Verbatim quotes are presented as translations by the author as well as in the original German language. All interviews were conducted face-to-face in October and November 2015. To ensure each study participant's anonymity,

nicknames from the Star Trek universe were assigned to each participant, as outlined in Section 3.8.

5.2.1. Background of Interviewees

Interviews were conducted with Odo, Charles, Geordi, Natasha and Hoshi. Three of the interviewees were male, two were female. This sub-sample represents team members from three of the five APE_n teams and three of the four APE_e teams. During the time of the data collection, three of these participants were studying for a bachelor degree and two were studying for a master degree. Two of the interviewees had a background in business studies, one in engineering, one in psychology and one in social sciences and music.

5.2.2. Summary of Interview Responses

In the following section, short discussions based on the individual comments to each research statement are presented.

Multidisciplinary design thinking teams achieve a better final performance than single-discipline teams.

Odo: ✓✓	Charles: ✓✓	Hoshi: ✓✓	Natasha: ✓✓	Geordi: ✓✓

Within the in-sample validation group a consensus existed that multidisciplinary design thinking teams perform better than single-discipline teams. Three interviewees pointed out that working in multidisciplinary teams opens up new perspectives for innovation which are generally not uncovered while staying within one's disciplinary framework. Odo explained that *"the results in the end are better, because the abundance of ideas and the augmentation through different perspectives, which are added by the different disciplines, overall enrich the team*." [German: …die Ergebnisse hinten raus sind deswegen besser, weil im Prozess die Fülle der Ideen oder die Bereicherung durch verschiedene Perspektiven und Aspekte, die Leute mit verschiedenen Hintergründen reinbringen, das Team anreichern.].

Natasha added that working in multidisciplinary teams challenges each team member to question one's own assumptions. Odo also pointed out that overall, this results in a higher amount of diverse ideas, especially in the divergent phases of projects. According to Geordi, single-discipline teams also tend to form opinions faster. He emphasised that "*if everyone [in a team] has received similar training, opinions are formed faster.*" [German: Wenn man alle dieselbe Ausbildung hat, ist man schneller einer Meinung.]. However, Natasha as well as Charles highlighted the fact that working in multidisciplinary teams also tends to be more demanding. Both participants explained that multidisciplinary teamwork is more challenging on an emotional level and requires more intrinsic motivation and patience. "*You have to exercise patience to permit, absorb, and process other ways of thinking*", Natasha illustrated. [German: Man muss sich selbst in der Geduld üben, die anderen Denkweisen zuzulassen, aufzunehmen und zu verarbeiten.].

The diversity of Big Five personality traits within a team does not influence its final performance.

Odo: ✓✓	Charles: ✓	Hoshi: ✓✓	Natasha: **–**	Geordi: ✘

As Charles indicated, different personalities lead to different behaviours. This requires a willingness to make compromises within a team. However, Charles argued that this likely does not influence a team's performance directly. This argument is in line with the comments provided by Odo and Hoshi who both agreed that team diversity according to the Big Five personality traits did not influence their APE team performances directly. Natasha indicated that for her, team performance is more dependent on personal sympathies than personality traits. She explained that "*sympathy [within a team] makes up for a lot.*" [German: Wenn man sich sympathisch ist, wiegt das ganz viel auf.]. However, Geordi voiced slight disagreement with the provided statement. For him, diverse personalities and therefore diverse behaviours are a crucial element of high-performance design thinking teams.

Multidisciplinary design thinking teams do not iterate more than single-discipline teams.

Odo: ✓✓	Charles: ✓✓	Hoshi: –	Natasha: –	Geordi: ✓✓

Three out of five respondents indicated high levels of agreement with the above statement. Iteration behaviour does not appear to be influenced by the composition of a design thinking team. Instead, Odo proposed that iterative behaviour is more dependent on "*if a team […] understands what an iterative process is.*" [German: Die Frage ist, ob ein Team […] versteht, was ein Iterationsprozess ist.]. According to Charles, iterations within a project will mainly occur, if a team hits a "roadblock" which they cannot surpass. He explained that in his past APE projects, his teams only iterated "*if they had reached an insurmountable obstacle.*" [German: Wenn wir iteriert haben, war es weil wir an eine unüberwindbare Hürde gekommen sind.]. In such instances, his teams would return to doing more research and picking a different direction for their project. However, internalising the iterative approach inherent to design thinking appears to be related to the disciplinary training a person has received. As a trained engineer, Geordi commented that in the beginning, grasping the concept of iteration was hard for him, because he had never been confronted with it during his formal education. Commenting on his university education, he stated that "*this [iterative approach] is not taught to engineers.*" [German: Ingenieuren wird das nicht beigebraucht.]. Instead, Geordi explained that engineers are trained to approach problems in a very planned and linear way.

More experienced design thinking teams iterate less than novice teams.

Odo: ✓	Charles: ✓✓	Hoshi: ✘	Natasha: ✓	Geordi: ✓✓

Novice design thinking teams appear to be heavily influenced by how design thinking theory emphasised iteration as a key concept and how this theory is taught to novices. Odo explained that in his experience, novice teams approach their projects in a more iterative way, "*because you have learned it this way*." [German: …weil man es so gelernt hat.]. Geordi added that in his

first APE project, study participants "*forced themselves [to be more iterative], because it was expected.*" [German: [Im ersten Projekt] hat man sich noch mehr gezwungen, weil es so verlangt war.]. As both Odo and Natasha explained, novice design thinking teams deal with higher levels of uncertainty due to the fact that the applied tools and methods are mostly new to them. Over time, the study participants "*were better able to judge*" if iterations are necessary to advance a project, as Natasha pointed out. [German: Man konnte eher einschätzen…].

The amount of iteration within a design thinking project does not affect the final performance.

Odo: ✓✓	Charles: ✓	Hoshi: ✓✓	Natasha: **–**	Georgi: ✘

Overall, three out of four respondents indicated that iterations within design thinking projects do not necessarily influence the final performance of teams. These interviewees explained that in their opinion, iterations are only needed if a team fails at one point, hits a roadblock or has taken a wrong turn within a project. Odo clarified that "*as long as you feel comfortable on the way, you will progress linearly. But, as soon as you realise it is not working, you go back one step.*" [German: So lange du dich wohlfühlst auf dem Weg, gehst du linear durch. Aber, sobald du merkst es funktioniert nicht, gehst du einen Schritt zurück.]. However, Charles also cautioned that design thinking projects should not be restrained by traditional project management, so that iterations remain possible if they are needed. In contrast, Geordi voiced slight disagreement with the proposed statement due to his experience in a high-tech start-up. He explained that in his current role, continuous and rapid iterations were necessary. Geordi highlighted that in his start-up, "*we want something which we can test very fast.*" [German: [In unserem Start-up] wollen wir schnell etwas haben, was wir testen können.].

During a design thinking project, rational conceptualisation dominates over intuitive decision making.

Odo: ✓✓	Charles: ✓✓	Hoshi: ✓✓	Natasha: ✓✓	Geordi: ✓

A consensus between the interview respondents existed that rational conceptualisation dominates over intuitive decision making within design thinking projects. Both Odo and Natasha attributed the dominance of rational thought processes to how they were educated in the German school and university system, which prioritises analytical thinking. Natasha pointed out that "*coming from a German university you are still overly intellectual.*" [German: Von der deutschen Uni ist man noch sehr verkopft."]. As a result, university graduates tend to stick to a more analytic way of thinking, as Charles clarified. Multiple interviewees pointed out that this conditioning had sometimes discouraged them from testing prototypes early on in their APE projects. As the follow-up interviews were conducted almost one year after the participants had graduated from the programme, Charles added that with the experience he has gained since, he now trusted himself to make more intuitive decisions, because he had gained a different perspective on design thinking. He illustrated that this change in perspective likely happened, "*because I have more experience, I evaluate things differently and look at the [design thinking] process in a different way.*" [German: Weil ich mehr Erfahrung habe und das anders einschätze und auf den Prozess anders blicke.].

A balance of cognitive learning styles within a design thinking team positively affects its final performance.

Odo: –	Charles: ✓✓	Hoshi: ✓	Natasha: –	Geordi: ✓✓

All three interviewees who commented on this finding agreed that utilising and balancing different cognitive learning styles within a design thinking team has a positive effect on the final project performance of a team. As Hoshi pointed out, learning styles are not directly observable during team work and are therefore hard to grasp. However, Geordi explained that his APE project

teams reflected on the use of different learning styles and were therefore able to observe several positive implications of utilising different learning styles within a team. Charles speculated that the preference for an individual dominant learning style might have been connected to the disciplinary background of each individual team member.

Perceived effectiveness and ease ("creative confidence") increases linearly throughout a project.

Odo: ✓✓	Charles: ✓✓	Hoshi: ✘	Natasha: ✓✓	Geordi: ✓✓

Several interviewees indicated that the development of creative confidence is connected to the inherent uncertainty and ambiguity in design thinking tasks, especially during the initial stages of being confronted with a new problem to solve. According to Odo, how you perceive this uncertainty and ambiguity is moderated by a positive attitude towards your current task. He explained that "*of course you are uncertain in the beginning. This is superseded by your general positive attitude.*" [German: Du hast am Anfang natürlich noch eine Unsicherheit. Diese wird überdeckt von deiner positiven Grundhaltung.]. It also appears that the more the participants dove into their challenges and applied design thinking tools and methods, the more confidence they gained. Geordi pointed out that "*the more you know about the matter, […] the more composed you approach the challenge.*" [German: Umso mehr man sich mit der Materie auskennt, […] umso beruhigter geht man an die Sache ran."]. Natasha described that her APE team members had trust in themselves and had accepted the fact that they had to try out several different approaches to succeed. She explained that she often took stock of everything the team had already tried and told herself: "*This is what we have already done. […] This will lead to a result.*" [German: "Das haben wir schon alles gemacht. […] Das führt auf ein Ziel hin."].

Individual's perceived effectiveness and ease ("creative confidence") in the application of design thinking carries over to new projects and teams.

Odo: ✓✓	Charles: ✓✓	Hoshi: ✓✓	Natasha: ✓✓	Geordi: ✓✓

All study participants strongly agreed that creative confidence is a transferable competence. In their comments, the interviewees suggested that the experience they had gained from each APE project and team setting allowed them to feel more confident on an individual level in each subsequent situation. Charles illustrated that through extensive prior experiences "*you know what is going to happen*" which mitigates parts of the existing uncertainty and boosts your confidence as an innovator. [German: Du weißt, was passieren wird.]. Similarly, Geordi pointed out that you also gain confidence in the design thinking methods and tools, because "*you know it works.*" [German: Man weiß, es funktioniert.]. Moreover, higher levels of individual creative confidence amongst team members appear to affect the way a team collectively approaches a design thinking task, as Hoshi noticed. When comparing her involvement in the experienced and novice APE teams, Natasha described the experienced teams as "*having found their rhythm*" [German: Man war dann so eingegroovt.].

The level of perceived effectiveness and ease ("creative confidence") does not influence the final performance of a design thinking team.

Odo: ✓✓	Charles: ✓	Hoshi: ✓✓	Natasha: ✓✓	Geordi: ✓

Several study participants pointed out that creative confidence is not necessarily connected to the final performance of a team. In Natasha's opinion, "*confidence is not necessarily related to performance.*" [German: Das Selbstvertrauen hat nicht unbedingt etwas mit der Leistung zu tun.]. As Hoshi explained, creative confidence in her APE teams has been important, because it had a positive influence on how well the teams worked together. Odo added that during a project, you tend to isolate yourself and therefore do not rely on outside feedback too much. He described that "*during a project,*

you are in your own world. […] You hype yourself in some way." [German: Du bist in deiner eigenen Welt. […] Du hypst dich ja quasi selbst.]. Moreover, a miss-match between how teams and external professionals or clients evaluate an ongoing project does not appear to directly influence the confidence level of a team. In the case of Natasha's APE teams, their confidence was mainly based on how many different approaches and direction the teams had evaluated during the limited timeframe.

The relative importance of individuals changes throughout a design thinking project.

Odo: ✓✓	Charles: ✓✓	Hoshi: ✓✓	Natasha: ✓✓	Geordi: ✓✓

All interview respondents strongly agreed with the study finding that the relative importance of individuals in design thinking teams changes over the course of projects. During the early stages of a project, Odo ascribed this social phenomenon to the fact that in each new team, you slowly have to find out what you and other people are actually good at. Natasha explained that over time, this led her to judging people by prior encounters and the overall quality of help they could provide for her. During later stages, Geordi attributed this behaviour to the variety of skill-sets present within a team, which are continuously matched to the various design thinking tasks. He emphasised that "*there are people who are either particularly effective or not effective during specific phases.*" [German: Es gibt Leute die in einer Phase besonders stark oder eben nicht so stark sind."]. Similarly, Charles pointed out that group dynamics shift due to what each individual can offer at a certain point. He recalled several instances where "*someone said something amazing and suddenly everyone was approaching him/her.*" [Einer hat was geiles erzählt und auf einmal rennen alle auf ihn zu."] However, Charles continued, this situation often changed once the teams had iterated or had chosen a different path to follow.

Design thinking teams with a high degree of internal cohesion achieve a worse final performance than teams with a low degree of internal cohesion.

Odo: ✓✓	Charles: ✓	Hoshi: –	Natasha: ✓	Geordi: ✓

Overall, the study participants tended to agree with this research finding and provided two potential reasons for the negative effect of high internal team cohesion on final performance. On the one hand, Natasha as well as Odo pointed out that higher cohesion and frequent interactions likely lead to stronger sympathies within a team. Stronger sympathies, in turn, can cause team members to be less critical with each other and lose track of the actual goals of a project. Odo explained that "*if you have strong cohesion, you get along well on a personal level. Getting along on a personal level does not automatically make you more productive. It can also hold you back, because you don't open your mouth when something goes wrong and because you are not as open with each other.*" [German: Wenn du einen starken Zusammenhalt hast, verstehst du dich menschlich gut. Sich menschlich zu verstehen, heißt nicht automatisch, dass du produktiv bist. Das kann dich auch bremsen, weil du nicht den Mund aufreist, wenn etwas schief läuft und weil du nicht so offen miteinander redest.]. On the other hand, Charles and Geordi pointed out that high cohesion and frequent communication amongst team members may also imply that a lot of trivial communication is taking place, which might distract you from more important decisions. Charles proposed that highly cohesive APE teams might have performed worse, "*because they have just blabbered on.*" [German: …weil vielleicht nur gelabert wurde.]

Design thinking teams with a high degree of external cohesion achieve a worse final performance than teams with a low degree of external interaction.

Odo: –	Charles: ✓✓	Hoshi: ✓	Natasha: –	Geordi: –

According to the comments by the interviewees, external communication with other APE teams did not take place very frequently. Both Odo and Hoshi explained that their APE teams had not felt that they could have spared the time to talk to the other teams much. Hoshi pointed out that this behaviour had slightly varied depending on what phase of the project her teams had been in. Charles provided one possible explanation for why external cohesion might have had a negative effect on the final performance of the APE teams. He speculated that when communication with other teams had taken place, this had mainly been motivated by a need to benchmark yourself with others, and not by a desire to look for new ideas and inspiration. He explained that "*uncertainty [about one's own work] might have increased, because you compared [your performance] with each other too much, instead of picking up new ideas.*" [German: Weil man vielleicht mehr Unsicherheit bekommen hat und man zu viel miteinander verglichen hat, als das man sich Ideen geholt hat.].

What aspects about the composition and performance of design thinking teams might I have missed?

Based on their experience in the APE, the study participants pointed out the following additional factors which influence the performance of design thinking teams:

- The need for regular team reflection and good team feedback mechanisms
- The amount of productive conflict within a team
- High levels of intrinsic motivation and commitment
- The willingness for someone to take the lead for each required task

Do you think design thinking is useful only for certain industry sectors?

The interviewees universally agreed that design thinking can add value to many different industry sectors. Odo illustrated that he "*perceives design thinking as way to deal with problems and in whichever industry sector you are, there are always problems.*" [German: Weil ich Design Thinking als etwas wahrnehme, was eine Art und Weise ist mit Problemen umzugehen und egal in welcher Branche du bist, es gibt überall Probleme.]. However, Hoshi also highlighted that in her experience "*the problem is that many organisations don't allow [such kind of approaches].*" [German: Das Problem ist, das viele Unternehmen das nicht zulassen.].

5.3. External Validation

The following five external validation interviews were conducted to provide further validity to the research findings presented in previous chapters. The interviews opened up the interpretation of the empirical findings to experienced design thinking practitioners and coaches, who had not been directly involved with the empirical study. All five interviews were scheduled between October and November 2015. Three interviews were conducted face-to-face, while two interviews had to be conducted via Skype. Each interviewee agreed to go on the record, so that their names and affiliations could be included in the discussions below.

5.3.1. Background of Interviewees

Five experienced practitioners were recruited through the network of the SCE. Each practitioner was chosen because of his professional experience and substantiated understanding of design thinking. The following five personal profiles introduce each interviewee, before the discussion of the interview comments is provided further below.

Alexander Grots (AG)

Alexander Grots is an independent innovation and design thinking consultant with more than 15 years of experience in this field. He used to be a partner at

IDEO in Palo Alto and led the IDEO Munich office for several years as the managing director, after which he co-founded the design innovation consultancy Gravity Europe. Mr Grots is also the co-founder of several technology start-ups, among them Picar, an early provider of voice recognition software, and ProGlove, a recent wearables for industry start-up. Mr Grots is a frequent speaker on design thinking in several executive training programmes around the world.

Dr Michael Lewrick (ML)

Dr Michael Lewrick is the Head of Strategic Growth & Innovation at Swisscom, one of Switzerland's major telecommunication providers. Dr Lewrick has been a visiting scholar at the Center for Design Research at Stanford University. He has initiated and taught several design thinking projects together with the Hasso Plattner Institute and the universities of Sankt Gallen, Lucern and Ulm. In his opinion, design thinking supports the innovation process for new products and business models. The set-up of radical collaboration creates fresh ideas in an agile manner, in which the user is at the centre for the hunt for new ideas.

Dr Jan Auernhammer (JA)

Dr Jan Auernhammer currently is a visiting scholar at the Center for Design Research at Stanford University. He has previously worked as a design thinking educator and consultant at the Institute of System Science at the National University of Singapore. Dr Auernhammer has extensively researched creativity and innovation in the organisational context, which gradually led him to the field of design thinking. He is a frequent guest lecturer on design thinking and innovation at several institutions worldwide.

Dr Steven Gedeon (SG)

Dr Steven Gedeon is a serial entrepreneur and expert on angel investments. He has founded or led over a dozen private, public, venture capital, and non-profit organisations. Since 2006, he serves as an associate professor of

entrepreneurship and strategy at Ryerson University in Toronto. Furthermore, he is involved with the Fraunhofer Venture group in Germany. Dr Gedeon has come across design thinking during his sabbatical in Europe. For him, design thinking is in harmony with many different concepts he already applies in entrepreneurship education programmes. Learning about different approaches of design thinking allowed him to further solidify his teaching approach.

Assaf Shamia (AS)

Assaf Shamia has more than twelve years of experience in venture capital. At the moment, Mr Shamia is a principal investment manager at Siemens Venture Capital in Munich. Previously, he has worked as a venture capitalist with Camel Ventures in Tel Aviv and as a new venture advisor and entrepreneurship educator. Mr Shamia has learned about design thinking during his entrepreneurship teaching engagements at various German universities. To him, the main benefits of design thinking within organisational settings are twofold. First, design thinking helps with embracing action-orientation and introduces a mentality of experimentation. Second, it allows organisations an outside-in perspective on innovation through its user-centred approach and emphasis on need-finding.

5.3.2. Summary of Interview Responses

In the following section, short discussions based on the individual comments to each research statement are presented.

Multidisciplinary design thinking teams achieve a better final performance than single-discipline teams.

AG: ✓✓	ML: ✓✓	JA: ✓✓	SG: ✓✓	AS: ✓

Overall, the interviewed practitioners agreed with the study finding that multidisciplinary design thinking teams achieve a better final performance than single-discipline teams. According to Mr Grots, this can be attributed to

having a wider set of perspectives and resources at hand. He explained that "*if you bring several perspectives, backgrounds, sets of expertise, and sets of deep knowledge [together], [the results] can only get better*." However, he also added that in addition, good teams also tend to have a more dominant alpha person who drives the whole team forward. While drawing parallels to the start-up world, Mr Shamia noted that in his experience, successful start-up teams also tend to be made up of co-founders from different disciplines. While agreeing with the statement, Professor Gedeon highlighted that setting up and running interdisciplinary teams and projects also tends to be more difficult.

The diversity of Big Five personality traits within a team does not influence its final performance.

AG: ✓	ML: ✓	JA: ✓✓	SG: ✓	AS: ✓

The interviewed practitioners tended to agree that team diversity according to the Big Five personality traits taxonomy is not a major influence on the performance of design thinking teams. However, several interviewees cautioned that diversity according to other personality classification models might indeed be related to the final performance of design thinking teams. As Mr Shamia commented, what this research study has outlined is only "*one way of looking at personality traits.*" Dr Lewrick illustrated that in his experience, a well-distributed team over the Herrmann Brain Dominance Instrument (HBDI) has a significant influence on the overall performance of such teams. Similarly, both Professor Gedeon and Mr. Shamia speculated that team diversity according to the Myers-Briggs Type Indicator (MBTI) would positively influence how well a team performs in design thinking tasks. Based on his experience in multiple design-driven companies, Mr Grots pointed out that extended domain knowledge, experience, and confidence are more important to performance than personality diversity. He explained that "*[very experienced people] can contribute because they feel secure that they know something. […] They see themselves with the confidence of an expert, so they can actually share their thoughts. […] That counts more than*

personality. […] Personality is not the main ingredient." Dr Auernhammer also pointed to a potential negative effect of personality diversity. He indicated that too much diversity in terms of personality often also creates conflict within teams, which can negatively impact their performance.

Multidisciplinary design thinking teams do not iterate more than single-discipline teams.

AG: ✓✓	ML: ✘	JA: ✓✓	SG: ✓✓	AS: : ✓✓

Four out of five practitioners agreed with the research finding that multidisciplinary design thinking teams do not iterate more than single-discipline teams. Iteration appears to be heavily influenced by the standardised process models which are often used to conceptualise design thinking. According to Dr Auernhammer, such models provide very logical frameworks which encourage a linear approach. Mr Grots therefore argued that intuitive and iterative behaviour can only be developed through extended practice of design thinking. Design thinking novices therefore often struggle to apply the design thinking principle of iteration in practice. Mr Grots explained that "*only the ones that really know their craft iterate based on habit, not because there is a process and they know that they should iterate. [Novice practitioners] have a hard time iterating, because they don't understand why they should iterate.*" Mr Shamia pointed out that within a team setting, iterative behaviour is also influenced by the amount of disagreement within a team. He highlighted that having multiple strong-minded people in team encourages iteration in practice. In contrast to the comments above, Dr Lewrick speculated that single-discipline teams would actually iterate less than multidisciplinary teams. Based on his experience, he argued that people with similar disciplinary background tend to agree on a direction faster and would therefore also be less likely to iterate during a design thinking project.

More experienced design thinking teams iterate less than novice teams.

AG: –	ML: ✓✓	JA: ✓✓	SG: ✓	AS: –

Through experience, individuals in design thinking teams build routines and become better at evaluating different strategies for approaching design thinking tasks. Dr Auernhammer described that "*if you are an experienced team, you follow that logical chain of events in design thinking*." Dr Lewrick added that more experienced teams also tend to know sooner when to move from divergent to convergent thinking and vice versa. Professor Gedeon remarked that if teams find themselves in a competitive environment with external deadlines, iteration is often neglected. Commenting on this point he explained that "*efficiency dictates that you go through [the design thinking process] once.*" However, the practitioners agreed that thinking in routines is generally not beneficial in design thinking projects, as it limits the amount of exploration taking place. Mr Grots explained that in cases where design thinking is being applied in other domains outside of traditional design, for example in the business world, it is used in a more analytical way. In those cases, he explained that "*we approach projects with our heads not our hands*." This approach is different to how trained designers would approach a given problem. Mr Grots thus added that in contrast, "*designers who actually learned their craft, who did not learn a methodology or a process or a thought tool like we learn, they iterate*." Based on a similar argument, Professor Gedeon also pointed out that if one accepts iteration as a key principle of design thinking, educators may be required to change their pedagogical approach and "*force*" more experienced participants to iterate earlier on.

The amount of iteration within a design thinking project does not affect its final performance.

AG: –	ML: ✘✘	JA: ✓✓	SG: ✘	AS: ✓✓

Overall, the practitioners' opinions were split on whether the amount of iteration within a design thinking project influences a team's performance. On the one hand, two practitioners argued that iterations sometimes are not

necessary, if a team identifies good opportunities early on and the project is going well. Mr Shamia explained that "*to iterate, just for the sake of iteration doesn't make sense. […] Just go ahead and do it*." Similarly, Dr Auernhammer described that "*sometimes you hit a home run.*" However, other practitioners voiced the opinion that they do believe that more iteration also leads to better results. For example, Professor Gedeon argued that generally, the more often you iterate through the process steps, the better the results gets. To offer a potential explanation for this study finding, Mr Grots speculated that even if the research participants in the current study had spent more than 500 hours across ten month practicing their design thinking skills, they might still not have been experienced enough to fully grasp and therefore apply iteration as a key design thinking principle.

During a design thinking project, rational conceptualisation dominates over intuitive decision making.

AG: ✓✓	ML: ✘	JA: –	SG: –	AS: ✓✓

When prompted with this research finding, two interviewees pointed out that whether rational conceptualisation or intuitive decision making is dominant during design thinking projects will mainly depend on the characteristics of the individual team members. Mr Grots recalled that back when he started at IDEO in 2002, it was still mostly designers who worked there and the intuitive physical component of designing was still dominant. Once the term "thinking" was added to design, their work "*moved into the strategic world, where everybody can use it*" and conceptualising became more dominant. Similarly, Professor Gedeon speculated that this tendency depends on the underlying subject group. He proposed that "*if you ask a bunch of designers the same questions, going through the same process, you might find exactly the opposite results, because designers tend to use intuitive decision making over rational decision making. If you teach primarily engineers, you will get exactly the opposite.*" However, Dr Lewrick pointed out that even in more analytically-minded groups, intuition matters. He explained that many of the tasks within a design thinking project have an emotional component, for

which intuitions is needed to solve these tasks. Similarly, Dr Auernhammer argued that both modes of thinking and decision making are equally needed in design thinking and can rarely be separated in practice.

In design thinking projects, individuals move between different cognitive learning styles (cycle).

AG: ‒	ML: ✓✓	JA: ✓✓	SG: ✓✓	AS: ‒

Three practitioner interviewees provided support for the research finding that individuals cycle through Kolb's learning styles during a design thinking project. In this regard, Professor Gedeon highlighted that this is one of the greatest benefits of design thinking. He explained that design thinking as a "*pedagogy really emphasises multiple learning styles*." Dr Auernhammer stressed that these learning cycles happen continuously while we engage in problem-solving activities and are not specific to any single design thinking task. He explained that "*experiential learning is something [which happens] within us. […] In any step of this process, every single individual runs through this learning cycle a million times.*"

A balance of cognitive learning styles within a design thinking team positively affects final performance.

AG: ✓✓	ML: ✓✓	JA: ✓✓	SG: ✘	AS: ✓✓

Four out of five interviewed practitioners provided strong support for the research finding that a balance of Kolb's learning styles within design thinking teams is positively correlated with their final performance. Dr Auernhammer illustrated that the ability to use different learning styles is generally a good representation of the amount of critical reflection happening in a project. He argued that subsequently this also tends to lead to better results. Likewise, Mr Shamia recalled similar findings from an internal empirical study of start-up teams which his previous venture capital firm in Israel invested in. Mr Grots pointed out that utilising different learning styles within a design thinking team will likely also positively influence the team's confidence. He

explained that "*if you have a balanced approach, if you try things out, even if they didn't leave a mark, you did it. You can take it off your list and say ok, that was valuable or that was not that valuable at all. Everything I could do, I did. So I feel confident that this is actually a good result*." However, Professor Gedeon pointed out that individual team members will likely be most productive, if they are able to utilise their preferred learning style during this process. A balance of learning styles within a team should therefore be created by recruiting team members with different dominant learning styles and not by moving people out of their preferred learning styles.

Perceived effectiveness and ease ("creative confidence") increases linearly throughout a project.

AG: ✓✓	ML: ✓	JA: ✓✓	SG: ✓✓	AS: ✘✘

The majority of the interviewed practitioners agreed that creative confidence, as measured by the individual levels of perceived effectiveness and ease, increases linearly over the course of a design thinking project. Dr Auernhammer related this finding to the flow model popularised by Mihaly Csikszentmihályi. He explained that in a good design thinking project, individuals and teams will likely develop a flow state, which has also been shown to develop linearly. Professor Gedeon speculated that the linear growth in creative confidence might also speak to the influence of the facilitator or educator mentoring a team. He described that a confident and experienced mentor can help a group to mitigate and embrace the inherent confusion and ambiguity within design thinking projects. However, Mr Shamia found this finding surprising. In his experience, team confidence is often negatively impacted by external feedback. He elaborated that "*almost always, […] a team would come up with something that gets really cold shower feedback from an external party. […] I cannot image people feeling confident, effective, and at ease at this point*."

Individual's perceived effectiveness and ease ("creative confidence") in the application of design thinking carries over to new projects and teams.

AG: ✓✓	ML: ✓✓	JA: ✓✓	SG: ✓✓	AS: ✓✓

Among the practitioner interviewees a strong consensus existed that creative confidence carries over to new projects and teams. Dr Auernhammer pointed out that past experiences help individuals to build their confidence, which can then be applied to other scenarios. He illustrated that "*if you have dealt with ambiguity [before], the next time it will be easier*". The interviewees specified that this finding likely relates to both individual self-confidence in ones role as an innovator as well as to a general confidence in design thinking methods as an effective problem-solving approach. Several interviewees have also stressed the fact that to develop ones creative confidence to a high level will require extended practice across several projects, settings, and teams.

The level of perceived effectiveness and ease ("creative confidence") does not influence the final performance of a design thinking team.

AG: ✓✓	ML: ✓✓	JA: ✓✓	SG: –	AS: –

Three interviewees voiced agreement with the study finding that the level of creative confidence does not necessarily lead to a better final project performance. In that sense, it can be argued that confidence levels within a team may not be connected to how external stakeholders, such as clients or industry experts, evaluate the outcomes of a project. Professor Gedeon summarised that "*confidence is how <u>you</u> feel and if <u>you</u> have done a good job or not. Confidence reflects your [personal] understanding of whether the outcome is good or not.*" Mr Grots added that the general team climate also influences creative confidence. He highlighted that "*the team spirit and culture have a big effect there.*" However, Professor Gedeon stressed that this disconnect between team confidence and final performance is also a cause for concern, as "*it either speaks to over-confidence, that you have people who perform badly, that don't know that they are performing badly or*

that you have people that are performing well and they don't know that they are performing well." However, Mr Shamia argued that in his experience, especially in several start-up environments, the level of team confidence does not necessarily influence the quality of the project outcomes, but still becomes apparent during the interaction with external stakeholders, because teams who lack confidence cannot sell their ideas very well.

The relative importance of individuals changes throughout a design thinking project.

AG: ✓✓	ML: ✓✓	JA: ✓✓	SG: ▬	AS: ✓✓

All four practitioners who commented on this research finding strongly agreed that the relative importance of individual people changes over the course of a design thinking project. These changes in individual importance are likely caused by shifts in the team dynamics and power structures, Dr Auernhammer speculated. Mr Grots explained that this is an effect he has also often observed in multiple project and team settings in his career. He strongly advised that certain team roles should be dynamic and not assigned to a specific person. As an example, he described that "*project management or project leadership should not be one person. It should be a team role*." Throughout projects, this role can be taken on by different team members. However, as Dr Lewrick pointed out, in larger organisations fixed roles, such as a project lead, are often required to be defined prior to the start of projects. In such cases, Mr Grots advised that the multiple sill-sets available within a team should still be leveraged, even if the leadership role is pre-assigned. He clarified that in these cases, "*the manager's role should not be to do it best, but to know how he/she can apply everyone else to what we are doing right now*."

Design thinking teams with a high degree of internal cohesion achieve a worse final performance than teams with a low degree of internal cohesion.

AG: ✓	ML: ✘ ✘	JA: ✓ ✓	SG: ✓ ✓	AS: ✘

The practitioner opinions were split about whether a high degree of internal cohesion within a team negatively impacts their performance. On the one hand, Dr Auernhammer backed up this finding by linking it to existing research on creativity. He explained that creativity theory often mentions a need for individuals to isolate themselves to think, slow down and reflect on their own. He speculated that weak ties might be more important than strong ties for creative tasks within design thinking and proposed that this selective isolation might need to be cultivated more. Mr Grots suggested that this "*might be a social thing as well*" and that well-connected teams might tend to talk too much and therefore shy away from actually trying out several different approaches. He explained that he has often observed this phenomenon in larger organisations and criticised that "*companies discuss forever.*" On the other hand, Dr Lewrick argued that in his opinion, every kind of communication or exchange has a positive effect on a design thinking project, although this is hard to measure objectively. Mr Shamia also proposed that being well-connected ensures that "*everybody is in sync*" and creates a shared feeling of "*we are making progress together.*"

Design thinking teams with a high degree of external cohesion achieve a worse final performance than teams with a low degree of external interaction.

AG: ✓ ✓	ML: ✘ ✘	JA: ✓ ✓	SG: ✓ ✓	AS: ✓ ✓

Four out of five interviewees agreed that a high degree of external cohesion negatively impacts a design thinking team's final project performance. Overall, the practitioners provided three potential reasons for this observed effect. First, Dr Auernhammer pointed out that engaging with too many available impulses will likely distract a team and therefore be harmful to the creative

process. Second, Mr Grots posited that when teams look for external people to talk to, they often use the wrong search criteria. He explained that team members often establish outside connections based on personal sympathies, rather than on an evaluation of what expertise an outside connection might have to offer. He clarified that asking yourself: "*Do I like that person and do they like me?*" is not a good search criteria, if the goal is to improve project outcomes. Third, Mr Shamia assumed that most teams will establish these outside connections to benchmark themselves against other projects and teams. However, he argued that the urge to benchmark your work with others will likely be stronger in teams who lack confidence. In such cases, connections will be formed "*because you think you are underperforming*." Professor Gedeon noted that based on this finding, establishing weak ties to outside parties is likely the best strategy. He explained that "*bonds are OK or even good up to a point where they become too tight and dysfunctional*." Contrary to the above opinions, Dr Lewrick suggested that strong outside connections are likely to improve a team's final project outcomes. He explained that within Swisscom, such connections are actively encouraged and facilitated in innovation projects.

How do you think these results might affect design thinking practice and training?

Overall, the interviewed practitioners agreed that several of the presented research findings are important stepping stones for the future development of design thinking practice and training. Two of the interviewees described that since design thinking has gained popularity in domains outside of traditional design, an ongoing frustration with how design thinking is presented at the moment became apparent. Mr Grots explained that "*every time when something becomes very popular, there is a counter movement where lots of critics come up onto the scene and I think they will look for arguments that go a little deeper.*" He points out that these critics are looking for more concrete proof than the currently available popular sources on design thinking have to offer. Picking up on this point, Dr Auernhammer stressed that this development is necessary to further advance design thinking. He argues that

"*these debates need to happen based on long-term research*." Similarly, Professor Gedeon pointed out that "*sometimes conventional wisdom doesn't pan out*" and that therefore, more research is needed to further solidify design thinking theory.

Commenting on the research study, Mr Grots illustrated that the presented findings are especially relevant for experienced design thinking practitioners. He highlighted that "*there are some dynamics in there that a very interesting, especially to the ones who know about design thinking already and want to understand more.*" Mr Shamia indicated that for example, "*learning styles is a point which is totally ignored in current design thinking teaching and coaching.*" Professor Gedeon also noted that many of the presented findings are quite important to practice, such as that diversity, the number of iterations, the amount of confidence, and how well you get along with each other might not matter as much as previously assumed. He highlighted that these findings are important, especially because they go against the conventional wisdom in this domain, which talks to the importance of conducting more robust research on design thinking. Dr Lewrick also explained that many of the presented research findings are especially important to design thinking facilitators, as they can help team mentors in better understanding individuals and teams in design thinking projects.

What aspects about the composition and performance of design thinking teams might I have missed?

Based on their experience, the interviewed practitioners pointed out the following additional factors influencing the performance of design thinking teams:

- The physical space a team is working in
- The duration (timespan) of a project
- The influence of the external client
- The quality and clarity of the initial design brief
- The influence of project mentors or course instructors
- Which design thinking methodology is applied (e.g. IDEO, d.school or ME310)
- The influence of creativity as the core of design thinking
- The level of intrinsic motivation within a team
- Humour

Are there differences in how different cultures/nationalities use design thinking?

Several practitioners pointed out that both the cultural context a project is situated in as well as the cultural background of practitioners and mentors influence how design thinking is being developed and applied. Two interviewed practitioners were particularly sceptical whether current approaches to design thinking are an effective way to approach innovation in Asian countries. However, as Mr Grots pointed out, mixing different cultures within design thinking teams can also add another useful layer of team diversity and overall have a positive effect on the quality of ideas.

Do you think design thinking is useful only for certain industry sectors?

The practitioners tended to agree that design thinking can add value to many different industry sectors, but not to all industry sectors. Mr Shamia pointed out that consumer or service-oriented sectors will likely benefit more from design thinking than B2B or technology-oriented sectors. According to Mr Grots, a design thinking approach is especially useful for solving problems where people are involved. He explained that "*whenever humans are involved, design thinking might apply – which is almost anywhere*."

How do you think design thinking will develop in the future?

Each interviewed practitioner provided a very distinct outlook on how design thinking might develop in the future. Mr Grots was of the opinion that design thinking will continue to grow and remain relevant and pointed out that "*through [research] like this, it will get better and better and more understood.*" According to Dr Lewrick, design thinking will also be increasingly influenced by new technology enablers such as big data analytics. Commenting on the future of design thinking, Dr Auernhammer expressed hope that design as a paradigm will be applied in many more areas and that the educational systems will start to teach it to a broader audience and at a much younger age. However, he also warned that currently, design thinking is often used by several groups as a compelling label for already existing innovation approaches, which dilutes its meaning and leads to a superficial understanding of its origins and mechanisms. While Mr Shamia acknowledged that at the moment, design thinking is very instrumental in promoting concepts of innovation and entrepreneurship in areas where these concepts are still alien, he also posited that in the management domain, some of the current attention will fade away as another management fad. According to Professor Gedeon, for design thinking to remain relevant outside of traditional design, it needs to be unified more. He proposed that "*you need to develop some kind of common language around it*."

5.4. Discussion of Findings from the Validation Interviews

In this chapter, two sets of discussions relating to the key findings of the presented study have been illustrated. The first set of interviews was conducted with five participants of the research study to explore potential explanations for the observed phenomena and strengthen the conclusions drawn from the quantitative data analysis. The second set of interviews was conducted with five design thinking practitioners, to open up the interpretation of the key findings to a wider audience and extend their interpretation.

In the following Table 5.1, a visual summary of each interviewee's level of agreement with each statement is provided.

Table 5.1: Summary of Validation Interviewees' Levels of Agreement

	In-Sample					Practitioners				
	Odo	Charlies	Hoshi	Natasha	Geordi	Alexander Grots	Michael Lewrick	Jan Auernhammer	Steven Gedeon	Assaf Shamia
Multidisciplinary design thinking teams achieve better final performance than single discipline teams.	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓
The diversity of Big Five personality traits within a team does not influence final performance.	✓✓	✓	✓✓	–	✘	✓	✓	✓✓	✓	✓
Multidisciplinary design thinking teams do not iterate more than single discipline teams.	✓✓	✓✓	–	–	✓✓	✓✓	✘	✓✓	✓✓	✓✓
More experienced design thinking teams iterate less than novice teams.	✓	✓✓	–	✓	✓✓	–	✓✓	✓✓	✓	–
The amount of iteration within a design thinking project does not affect the final performance.	✓✓	✓	✓✓	–	✘	–	✘✘	✓✓	✘	✓✓
During a design thinking project, rational conceptualisation dominates over intuitive decision making.	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✘	–	–	✓✓
In design thinking projects, individuals move between different cognitive learning styles (cycle).						–	✓✓	✓✓	✓✓	–
A balance of cognitive learning styles within a design thinking team positively affects final performance.	–	✓✓	✓	–	✓✓	✓✓	✓✓	✓✓	✘	✓✓
Perceived effectiveness and ease ("creative confidence") increases linearly throughout a project.	✓✓	✓✓	✘	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✘✘
Individual's perceived effectiveness and ease ("creative confidence") in the application of design thinking carries over to new projects and teams.	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
The level of perceived effectiveness and ease ("creative confidence") does not influence the final performance of a design thinking team.	✓✓	✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	–	–
The relative importance of individuals changes throughout a design thinking project.	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	–	✓✓
Design thinking teams with a high degree of internal cohesion achieve a worse final performance than teams with a low degree of internal cohesion.	✓✓	✓	–	✓	✓	✓	✘✘	✓✓	✓✓	✘
Design thinking teams with a high degree of external cohesion achieve a worse final performance than teams with a low degree of external interaction.	–	✓✓	✓	–	–	✓✓	✘✘	✓✓	✓✓	✓✓

Overall, the in-sample validation group provided support for the key research findings. Four key findings were universally supported by the study participants. First, the interviewees agreed that multidisciplinary design thinking teams outperform single-discipline teams. Second, they offered support for the finding that rational conceptualisation dominates over intuitive decision making during design thinking projects. Third, the study participants concurred that creative confidence, as measured by the levels of perceived effectiveness and ease, carries over to new projects and teams. Fourth, the study participants backed up the research finding that the relative importance of individuals in design thinking teams changes over the course of a design thinking project.

The second set of validation interviews was conducted with five experienced design thinking professionals who had not been directly involved in the underlying research study. These interviews extended the interpretation of the key findings from the research study. Overall, the interviewed practitioners supported many of the key research findings. They provided unified support for three findings in particular. First, they agreed that multidisciplinary design thinking teams outperform single-discipline teams. Second, the practitioner interviewees agreed that higher levels of team diversity according to the Big Five personality traits taxonomy do not influence the final performance of a design thinking team. Third, the practitioners acknowledged that the relative importance of individuals in design thinking teams changes over the course of a design thinking project. Overall, the practitioners showed to most disagreement over whether more iteration leads to better final project outcomes and whether higher levels of internal team cohesion lead to a worse final team performance.

6. Discussion and Conclusion

6.1. Chapter Introduction

Interest in design thinking has been steadily growing in past years, especially in the management and innovation domain. Chapter 1 presented several examples of companies, which have discovered design thinking as a valuable strategy towards fostering their competitive advantage. In Chapter 2, it was argued that design thinking is a multi-faceted phenomenon and its meaning and being are constantly being reshaped. The author therefore chose to summarise the available literature as several overlapping perspectives on design thinking, rather than limiting the discussion to only one line of argument. Based on this thorough review of the literature, five broad themes were synthesised which warranted further exploration in the subsequent research study. Theme 1 explored the effects of multidisciplinarity and personality traits diversity in design thinking teams. Theme 2 focussed on the application and influence of iterations, as defined as recursive movement in the process, as a key principle in design thinking. Theme 3 investigated conceptual links between design thinking as a continuous learning activity and Kolb's learning styles. Theme 4 examined the effects of creative confidence as a precondition for design thinking. Theme 5 explored the emergence and influence of communication patterns within multidisciplinary design thinking teams from a network perspective. Based on these five research themes, 13 testable hypotheses were developed in Chapter 3 and tested in a quantitative longitudinal quasi-experimental study in Chapter 4. The series of validation interviews presented in Chapter 5 allowed to further substantiate the conclusions drawn from the quantitative data analysis and extended the presented theoretical arguments.

Following a brief reflection on what has been achieved with this thesis, the key study findings and their relation to existing theories are discussed on a more holistic level in this chapter. Subsequently, a discussion of potential limitations of this study is presented before illustrating the developed

contribution to knowledge of this thesis. This chapter concludes with the presentation of several recommendations for design thinking practitioners and educators, as well as for future researchers in this field.

6.2. Aims and Objectives Revisited

Within this section, the author sets out to take stock of what has been achieved during the process of researching and writing up this thesis.

In Table 6.1, the initial aims and objectives presented in Chapter 1.6 are revisted and supplemented with summaries of how each aim and objective has been addressed throughout this thesis.

Table 6.1: Aims and Objectives Revisited

Thesis Aim	How Aim Has Been Achieved
Understand and improve the education process for design thinking novices working in multidisciplinary teams	This thesis explored five separate themes relating to the way multidisciplinary teams use design thinking. The longitudinal research design allowed the author to follow research participants across an extended time period. This approach provided deep insights into how novices develop design thinking capabilities over time. Contrasting participants with no prior experience in design thinking with more experienced participants enabled the researcher to draw conclusions on how the education process of design thinking novices can be improved. Within each theme, correlations between individual variables and the outcome variable of final team performance were explored to identify success factors for this education process.

Thesis Objectives	How Objectives Have Been Achieved
Critically synthesise the current literature on design thinking to shed light on under-researched themes in design thinking theory	A synthesis of the current relevant literature on design thinking was provided in Chapter 2. To acknowledge the richness of the current discussion about what and how design thinking is, this synthesis was presented as several overlapping perspectives on design thinking.
Critically identify research variables from key research themes which can be developed into testable hypotheses	Based on identified gaps and unsubstantiated theoretical formulations in the design thinking literature, five broad research themes were derived from the structured literature review presented in Chapter 2. Each theme demarcated an area which warranted further investigation. Subsequently, 13 research hypotheses were formulated and tested in Chapter 3.
Collect an original longitudinal dataset from an appropriate population which allows the researcher to study the development process from novice to experienced design thinker	As detailed in Chapter 3, the dataset used to facilitate the testing of the 13 research hypotheses was comprised of three sample groups. The main sample consisted of five novice and four experienced multidisciplinary design thinking teams recruited from an elite entrepreneurship education programme in Munich. A single-discipline sample of business administration students formed a control group for some of the statistical tests. Data was collected during “live” design thinking projects to build a comprehensive longitudinal dataset. This dataset allowed the researcher to observe and measure key indicators during the development process from novice to experienced design thinker.

Validate findings and conclusions drawn from the quantitative study	To validate the findings from the quantitative research study presented in Chapter 4, several validation interviews were conducted and summarised in Chapter 5. Five interviews were conducted with participants of the study to validate the interpretation and drawn conclusions from the data analysis. Five additional interviews were conducted with experienced academics and industry practitioners to extend the presented theoretical arguments and uncover areas which warrant further exploration in future research studies.
Develop recommendations for research and practice	This final chapter concludes with the presentation of several recommendations for design thinking practitioners and educators as well as for researchers interested in extending design thinking theory through future research.

Fulfilling this aim and these objectives allowed the author to add to the existing body of knowledge about design thinking and provide a substantial contribution to knowledge.

The following section presents an in-depth discussion of the research findings from the quantitative study and their connection to existing theory. Whereas some findings validate existing design thinking theory, others propose alternative explanations. Some statistically significant findings from the presented study also highlight reverse effects and therefore call for a re-examination and potential adjustment of current design thinking theory.

6.3. Discussion of Key Findings

This thesis set out to investigate and evaluate success factors in multidisciplinary design thinking teams. The main research findings have been presented in Chapter 4. These findings were supplemented by in-sample and external practitioner validation interviews which strengthened the conclusions drawn from the quantitative data analysis and extended the overall discussion. Within the following section, a discussion of the main

research findings, their interrelation, and their connection to existing theory is provided. To ensure consistency and readability, this discussion is structured in the sequence of the five broad research themes which have been prevalent throughout this thesis. General statements are introduced to summarise each cluster of findings and to act as signposts for future research.

Theme 1: Disciplinary team diversity positively affects design thinking project outcomes, while Big Five personality traits diversity does not.

In this research study, multidisciplinary teams were found to significantly outperform single-discipline teams (Hypothesis 1a, accepted). Based on the review of the current literature on design thinking, this did not come as a surprise. As highlighted in Section 2.2.4, many scholars and practitioners have positioned design thinking as a holistic team-based approach which benefits from diverse disciplinary perspectives (e.g. Brown, 2008; Brown, 2009; Carlgren et al., 2016; Dym et al., 2005; Gruber et al., 2015; Kelley & Kelley, 2013; Kelley & Littman, 2006; Lojacono & Zaccai, 2004). However, many of these arguments are anecdotal. What the current thesis adds to these arguments is additional empirical evidence from a quasi-experimental research study.

In general, multidisciplinary teams can draw from a wider variety of skills and competencies in their problem-solving approach. In a newly formed team confronted with an open-ended project, these diverse skills and points of view start out as “symmetries of ignorance” (Fischer, 2000), which force the team members to create a new shared mental model. During this process, team members question each other’s assumptions and positions in constructive ways, which results in a deeper analysis, more robust arguments, and higher overall creativity. While comparing the novice multidisciplinary teams and the novice single-discipline teams in this study, it appeared that the single-discipline teams took less time to form a shared mental model. They moved out of divergent activities (i.e. creating choices) into convergent activities (i.e. making choices) more quickly. Multidisciplinary teams, on the other hand, appeared to be more comfortable with remaining in

divergent activities for longer periods of time. It has previously been argued that the likelihood of producing radically new ideas is connected to a team's capacity to endure the inherent ambiguity within design thinking projects, which is most often associated with diverging activities. One might therefore argue that multidisciplinary teams are generally also better able to deal with the inherent ambiguity within design thinking projects.

However, working in multidisciplinary teams also complicates the process of working together. Therefore, team diversity needs to be actively managed. Each team member has to believe in the positive effect of team diversity and needs to explicitly agree on how they want to deal with the negative aspects of multidisciplinary teams.

Unlike disciplinary diversity, Big Five personality traits diversity within design thinking teams was not found to significantly influence the final project outcomes in the presented study (Hypothesis 1b, rejected). Having diverse types of personality present within a team did not appear to lead to beneficial team behaviours, such as scrutinising each other's arguments and establishing a shared mental model. As Professor Gedeon as well as Mr Shamia, two of the interviewed practitioners, pointed out, this finding might be specific to the Five Factor Model of personality used in this study. Using other personality classification systems, such as the Myers-Briggs Type Indicator (MBTI), in future research studies might yield different results.

Theme 2: In design thinking theory, iteration is important. In day-to-day practice, it rarely happens.

In theory, iteration has been positioned as one of the key principles of design thinking by many separate authors. Even though, several different process models of design thinking have been defined, these models are not intended to be used as strictly linear step-by-step instructions. Rather, they are envisaged as sets of connected activities which encourage iterative learning and feedback loops. For the purpose of this study, iteration was defined as recursive movement within the design thinking process.

Despite the theoretical importance of iterations, only very little iterative behaviour could be observed in this research study. Higher levels of iteration within a design thinking team also did not show a significant correlation with the final team performance (Hypothesis 2c, rejected). This finding might be connected to how the projects were set up during this research study. For each project, a fixed kick-off date and a rigid deadline were defined, resulting in 13 to 18-week timeframes in which each team progressed from an initial project brief to a final oral and written concept pitch. As has previously been argued, when a team is faced with restrictive deadlines, it will prioritise task completion. Breaking down design thinking projects into manageable and moderately-sized tasks also instils a feeling of control and moving forward, even if the end state is still uncertain. In this study, it appeared that both novice and experienced design thinking practitioners were more comfortable with less iterative and recursive approaches towards design thinking projects. Teams only seemed to iterate, if forced to do so, for example by failing to properly synthesise the available insights in the “point of view” phase due insufficient (user) research during previous phases. Novice design thinking teams iterated the most during the third quarter of each project, where teams started to move out of the “generate ideas” into the “prototyping & business model” phase. This behaviour was likely triggered by uncovering additional insights about a concept within the “prototyping & business model” phase.

Furthermore, whereas it was previously assumed that a more iterative and recursive approach is needed to reconcile multiple disciplinary perspectives within a team, no significant difference in iteration behaviour was found between multidisciplinary teams and single-disciplinary teams in this research study (Hypothesis 2a, rejected).

Contrary to previous assumptions, experienced multidisciplinary design thinking teams iterated even less than novice multidisciplinary teams (Hypothesis 2b, rejected). Several sources in the current literature on designerly thinking and design thinking suggests that over time, individuals grow more confident in the application of design thinking and develop more elaborate, flexible, and intuitive problem-solving strategies. It was therefore

assumed that more experienced design thinking teams would be better able to appreciate and utilise iterations as feedback and learning mechanisms for their projects. However, experienced teams approached their projects even more sequentially than the novice teams in this research study. It was also observed that the experience gained from their first two projects did not lead to a more iterative and recursive approach. Instead, the gained experience seemed to result in an increased ability and need to plan and structure design thinking projects to achieve the desired outcomes. This conclusion was backed up by statements from the weekly open survey questions as well as the in-sample validation interviews. All of the interviewed participants described their approach in their final ("experienced") project as more structured, planned, and intentional. Overall, the experienced teams decreased their time investment in the initial phases within the design thinking process in favour of spending more time making sense of the collected insights in the "point of view" phase. This behaviour is in line with previous accounts provided by Weth (1999) and Cross (2004) who argue that experienced designers are "ill-behaved" problem solvers in the sense that they spend less time defining a problem and more time scoping a problem and prioritising criteria for potential solutions.

Theme 3: Kolb's learning styles model offers an interesting lens through which the performance of design thinking teams can be further conceptualised.

In this research study, it has been argued that Experiential Learning Theory (ELT), and specifically Kolb's learning styles model (Kolb, 1984), provide an additional perspective on how to conceptualise design thinking. In their conceptual paper, Beckman and Barry (2007) have argued that there appear to be several theoretical links between Kolb's model and how design thinking is applied in projects. They argue that, in essence, design thinking projects are journeys of continuous experiential learning and sensemaking and can therefore benefit from connecting them to already established theories of experiential learning.

In general, individuals in this research study favoured grasping new information through abstract conceptualisation, resulting in a dominance of assimilating and converging learning styles. Grasping new information through concrete experience was less often used. Which learning styles were dominant, changed throughout the projects. The assimilating learning style dominated during the early phases of the design thinking projects and then gradually lost importance. The converging learning styles on the other hand, grew in relevance over time and dominated the final phases of the projects. From the observed dominance of abstract conceptualisation over concrete experience, one may conclude that design thinking in practice is less intuitive and instinctive and more calculated and deliberate. However, the dominance of abstract conceptualisation might also be a representation of composition of the underlying sample, which was in large parts made up of business and engineering students.

In line with previous speculations by Beckman and Joyce (2009), this research study provided empirical evidence that the distribution of learning styles within design thinking teams is connected to the final performance of teams. It was found that teams which demonstrated a balance of the four Kolb learning styles, achieved a better final team performance than those teams in which the learning styles were distributed more unevenly (Hypothesis 3b, accepted). This finding is in line with previous arguments in other domains, such as entrepreneurship education (Corbett, 2005), engineering education (Halstead & Martin, 2002), and learning simulations (Kayes et al., 2005). In this thesis, it has also been argued that learning styles influence the specific tasks individuals will excel in. Furthermore, it has been proposed that the utilisation of multiple learning styles leads to deeper learning on an individual level. The author therefore speculates that a balance of the utilised learning styles within a team also leads to deeper learning on a team level. Deeper learning, in turn, allows a team to continuously evaluate available information from multiple perspectives to inform better decisions, which ultimately leads to better project outcomes. The author therefore proposes that learning styles distribution and utilisation

offer an interesting new perspective on how design thinking team composition and performance can be further understood and improved.

On an individual level, no significant evidence was found that design thinking team members cycle through Kolb's learning styles in a systematic manner (Hypothesis 3a, rejected). However, the connection of the sequential use of learning styles, as suggested by Kolb's model, and individual thinking patterns of design thinking team members warrant further investigation, as the statistical power of employed non-parametric runs test was severely restricted by the limited amount of available cases due to the fixed measurement intervals and project time frames.

Theme 4: Creative confidence develops steadily and linearly over the course of design thinking projects, but does not directly impact project outcomes.

The concept of creative confidence as a fundamental requirement for design thinking has received increased attention since the publication of the mass-market book *Creative Confidence* by Kelley and Kelley (2013). Within the literature on design thinking, some narrative accounts and qualitative treatments of creative confidence are provided. These publications are loosely connected to other streams of discussions on design sensibilities, informed intuition, and expert design abilities in the design literature. However, the author failed to identify attempts to operationalise the concept of creative confidence for longitudinal quantitative studies. Hence, in an initial attempt to define variables to measure this concept, the author introduced "perceived effectiveness" and "perceived ease" in the application of design thinking as two proposed variables for assessing creative confidence in quantitative studies. During the data analysis, these two variables were found to highly correlate and were therefore combined into the joint variable of "perceived effectiveness and ease".

The levels of perceived effectiveness and ease of participants was found to grow steadily and almost linearly across the timespan of each project observed in this study. This finding is in line with previous arguments, for

example by Suri and Hendrix (2010), Jobst et al. (2012), and Kelley and Kelley (2013), who propose that such intuitive design capabilities generally develop over time. However, this finding does not back up the argument posited in one of the most widely-read books on design thinking by Brown (2009, p. 65), who describes that confidence generally follows a U-shaped pattern throughout a project (Hypothesis 4a, rejected). Both the novice as well as the experienced design thinking teams reported moderate levels of initial confidence. In one of the initial weekly survey questions, participants indicated that, although they did not yet know the direction they were taking their projects in, they nonetheless felt confident about achieving satisfactory outcomes. Subsequently, during the projects, the levels of perceived effectiveness and ease grew almost linearly, the more time each team spend working towards a solution for the proposed design challenges. This behaviour was observed for all participants, regardless of their disciplinary background. Several participants in the in-sample interviews as well as one interviewed practitioner hinted to the fact that the growth in confidence might also be connected to the development of trust in design thinking as an effective problem-solving methodology.

Counter to previous assumptions, only weak evidence was found that individual perceived effectiveness and ease carried over to new projects and teams (Hypothesis 4b, rejected). Only six out of 22 participants showed significantly higher levels of perceived effectiveness and ease in their third and final design thinking projects, as compared to their first project. Ten of the remaining 16 participants also showed higher levels of perceived effectiveness and ease in their final project, although these differences were not statistically significant. This research study was limited to a 10-month timeframe where participants invested around 600 hours in three design thinking projects. As Mr Grots, one of the interviewed practitioners, pointed out, this may not have been a long enough time period to fully develop this intuitive design competence to an extent where it becomes a transferable skill. Based on these findings, the author speculates that creative confidence, as measured by the levels of perceived effectiveness and ease, is likely transferable to new projects and teams, although the development of creative

confidence requires extended amounts of practice and reflection in excess of what this research study was able to cover.

However, the aggregated levels of perceived effectiveness and ease do not appear to be directly connected to the project outcomes. Whereas it was previously hypothesised that teams comprised of individuals with high levels of perceived effectiveness and ease would achieve a better final performance, no evidence was found to support this assumption (Hypothesis 4c, rejected).

Creative confidence, as measured by the levels of perceived effectiveness and ease, appears to be more expressive of the internal team climate than of external performance assessments. This was also indicated by the study participants in both the novice and experienced sample groups during one of the weekly open survey questions. When participants were asked about how happy they were with the final results of their projects, all participants indicated very high levels of satisfaction with their final project outcomes, despite noticeable differences in how external professionals evaluated each team's performance. Statistically, the differences in the aggregated levels of perceived effectiveness and ease per team also showed only minor variation across the different samples.

Theme 5: Design thinking team hierarchies are dynamic. Frequent communication and high team cohesion can negatively affect project outcomes.

Multidisciplinary teamwork is multi-faceted. As has been argued in this thesis, a successful design thinking team needs to create a shared mental model, which utilises the different disciplinary backgrounds and perspectives of each team member. This leads to a "cross pollination" of ideas (Kelley & Littman, 2006) and propels a team towards the development of a shared "collective intelligence" (Woolley et al., 2010), which ultimately drives its performance. Through radical collaboration – one of the key principles of design thinking – teams enact and re-enforce their collective intelligence in practice. The principle of radical collaboration encourages the frequent exchange of ideas, insights, and information among team members during the design process.

This continuous process is facilitated by open “conversational spaces” (Kayes et al., 2005) within design thinking teams.

In general, team communication is a highly complex phenomenon. This research study therefore introduced social network analysis to the investigation of communication patterns within design thinking teams. The interpretation of the compiled social network graphs and metrics indicated that connections between team members grew stronger over time. The observed teams tended to communicate most extensively about project-specific information, but also reflected on design thinking tools and principles on a more holistic level.

Within the analysed team networks, the relative importance of individuals, as measured by their eigenvector rank within their team, changed frequently throughout the design thinking projects (Hypothesis 5a, accepted). For the experienced design thinking teams, these changes in the eigenvector rank were most prevalent during the early phases of a project and subsequently became less regular. At each point in time, a few opinion leaders could be identified who dominated the conversations within each team. In this research study, opinion leaders were defined by a high level of weighted in-degree within the social network. This meant that internal opinion leaders were determined by popular demand and according to what they had to contribute to the project at each point in time. In most teams, these opinion leaders changed over time. The answers to one of the weekly survey questions also revealed that the observed teams generally did not assign fixed roles within their groups, but rather tended to assign temporary roles based on the requirements of the current task at hand. These findings are in line with prior observations by Beckman and Barry (2007) as well as Beckman and Joyce (2009) who argue that good design thinking teams tend to rotate leadership position based on each team member’s skill level for a specific design thinking task. As multidisciplinary design thinking projects consist of many different “connected activities” (Brown, 2009), where each activity requires a slightly different skill-set, the observed dynamic team

hierarchies can be interpreted as a valuable coping mechanism for such projects.

One finding from the analysis of the social networks was particularly peculiar. Contrary to previous assumptions, a high degree of internal cohesion, as measured by the frequency and quality of interactions within a team, had a significantly negative effect on the project outcomes in this research study (Hypothesis 5b, rejected). This finding contradicts both the conclusion formed in a comprehensive meta-analysis on team-level predictors of innovation at work by Hülsheger et al. (2009) as well as the argument raised by Kelley and Littman (2001) in a very popular book on the dynamics of design thinking teams. In this study, too much shared information actually appeared to have diminished the quality of the decisions made within the observed teams. In a more recent study on novice multidisciplinary design thinking teams, Seidel and Fixson (2013) conclude that increased team reflexivity, as expressed by debating ideas, processes, and changes to concepts, is needed during concept generation, but leads to worse project outcomes during the concept selection. Based on the findings from the current study and the inferences drawn by Seidel and Fixson (2013), it was therefore concluded that the observed teams with high internal cohesion might have failed to transition from more-reflexive to less-reflexive ways of working during the project, which overall led to poorer project outcomes. Yet, another explanation might arguably be the existence of “groupthink” (Janis, 1982) within the observed teams, which has been shown to increase the likelihood of defective decision-making. As has been previously explained, high team cohesion is often argued to be an antecedent of groupthink. It has also been described that one of the most common reasons for engaging in groupthink is the desire of team members to maintain a positive view of the functioning of the group, which might also have influenced the observed teams within this study.

Furthermore, some evidence was found which suggested that a high degree of external cohesion, as measured by the frequency and quality of interactions with members of other teams, also had a negative effect on the final project outcomes in this research study, although this effect was not

significant. Initially, it was assumed that connections to other teams would expand the available resources, add additional perspectives, and inform better decisions. Overall, it was assumed that this would deepen the thought process, improve opportunity recognition, and ultimately lead to better final project outcomes for the observed teams. However, the evidence presented in this study suggests that extensive connections to other project teams have a reverse effect on project outcomes (Hypothesis 5c, rejected). In this study, all teams were working in parallel, sometimes on similar design challenges. One might speculate that this finding can also be explained by the need to compare your performance with other teams. Frequent interactions with other groups might therefore have distracted a team from fully committing to a trajectory for its own project, which ultimately led to poorer decisions and poorer project outcomes.

6.4. Summary of Key Findings

This study presented several findings relating to five broad research themes. While investigating team diversity, multidisciplinary teams were found to produce significantly better project outcomes than single-discipline teams. On the other hand, diversity of personality traits was not found to have a significant effect on the final performance of teams. The exploration of iteration behaviour revealed that multidisciplinary teams did not iterate significantly more than single-discipline teams. In addition, more experienced participants approached design thinking projects slightly less iteratively than novices. Overall, the degree of iteration was not found to have a significant effect on final performance. Regarding the use of different learning styles it was discovered that, design thinking teams with a balance of learning styles achieved significantly better project outcomes than less-balanced teams. In terms of learning styles, participants approached design thinking tasks mainly through rational conceptualisation rather than concrete experience. The analysis of individual and team confidence showed that creative confidence slowly and linearly developed over the course of the observed design thinking projects and only partly carried over to new project and team settings. Furthermore, no evidence was found that higher levels of creative confidence

within a team directly influence the quality of the project outcomes. The investigation of team communication revealed that the importance of individuals in design thinking teams significantly changed over the course of the observed projects. Contrary to previous assumptions, high degrees of internal team cohesion were found to have a significant negative impact on project outcomes.

6.5. Research Limitations

Following the distinction proposed by Johansson-Sköldberg et al. (2013) between *designerly thinking*, i.e. how professional designers practice design and *design thinking*, i.e. using design practice and competences beyond the traditional design context, this dissertation predominantly focussed on the still evolving domain of *design thinking* and the application of design in a wider context, such as entrepreneurship and innovation. This dissertation intended to provide an extensive overview of the key themes currently discussed under the umbrella term *design thinking* and explore five key success factors in the application of design thinking in multidisciplinary teams. Although, several connections to the *designerly thinking* literature are drawn to underline key design principles, this literature could not be covered in its entirety. Several *designerly thinking* theories, such as associative theories (especially Gestalt theory) and creativity theories relating to the role of emotions, were therefore out of the scope of this dissertation.

As a direct consequence of the choice of the research methodology and the corresponding research design, this study encountered a number of limitations, which are briefly discussed below.

- **Limited generalisability**: Although the quasi-experimental research design controlled for several factors during the research study, not all causal influences on the participants' behaviours could be captured and controlled for. For example, the attitudes and the resulting behaviours of research participants observed during this study might have been influenced by external people (such as classmates, work colleagues, and friends) as well as external life events and circumstances (such as jobs

and relationships). Despite the likely presence of such influences, their effect on the presented study was assumed to be minimal, due to the fact that participants were observed over an extended time period and in a setting, which was physically and mentally separated from their other ongoing activities.

- **Age and experience of study participants**: The main samples were comprised of students and young professionals with an average of 3.81 years of work experience. This limits the generalisability of the study findings to other groups, such as experienced managers. It could be argued that a sample group with more work experience would have approached the innovation challenges differently, because such a group would have been able to draw on their prior experiences for deeper background information, strategies, and heuristics, which would have influenced their decision-making processes. However, the innovation challenges in this study were based on open-ended problems and designed so that prior knowledge – besides each participant's disciplinary training – would only have a very limited effect.
- **Small sample sizes**: The small sample sizes available to the researcher reduced the explanatory power of some statistical tests and only allowed for the testing of linear correlations. However, the range of tests and observations as well as the validation interviews allowed the researcher to triangulate the presented findings and overall resulted in an acceptable degree of validity.
- **Comparability of samples**: For some hypothesis tests, a control group of business administration students from an elective entrepreneurship course was used. Although several strategies for controlling environmental influences on participant behaviour were put in place, between-sample comparability in quasi-experimental research is never absolute.
- **Lack of scientific measurement systems**: As highlighted before, only a few quantitative studies on design thinking have been conducted to date. Therefore, new measurement strategies and systems had to be devised for the majority of the hypothesis tests. These strategies and systems were initial attempts at quantitative conceptualisations of elusive concept

in design thinking theory and will need to be refined for future research studies. For example, iterations in this study was measured as recursive movement in the design thinking process. Whereas this measurement strategy allowed to measure the time allocation to the different process phases, it could not capture "sideways" iteration (e.g. iterating between multiple prototypes in the prototyping phase).

- **Focus on final team performance**: This study focused on the final team performance, as measured by an independent panel of external professionals, as the most important outcome variable. Other performance measurements and the performance during the projects were not considered.
- **Cultural bias**: The participants in this study were either Germans or have been living, studying or working in Germany for more than five years. The participant's cultural background as well as how they were trained to approach problem-solving tasks will have likely influenced their general attitudes towards innovation as well as how they communicated, discussed and shared information. As a result, the observed phenomena and the presented findings are likely restricted to the German culture.
- **Insider perspective of the researcher**: Although the research design for the predominantly quantitative study was finalised prior to engaging with the research participants in person, the "native" insider-perspective of the researcher during the research study may have influenced the interpretation of the collected data.
- **Influence of the researcher**: Several strategies have been used to minimise the influence of the researcher on the behaviour of the research participants. For example, all programme lecturers and mentors were briefed not to "steer" participants in a certain direction during the projects. Furthermore, a trained teaching assistant was used to hand-out and collect all surveys to create a perceived separation of the lead researcher from the research participants. In addition, the researcher implemented an independent grading panel to ensure impartiality during the performance assessment. However, the researcher's involvement during the observed projects still might have influenced the participants' attitudes and actions to some extent.

6.6. Contribution and Implications

In spite of these limitations, this thesis offers substantial contributions to the growing theory of design thinking.

On the one hand, methodological contributions have been made by devising longitudinal experimental measurement systems to conceptualise several ambiguous and elusive concepts in the design thinking theory, such as multidisciplinarity, iterations, learning styles, creative confidence, and team cohesion. This approach allowed the researcher to formulate concrete research hypotheses, collect an original dataset, and test the formulated hypotheses in a quantitative and rigorous way. The positivist research approach offers an antithetic perspective to the predominantly qualitative body of research on design thinking. As the data analysis and the resulting findings in this study illustrated, a positivist approach makes it possible to sufficiently define and measure design thinking concepts, which are otherwise hard to grasp. Overall, this widens the available research repertoire for future research studies and opens up research trajectories for triangulating positivist quantitative research findings with existing theory, which predominantly builds on qualitative research and exemplary case studies.

Furthermore, the presented longitudinal research design framework allows to accurately examine the development process of design thinking principles in practice over time and therefore provides opportunities for a deeper understanding of these principles than cross-sectional studies can provide. As several scholars such as Carlgren et al. (2014), Hobday et al. (2011), Johansson-Sköldberg et al. (2013), Kimbell (2011), Liedtka (2015) and Razzouk and Shute (2012) have noted, the theoretical underpinnings of design thinking within the business context still remain poorly understood and under-researched. Dinar et al. (2015) also point out that there are still no standards for designing, collecting and analysing data in design thinking research and that long-term project-based observations have been relatively few in design studies over the past 25 years. The formulated and tested research strategies presented in this thesis provide functional as well as

novel paths and guidelines to solidify the understanding of design thinking theory and practice through further research.

On the other hand, the findings from this study provide several contributions to the theory and practice of design thinking in an innovation and entrepreneurship context. Several of these findings present novel insights into how multidisciplinary design thinking teams operate. By correlating each examined principle with the final performance of design thinking teams, recommendations could be formulated which directly impact design thinking practice. While some of these findings provide support for existing theory, others highlight the need to revisit several assumptions inherent in contemporary design thinking theory.

Extending the arguments put forth by several authors such as Brown (2008), Brown (2009), Carlgren et al. (2016), Dym et al. (2005), Gruber et al. (2015), Kelley and Littman (2001), Kelley and Littman (2006), as well as Kelley and Kelley (2013), multidisciplinary teams were found to significantly outperform single-discipline teams in design thinking tasks (Hypothesis 1a, accepted). Based on the presented study findings, the author also supports previous speculations by Beckman and Barry (2007) as well as Beckman and Joyce (2009) who have theoretically conceptualised a positive link between the utilisation of different Kolb learning styles and design thinking team performance (Hypothesis 3b, accepted). Additionally, evidence was found which suggests that the relative importance of individuals changes throughout a design thinking project (Hypothesis 5a, accepted). This finding backs up initial observations by Beckman and Barry (2007) as well as Beckman and Speer (2006), who have proposed that well-performing design thinking teams will rotate team leadership positions based on the suitability of individual team members' skill-sets for specific tasks during design thinking projects.

In contrast to previous arguments by Brown (2009), creative confidence within a team, as conceptualised by the levels of perceived effectiveness and ease, was not found to develop in a U-shaped pattern, but instead developed linearly over the course of the observed design thinking projects (Hypothesis

4a, rejected). Furthermore, no evidence was found that the level of creative confidence within a team influences its final performance (Hypothesis 4c, rejected). Based on the data analysis and the conducted follow-up validation interviews, the author speculates that creative confidence in mainly built through gaining trust in design thinking as an appropriate innovation methodology and through exploring and testing multiple problem-solving strategies over the course of a project. Also, contrary to previous assumptions, high degrees of internal team cohesion were not found to improve the final performance of the observed teams (Hypothesis 5b, rejected). Instead, high levels of internal team cohesion have had a negative effect on the overall performance of the observed teams. Based on the data presented in this study, the author hypothesises that high levels of internal team cohesion lead to groupthink and an emphasis on debating thoughts and ideas, rather than utilising an experimental and iterative approach to design thinking tasks. Furthermore, based on its prominence in the design thinking literature, iteration was assumed to positively influence a design thinking team's final performance (e.g. Carlgren et al., 2016; Gerber & Carroll, 2012; Glen et al., 2015; Grots & Pratschke, 2009; Gruber et al., 2015; Kolko, 2015; Leifer & Steinert, 2011; Liedtka, 2000; Rodriguez & Jacoby, 2007; Tonkinwise, 2011; Tynan et al., 2016 forthcoming). However, no evidence was found in this study to support the argument that the amount of iteration influences the final team performance of novice and experienced design thinking teams (Hypothesis 2c, rejected). In addition, no evidence was found that more experienced design thinking teams iterate more than novice teams (Hypothesis 2b, rejected). In fact, the observed experienced teams tended to iterate slightly less than the novice teams, although this finding was not significant.

The presented findings are especially relevant for training design thinking novices in team settings in the context of innovation and entrepreneurship. To increase their learning effect and performance, novice design thinking teams should be diverse in terms of disciplinary background and preferred learning styles to provide different perspectives, enrich the team's shared mental models, and maximise the cross-pollination of ideas. Moreover,

novice teams should be actively encouraged to iterate within their problem-solving approach to quickly explore different trajectories within a project. Furthermore, design thinking novices need to be provided with ample opportunity to develop and reflect on their creative confidence across extended periods of time. In addition, novice teams also need to be made aware about the pitfalls of high levels of team cohesion, as these hinder the necessary process of individual contemplation and may lead to groupthink, which overall negatively impacts their performance.

In conclusion, this thesis provided a substantial contribution to knowledge by establishing a functional positivist research design framework to conceptualise and measure several ambiguous and elusive concepts relating to how high-performing multidisciplinary design thinking teams operate. In addition, the presented findings solidify the current understanding of how team diversity, iteration, learning styles, creative confidence as well as team communication influence the performance of novice multidisciplinary design thinking teams in the innovation and entrepreneurship context.

6.7. Recommendations

In this section, the presented findings are transformed into actionable recommendations for three separate target groups. First, recommendations are provided for practitioners who regularly use design thinking in innovation projects. Second, recommendations are formulated to provide educators with further guidelines on how to implement design thinking into their teaching activities in an effective way. Third, recommendations for fellow researchers point to several “weak spots” in design thinking theory, which warrant further investigation in future research studies.

6.7.1. For Practitioners

Based on the presented findings, several recommendations for design thinking practitioners can be put forth. The following recommendations are intended as additional guidelines to allow practitioners to further develop and reflect on their design thinking approach.

- Multidisciplinary teams are at the heart of design thinking. In projects, practitioners need to leverage the symmetries of ignorance caused by different disciplinary backgrounds to create a rich shared mental model to improve project outcomes. Teams must collectively agree on how to circumvent the negative aspects of multidisciplinary teamwork, such as increased miscommunication. In addition to including different disciplines in a design thinking project team, encouraging team diversity in terms of learning styles offers yet another strategy for stimulating the creation of richer mental models, which ultimately lead to improved project outcomes.
- Design thinking should be iterative, but in "live" project environments, which involve fixed deadlines and external clients, iterations are often neglected in favour of a "safer" and more structured approach. Practitioners need to be aware of this tendency and need to actively encourage and schedule time for iterations and the recursion into other process phases as a valuable feedback and learning mechanism.
- Creative confidence allows practitioners to leverage abductive logic and envision new solutions to new problems. Developing creative confidence requires deliberate practice over an extended period of time. In project teams, more experienced practitioners should guide design thinking novices in their development of creative confidence. Practitioners should be aware that the impact of creative confidence is subtle as well as multi-faceted and therefore does not impact traditional project key performance indicators directly.
- Internal team leadership should be dynamic. Design thinking consists of several connected activities. Each activity requires a slightly different skill-set. Internal team leadership positions should be rotated based on individual team member's preferences for specific design thinking tasks.
- Team communication needs to be reflective. Articulating each and every idea prematurely leads to a less-reflective practice and information overload. If the amount of information to be processed becomes overwhelming, a project's potential can be seriously diminished, especially during concept selection phases. Effective multidisciplinary design thinking teams must build collaboration spaces where

assumptions are challenged, team members are listened to, and differences are accepted. However, dysfunctionally high levels of team cohesion need to be avoided, as these may lead to groupthink, resulting in defective decision making within the team.

6.7.2. For Educators

As design thinking is growing in popularity and expanding its reach, especially in domains such as business management, innovation, and entrepreneurship education, solid pedagogical approaches are needed to facilitate the learning process of design thinking. Based on the presented findings, the following recommendations are intended to provide guidance for design thinking educators, both in academic as well as in organisational environments.

- Value creation is an inherently multidisciplinary activity. Whenever possible, courses on design thinking should therefore be set up as multidisciplinary experiential learning activities. This forces students to reflect on the value of their chosen discipline, while simultaneously learning about the value of other disciplines. The creation of shared mental models together with individuals from other disciplines allows students to evolve richer thought patterns and instils confidence in their problem-solving abilities.
- Effective collaboration in design thinking teams is highly complex. Simply mixing students from multiple disciplines does not suffice. Students need to be encouraged to reflect on the principles of effective collaboration. Well-functioning student teams need to be taught how to engage in radical collaboration without developing groupthink, which leads to defective decision-making. Their team communication needs to be reflective and purposeful. Good team communication is not build on sharing all information, but sharing the right information.
- Creative confidence is a sought-after quality in graduates across various disciplines. Educators should therefore aim to help students develop their creative confidence through reflective practice. However, developing this competence requires deliberate reflective practice over extended periods

of time. Semester or trimester course structures only allow for a limited involvement with individual students. Furthermore, the development of creative confidence is difficult to assess in a formal way and therefore is often neglected as a learning outcome in curriculum design. Where possible, educators should therefore push for the inclusion of creative confidence as a learning goal on a programme and school level.

- Design thinking offers powerful principles, models, and tools to encourage deep learning and personal development in experiential learning settings. However, simply confronting students with design thinking theory does not suffice. Many concepts in design thinking are radically different from how non-design students would generally approach a problem-solving task. For example, whereas iteration is highlighted as one of the fundamental principles in design thinking, the recursion into other process phases rarely happens in unguided novice multidisciplinary teams. The learning process of students therefore needs to be actively facilitated by experienced educators. Sometimes this requires "nudging" students out of their acquired routines and thought patterns.
- Experiential learning theory and Kolb's learning styles model offer a novel and effective lens through which the learning process in design thinking can be further conceptualised and enhanced. Including a continuous assessment of students' preferred learning styles in experiential learning projects allows educators to increase the diversity of learning groups and improve the final project outcomes. Fostering team diversity in terms of learning styles leads to deeper reflection during the learning process and enriches students' shared mental models. The assessment and utilisation of learning styles diversity should therefore be included in in the curriculum design of design thinking-based innovation and entrepreneurship programmes.

6.7.3. For Future Research

It has been frequently highlighted throughout this thesis that more academic research, based on rigorous research frameworks and methods, is needed to further solidify design thinking theory and practice. Based on reflections on

the research process of this thesis and its findings, the following recommendations were formulated to provide specific stepping stones for further research in this field.

- The author would especially welcome more quantitative research studies to back up initial findings from the several qualitative case studies available in this field. Experimental research should be used to drill down to the causal effects within individual phenomena, whereas more longitudinal studies should be conducted to further shed light on how design thinking principles, models, and tools are developed and internalised by practitioners and students over time. Subsequently, results from both quantitative and qualitative studies need to be pooled to triangulate their findings and further deepen the understanding of design thinking theory.
- Future research on design thinking in domains outside of traditional design needs to be more closely linked with already existing theories and models in the realm of designerly thinking. Unifying these currently separate discussions would allow researchers to formulate more robust and relevant theories in both domains.
- The link between design thinking and Experiential Learning Theory as well as Kolb's learning styles model has proven to be worth exploring. In this study, it has been shown that the diversity of learning styles in multidisciplinary design thinking teams has a significant positive effect on the overall performance of such teams. These findings provide a stepping stone for future research on how the collaboration and performance of design thinking teams can be enhanced. Future research should aim to further understand how learning styles influence individual and team approaches to specific design thinking tasks as well as how the use of different learning styles influences project outcomes.
- The use of social network analysis as a conceptual framework and analysis tool for capturing interactions within and between design thinking teams allowed for a comprehensive study of patterns of collaboration within this research study. Further use of social network analysis is suggested to study individual and team interactions in design thinking

projects. Analysing team interactions from a micro perspective would allow researcher to clarify how individual team members need to cooperate and communicate to achieve good performance. Analysing interactions on a macro level would enable researchers to gain a deeper understanding of how teams should interact with other external parties, such as other teams, clients, and external experts to improve the outcome of design thinking activities.

Researchers are invited to replicate and extend this research study in several ways. First, the author would suggest replicating this study in a different cultural context to compare and contrast the findings and further probe for cultural influences in the practice of design thinking. Second, a replication of this study with a larger sample would allow for the use of regression models and structural equation models to further investigate the causality and interrelation of the observed variables and effects. Third, this study should be extended to include other forms of assessing performance, which should be measured at several points in time throughout the experiments. Forth, extending this research approach into organisational settings, where design thinking is used within more restrictive boundaries and measured by more traditional key performance indicators, would increase the generalisability of findings for the design thinking practitioner community.

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Appendices

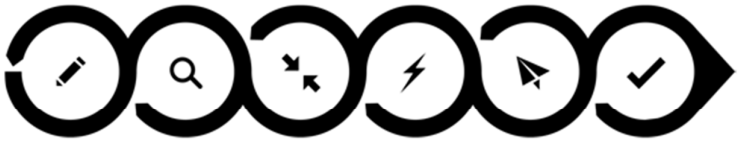
A. Weekly Team Survey

name | team | date

Let us assume that you have worked 10 hours on your project during the previous week. 1

Please divide these 10 hours across the project phases.

Please place your answers in the grey boxes below. It is likely that you will not spend *exactly* 10 hours on your project each week, but please stick to the format of dividing precisely 10 hours. Think of it as indicating the ratio of your time spend across the phases.



Understand | Observe | Point of View | Ideate | Prototype | Test

h | h | h | h | h | h

In your opinion, how much did the time you spend help you to move the project along? 2

1 2 3 4 5

Not at all — A lot

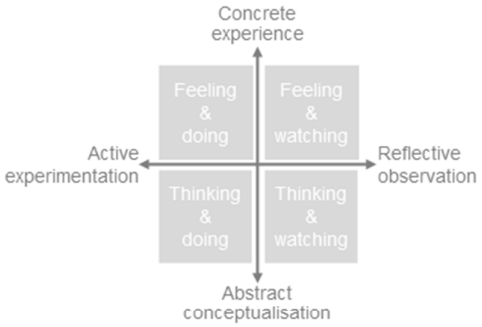
How at ease did you feel with your project last week? *(feeling at ease = sich wohlfühlen)* 3

1 2 3 4 5

Not at ease at all — Very at ease

Which learning style matches your activities over the last week? 4

Please chose only one option. You can highlight your choice by circling the quadrant (grey box) that matches your learning style during the last week most closely.



Please answer the following question. 5

Open question (this changes every week).

Please do not give answers longer than the space provided below. Try to answer in English. If you feel that you cannot express your idea well enough in English, you may make an exception and use German.

answer

B. Communication Behaviour Survey

name | team | date

Please list the names of **all** your team members in the first column. 1

Now please indicate **how frequently** you talk to your team members about…

(a) …the **issue** you are working on, like exchanging news articles and online resources.
(b) …**innovation methods**, like interview methods, prototyping, idea generation.
(c) …**private matters**, like your interests background and what's going on in your life.

Please also rate **how much this contributed** towards solving your project challenge.

To **rank your answers** you should use a scale from 1 (very little) to 5 (very much).
You could also answer 0 (not at all).

Names of your team members	(a) Talking about the subject…		(b) Talking about innovation methods…		(c) Talking about private matters…	
	…how frequent?	…how helpful?	…how frequent?	…how helpful?	…how frequent?	…how helpful?
1.						
2.						
3.						
4.						
5.						
6.						

Please list the names of **up to five** other students from the current course (not in your group) with whom you have communicated. 2

Please **rate** these interaction again for **frequency** and **helpfulness** in the same three categories (a), (b) and (c).

To **rank your answers** you should again use a scale from 1 (very little) to 5 (very much).

Names of up to five other students not from your team	(a) Talking about the subject…		(b) Talking about innovation methods…		(c) Talking about private matters…	
	…how frequent?	…how helpful?	…how frequent?	…how helpful?	…how frequent?	…how helpful?
1.						
2.						
3.						
4.						
5.						

C. Five-Factor Model of Personality Survey

name | team | date

Personality Survey

The purpose of this survey is to measure five broad personality traits. These five traits will form a rough personality profile of you. These profiles will help the programme facilitators to form the project teams and give individual feedback to you throughout the course. Please note that there are no "good" or "bad" personality traits and therefore there are no "right" or "wrong" answers in this survey. Just try to answer the questions as truthfully as you can following the instructions below.

It will take you about eight minutes to finish all questions.

You are free to withdraw from this study at any point. The data will be stored securely. In publications your name will not be disclosed and it will not be possible to track any of the gathered information back to you.

Instructions

On the following pages, there are phrases describing people's behaviours. Please use the rating scale on the next page to describe how accurately each statement describes you. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then tick the box that corresponds to the number on the scale.

For some of the questions German translations were provided and marked in light gray. Please refer to the translations only if the original English question is otherwise completely unclear to you.

1

no.	IPIP Big Five scale questions	very inaccurate	moderately inaccurate	neither inaccurate nor accurate	moderately accurate	very accurate
1.	I am relaxed most of the time.	☐	☐	☐	☐	☐
2.	I seldom feel blue. Ich fühle mich selten traurig.	☐	☐	☐	☐	☐
3.	I make people feel at ease. In meiner Gegenwart fühlen sich Leute wohl.	☐	☐	☐	☐	☐
4.	I take time out for others.	☐	☐	☐	☐	☐
5.	I am full of ideas.	☐	☐	☐	☐	☐
6.	I am quick to understand things.	☐	☐	☐	☐	☐
7.	I don't mind being the centre of attention.	☐	☐	☐	☐	☐
8.	I spend time reflecting on things.	☐	☐	☐	☐	☐
9.	I have a vivid imagination. Ich habe eine lebendige Vorstellungskraft.	☐	☐	☐	☐	☐
10.	I have excellent ideas.	☐	☐	☐	☐	☐
11.	I leave my belongings around.	☐	☐	☐	☐	☐
12.	I make a mess of things.	☐	☐	☐	☐	☐
13.	I often forget to put things back in their proper place.	☐	☐	☐	☐	☐
14.	I shirk my duties. Ich drücke mich vor meinen Aufgaben.	☐	☐	☐	☐	☐
15.	I worry about things.	☐	☐	☐	☐	☐
16.	I get stressed out easily.	☐	☐	☐	☐	☐
17.	I have frequent mood swings.	☐	☐	☐	☐	☐
18.	I like order.	☐	☐	☐	☐	☐
19.	I get chores done right away. Ich erledige Hausarbeit sofort.	☐	☐	☐	☐	☐
20.	I pay attention to details.	☐	☐	☐	☐	☐
21.	I am always prepared.	☐	☐	☐	☐	☐
22.	I keep in the background.	☐	☐	☐	☐	☐
23.	I am quiet around strangers.	☐	☐	☐	☐	☐
24.	I feel little concern for others.	☐	☐	☐	☐	☐
25.	I am not interested in abstract ideas.	☐	☐	☐	☐	☐
26.	I have little to say.	☐	☐	☐	☐	☐

no.	IPIP Big Five scale questions	very inaccurate	moderately inaccurate	neither inaccurate nor accurate	moderately accurate	very accurate
27.	I have difficulty understanding abstract ideas.	☐	☐	☐	☐	☐
28.	I do not have a good imagination.	☐	☐	☐	☐	☐
29.	I am easily disturbed.	☐	☐	☐	☐	☐
30.	I follow a schedule.	☐	☐	☐	☐	☐
31.	I am exacting in my work. Ich erledige meine Arbeit gewissenhaft.	☐	☐	☐	☐	☐
32.	I start conversations.	☐	☐	☐	☐	☐
33.	I have a rich vocabulary.	☐	☐	☐	☐	☐
34.	I talk to a lot of different people at parties.	☐	☐	☐	☐	☐
35.	I use difficult words.	☐	☐	☐	☐	☐
36.	I am interested in people.	☐	☐	☐	☐	☐
37.	I sympathize with others' feelings.	☐	☐	☐	☐	☐
38.	I am the life of the party.	☐	☐	☐	☐	☐
39.	I feel comfortable around people.	☐	☐	☐	☐	☐
40.	I feel others' emotions.	☐	☐	☐	☐	☐
41.	I have a soft heart.	☐	☐	☐	☐	☐
42.	I change my mood a lot.	☐	☐	☐	☐	☐
43.	I get upset easily.	☐	☐	☐	☐	☐
44.	I often feel blue.	☐	☐	☐	☐	☐
45.	I am not really interested in others.	☐	☐	☐	☐	☐
46.	I don't like to draw attention to myself.	☐	☐	☐	☐	☐
47.	I don't talk a lot.	☐	☐	☐	☐	☐
48.	I am not interested in other people's problems.	☐	☐	☐	☐	☐
49.	I get irritated easily.	☐	☐	☐	☐	☐
50.	I insult people.	☐	☐	☐	☐	☐

Thank you for taking the time to answer this survey. If you are interested in knowing your "Big Five" personality profile, just come and see me after one of our workshops.

D. Feedback Template for Big Five Personality Traits

Your Profile

Openness	
Conscientiousness	
Extraversion	
Agreeableness	
Neuroticism	

Five Broad-Level Personality Traits (the Big Five)

Characteristics of the High Scorer	Trait Scales	Characteristics of the Low Scorer
	Openness (O)	
curious, broad interests, creative, original, imaginative, untraditional	Assesses proactive seeking and appreciation of experience for its own sake; toleration for and exploration of the unfamiliar.	conventional, down-to-earth, narrow interests, unartistic, unanalytical
	Conscientiousness (C)	
organized, reliable, hard-working, self-disciplined, punctual, scrupulous, neat, ambitious, persevering	Assesses the individual's degree of organization, persistence and motivation in goal-directed behaviour. Contrasts dependable, fastidious people with those who are lackadaisical and sloppy.	aimless, unreliable, lazy, careless, lax negligent, weak-willed, hedonistic
	Extraversion (E)	
sociable, active, talkative, person-oriented, optimistic, fun-loving, affectionate	Assesses quantity and intensity of interpersonal interactions; activity level; need for stimulation; and capacity for joy.	Reserved, sober, unexuberant, aloof, task-oriented, retiring, quiet
	Agreeableness (A)	
soft-hearted, good-natured, trusting, helpful, forgiving, gullible, straightforward	Assesses the quality of one's interpersonal orientation along a continuum from compassion to antagonism in thoughts, feelings, and actions.	cynical, rude, suspicious, uncooperative, vengeful, ruthless, irritable, manipulative
	Neuroticism (N)	
worrying, nervous, emotional, insecure, inadequate, hypochondriacal	Assesses adjustment vs. emotional instability. Identifies individuals prone to psychological distress, unrealistic ideas, excessive cravings or urges, and maladaptive coping responses.	calm, relaxed, unemotional, hardy, secure, self-satisfied

E. Participation Consent Form

Introduction

Thanks for taking the time to read the following information **carefully!**

We are currently undertaking research to better understand how **innovation teams** work. We hope that this research will contribute to making entrepreneurship education more beneficial for future generations of students. We have invested a lot of time in this endeavour, because we think it is worth it. We hope you do to.

If you agree to participate in this research project you will be asked to fill out one or two **very short surveys** each Monday. This will only take you a couple of minutes. We kindly ask you to treat this task in a diligent way and make it part of our workshop routine.

You are free to **withdraw** from this study at any point. The collected data will be **stored securely**. Your **name will not be disclosed** in any publications and it will not be possible to track any of the gathered information back to you. The collected data will be employed for research purposes only. The **results may be published** in the form of a doctoral dissertation as well as journal articles and may be presented at academic conferences. Please note that all of this will have **no effect on** your **grades**, team compositions, and project assignments.

If you have any further questions about this study, feel free to talk to Florian at one of the upcoming workshops or contact any of the collaborating researchers. Details are provided below.

Participation Consent Form

I understand that I have the right to **decline** to answer **any specific questions** or to **withdraw my consent** for this study at any point in time without giving any reason. I have had an opportunity to ask questions about my participation in this study. **I have read and understood** the information and agree to participate in this study.

Name

Date

Signature

Do you want to receive a brief report containing the study's results?

☐ Yes, please. ☐ No, thank you.

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F. CAT Team Performance Evaluation Tool

Study Programme.	Date.
Evaluator.	Type.
Team name.	Who presented.

How to use this assessment form.
Please complete this assessment form for each presentation after it has finished. The scales range from ☹ to ☺. Indicate your rating by marking the line. You should rate all five categories quickly in a row. Please base your assessment on your intuition, experience and "gut feeling". Feel free to use the whole range of each scale. This assessment will be used for team feedback and will not represent the students' final grades. You can leave additional comments to be passed along either to the student team and/or the programme coaches. Thank you!

Desirability. Does the presented product or service address unmet/latent needs of the proposed target group(s)? Would customers buy this product?	☹ ☺
Viability. Do the key assumptions of the proposed business model and financial model make sense? Are they realistic?	☹ ☺
Feasibility. From a technology point of view, do you think that the product or service can be built by this team? (with/without external help)	☹ ☺
Selling & team. How well did the presenter(s) sell the concept to you? Do you think this team has what it takes to bring the product or service to market?	☹ ☺
Investment intent. Imagine you have 10.000 € in your pocket right now. You can put this money in a bank account to collect interest or invest (some of) it in the team. How much would you invest?	☹ ☺

Comments for the team.	Comments for the programme coaches.

G. Questionnaire for the External Validation Interviews

Expert Validation Interview

Thanks for agreeing to have this interview with me. Its main purpose is to validate the key findings of my PhD research. Through interviewing several industry experts, I hope to more accurately connect my research to practice. This interview will be recorded. Your edited answers will be published in my final PhD manuscript.

Section I: Background

Please provide some information about you which will help me to compile a short ½-page bio.

1. What do you currently do? Which "job title" would describe your current role(s) most accurately?
2. What were major steps in your career which shaped your views on design thinking?
3. Why do you think design thinking is important for companies?

Section II: Validation of Research Findings

I would now like to lead you through some of the key findings of my research. Each finding is presented as a short statement. From your point of view, I would ask you to briefly comment to what extent you agree or disagree with the statement and why.

4. Multidisciplinary design thinking teams achieve better final performance than single-discipline teams.
5. The diversity of Big Five personality traits within a team does not influence final performance.
6. Multidisciplinary design thinking teams do not iterate more than single-discipline teams.
7. More experienced design thinking teams iterate less than novice teams.
8. The amount of iteration within a design thinking project does not affect the final performance.
9. During a design thinking project, rational conceptualization dominates over intuitive decision making.
10. In design thinking projects, individuals move between different cognitive learning styles (cycle).
11. A balance of cognitive learning styles within a design thinking team positively affects final performance.
12. Perceived effectiveness and ease ("creative confidence") increases linearly throughout a project.
13. Individual's perceived effectiveness and ease ("creative confidence") in the application of design thinking carries over to new projects and teams.
14. The level of perceived effectiveness and ease ("creative confidence") does not influence the final performance of a design thinking team.
15. The relative importance of individuals changes throughout a design thinking project.
16. Design thinking teams with a high degree of internal cohesion achieve a worse final performance than teams with a low degree of internal cohesion.
17. Design thinking teams with a high degree of external cohesion achieve a worse final performance than teams with a low degree of external interaction.

Section III: Implications

The last few questions are related to what you think these findings mean for design thinking practice.

18. How do you think these results might affect design thinking practice and training?
19. What aspects about the composition and performance of design thinking teams might I have missed?
20. Are there differences in how different cultures/nationalities use design thinking?
21. Do you think design thinking is useful only for certain industry sectors?
22. How do you think design thinking will develop in the future?

Thank you!

H. Questionnaire for the In-Sample Validation Interviews

In-Sample Validation Interview

Thanks for agreeing to have this interview with me. Its main purpose is to validate the key findings of my PhD research. Through a conversation with people who have participated in my study, I hope to substantiate the interpretation of the findings from my empirical study. The interview will be recorded. Your edited answers will be published in my final PhD manuscript. This manuscript will not contain personal information about you.

Section I: Background

Now that some time has passed since you took part in the Academic Program for Entrepreneurship…

1. What do you currently do? Where do you currently work?
2. Are you working on other entrepreneurship-related projects besides your current job?
3. Has design thinking changed the way you think and work?

Section II: Validation of Research Findings

I would now like to lead you through some of the key findings of my research. Each finding is presented as a short statement. From your point of view, I would ask you to briefly comment to what extent you agree or disagree with the statement and why.

4. Interdisciplinary teams outperform single-discipline teams in design thinking projects.
5. The diversity of personality traits within a team does not influence final team performance.
6. Interdisciplinary teams do not iterate more than single-discipline teams.
7. While peoples levels of experience in design thinking increases, the total amount of iteration decreases.
8. The amount of iteration within a project does not greatly affect the final team performance.
9. During a design thinking project, rational conceptualization dominates over intuitive decision making.
10. A balance of cognitive learning styles positively affects final team performance.
11. Creative confidence increases linearly throughout a design thinking project.
12. Once people have developed creative confidence, it will carry over to new teams and projects.
13. The level of creative confidence does not influence the final team performance of a design thinking project.
14. How important a person is to their team changes during the different stages of a design thinking project. Teams with a lot of change of individual influence will have higher final team performance.
15. Very tight bonds within a project team are harmful to final team performance.
16. Very tight bonds to other project teams do not influence final team performance.

Section III: Implications

Almost done. Only two questions left…

17. What aspects about the composition and performance of design thinking teams might I have missed?
18. Do you think design thinking is useful only for certain industry sectors?

Thank you!

I. Mind Map: Teach the Teacher Workshop March 2013