Solving Problems with Design Thinking:
The relationship between practitioners' use of Design Thinking, problem specificity, and perceived team cooperation

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Dedicated to
Melba Greene King
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Abstract

Organizations constantly face complex problems that they must solve in order to serve their stakeholders. These organizations rely on their employees to isolate and solve these problems in order to provide their stakeholders with value. Organizations cannot always rely on particularly talented individuals and teams to solve every challenging problem that arises. In order to accelerate problem-solving across diverse teams and individuals, some organizations have recently started to rely on the design thinking (DT) process as a method to help employees systematically diagnose and solve problems.

However, DT, like any methodology, is not a panacea. Organizations' recent willingness to accelerate the adoption of DT raises questions about which problems the method is useful for solving, and which tools contribute most to solving them, at what point in the process. Particularly interesting questions revolve around DT's utility regarding problems' level of specificity as well as DT's impact on those employees using it. DT's association with ill-defined problems has dominated the literature, while less research has investigated how well-defined problems influence the application of the DT methodology. Regarding teams, recent research has looked at the degree to which specific DT steps influence innovation and teams in isolation, while research that examines the influence of the holistic DT process on teams' cooperation is scarce. As a result of this omission in the research and pressing need to better understand this widely deployed methodology, this dissertation explores the questions: Does the level of specificity in the problems that DT practitioners wish to solve influence their use of DT;

and does the practitioners' selective use of DT influence their levels of perceived cooperation within their teams?

To address these questions, this dissertation investigates the relationship between the DT tool-based problem-solving methods, the specificity of problems to be solved, and the perceived team cooperation. This research, by combining concepts from strategic problem specification and team cooperation, proposes a model that relates the phases of the DT methodology to problem specificity as well as perceived team cooperation. This research explores the degree to which problem-solvers specify their targeted problems influences their utilization of tools in certain phases DT tools, and the subsequent effect of practitioners' focus on these DT phases on the perceived cooperation within the problem-solving team.

The research context is a six-month long practice-based training program designed to help employees at a global company use DT to manage complex problems in their respective divisions. To test my hypotheses, I utilized detailed problem statements from 305 participants in the training program, evaluated surveys administered to the participants at the official end of the program, and reviewed training materials from the course.

Important implications for this research include addressing the current gaps in management literature regarding the relationship between the types of tools used in the DT methodology, problems to be solved, and cooperation within innovation teams. The findings may also provide DT practitioners with insights on the diversity of appropriate problems for the method and how to further foster individuals' ability to work together in problem-solving teams.

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1 Design Thinking and Problem-Solving

> *Over the course of a century of professional practice, designers have mastered a set of skills that can be productively applied to a wider range of problems than has commonly been supposed. These include complex social problems, issues of organizational management, and strategic innovation. Conversely, non-designers—those in leadership positions in companies, governmental and non-governmental organizations, professionals in a broad range of services and industries—can benefit from learning how to think like designers.*
>
> (Brown, T. & Katz, 2011)

Organizations that wish to improve their ability to serve their customers and stakeholders must continually solve complex problems in order to create opportunities for new value generation (Hsieh, Nickerson, & Zenger, 2007; Jones, G. R. & Butler, 1992). For organizations, managers, and entrepreneurs, problems are both barriers to progress and opportunities for unlocking new and profitable value (Ucbasaran, Westhead, & Wright, 2009). Organizations' success hinges on their ability and effectiveness at translating problems into cost-effective solutions (Drucker, 1984; Katila & Ahuja, 2002). The problems that problem-solvers detect and subsequently choose to engage are important antecedents to unlocking opportunities for learning and novel value generation (Simon & Hayes, 1976; Tversky & Kahneman, 1981). Problems that do not have well-defined boundaries are important for organizations to address because they hold the possibility of leading problem-solvers to hitherto undetected value propositions that advance the organizations' effectiveness as well as stakeholders' utility (Lyles & Mitroff, 1980; Vaghely & Julien, 2010; Volkema, Roger J., 1988).

The process by which problem-solvers choose to approach their targeted problem is important (Mitroff, Emshoff, & Kilmann, 1979). Many formalized methods exist that problem-solvers use to translate problems into sustainable solutions, including Total Quality Management (Powell, 1995), Six Sigma (Harry & Schroeder, 2006), Lean Start-up (Ries, 2011), TRIZ (Al′tshuller, 1999), and Agile (Cockburn & Highsmith, 2001). Design Thinking (DT) is currently among the more popular methodologies that problem-solvers use to manage the process of solving complex problems. DT attracts the attention of organizations that intend to address ill-defined problems that they and their stakeholders face (Beckman & Barry, 2007; Kolko, 2015; Verganti & Dell'era, 2009; Veryzer & Borja de Mozota, 2005). DT supports problem-solving, in part, through its activities that encourage reflexive thinking and action (Schippers, Edmondson, & West, 2014; Seidel & Fixson, 2013a; West., 2000). DT also influences the way teams work together and collaborate (Carlgren, Rauth, & Elmquist, 2016; Liedtka, 2015). As practitioners increase their use of DT to solve different kinds of problems (Elsbach & Stigliani, 2018; Liedtka, 2015), scholarship in DT and innovation methodologies benefit from an increased understanding of the degree to which practitioners fully apply DT to problems that are both ill-defined and well-defined as well as how the degree of application impacts team cooperation. To address these needs, this study investigates the questions: 1) to what degree do practitioners use DT phases when problems are either well-defined or ill-defined? and 2) what are the relationships between practitioners' selective use of DT phases and their teams' cooperation during the problem-solving process?

DT finds applicability across domains, from the broad demands of general management, to the more narrowly focused processes in new product development (Buchanan, 1992). Recent research indicates that DT differs from these other problem-solving methodologies through its ability to enhance organizations' user-centric focus, tolerance of ambiguity, affinity for collaboration, and creativity (Elsbach & Stigliani, 2018). Studies suggests that DT is effective across these dimensions because it establishes a common set of tools and language that individuals and teams can use in various industries and across different types of projects (Kolko, 2015; Ogilvie & Liedtka, 2011; Elsbach & Stigliani, 2018). This flexibility means that practitioners can use DT to solve problems across a range of organizational goals including product and service innovation where non-routine, complex problems are commonplace (Tippmann, Sharkey Scott, & Parker, 2017). As such, DT continues to be an important management methodology to investigate, because research cited above has shown that it provides value to organizations across many dimensions.

Managers in organizations as well as entrepreneurs apply DT to generate novel value propositions that are both quantifiable and unquantifiable in a plethora of industries and contexts (Leavy, 2010; Lockwood, 2010; Martin, 2009). The past decades have witnessed managers and entrepreneurs expand their use of DT to address a variety of problems in wide-ranging contexts (Carlgren, Rauth, & Elmquist, 2016a; Liedtka, 2017).

DT is a cyclical process comprised of phases that encourage its practitioners to A) acquire new information and knowledge about users' needs, B) analyze that information and knowledge and transform it into actionable goals, and C) test the utility of those goals with intended users in order to create valuable solutions to problems. Each phase includes a number of activity-based tools that support the goals of each phase. Practitioners benefit from revisiting these phases iteratively as they learn their way through the lack of information inherent in ill-defined problems (Buchanan, 1992; Smith, 1989; Volkema, 1983).

Problem Specification

Problems can range from well-defined problems that have clearly delineated boundaries and goals, to ill-defined problems that have unclear goals and specifications (Reitman, 1964a; Simon, 1973). Ill-defined problems do not include enough specifications for the problem-solver to generate a solution through reliance on the information immediately available, and ill-defined problems with low specifications usually have no unequivocal right answer (Archer, 1979). Problem-solvers who work with ill-defined problems with low specifications require flexibility to successfully identify and act on new concepts, which is part of the art and craft of business (Mintzberg, 2004).

However, DT’s rapid emergence raises questions about how its practitioners use the methodology in relationship to the level of definition in the problems that these practitioners choose to address. Authors Stempfle and Badke-Schaub (2002) highlight that design practitioners apply tools of the methodology in various ways to solve problems, despite the existence of highly normalized procedures that are taught throughout the world. Confirmatory search theory (Klayman & Ha, 1987; Shepherd, Haynie, & McMullen, 2012) suggests that DT practitioners are less likely to completely implement the DT tools afforded to them to solve problems when the practitioners have strong assumptions about likely solutions. Confirmatory search is a form of "motivated reasoning" that encourages prediction of future outcomes *ex ante* based on pre-existing assumptions (Peterson & Wong-On-Wing, 2000). Well-defined problems implicitly incorporate highly-specified assumptions that ill-defined problems exclude. Part of DT's role in problem-solving is to identify and test assumptions (Liedtka, 2015). The hypothesis testing literature indicates that problem-solvers tend to seek information that confirms their hypotheses which suggests that practitioners will avoid acquiring information that contradicts their expectations. While these literatures suggest that practitioners may minimize activities that will lead to the generation of information that contradict their assumptions, they do not provide an answer as to which phases practitioners will choose to use from the portfolio of normalized procedures in relationship to their targeted problems' level of specification. In order to address questions about the degree to which DT supports its practitioners in solving problems that they face, the following research investigates the relationship between the level of specificity that the practitioners include in their chosen problems, and the completeness with which practitioners use DT phases when solving their targeted problems.

Perceived Team Collaboration

DT's utility extends beyond its support of problem-solving; and organizations and teams that use DT have reported team-level outcomes (Carlgren, 2013; Liedtka, 2017). Design is an inherently social construct (Newell, 1990; Owens, 2000) and the process of deploying DT leads to improved team cooperation and task focus (Cross & Cross, 1995). DT's many phases and associated activities each have specific goals that can increase cooperative behaviors in teams (Alexander & Van Knippenberg, 2014). However, the team innovation and design literatures have yet to investigate the relationship between the completeness of practitioners' use of DT phases with their teams, and their perceptions of cooperation within their teams, at the conclusion of DT problem-solving projects. This research contributes to these literatures through its investigation of the relationship between DT practitioners' use of its phases, and practitioners' perception of team cooperation.

1.1 Motivation for this study

DT continues to enjoy a growing following of practitioners in the business world as evidenced by the impact of consulting firms like IDEO, frog, Peer Insight, and Doblin that all use DT to advance their clients' ever-changing needs. Despite the managerial use of this methodology, management scholars are in the early stages of comprehensively investigating how practitioners use DT in organizations and its impact in organizations, including standard performance effects and employees' experience of their work (Gruber, De Leon, George, & Thompson, 2015). Specifically, there is a gap in the literature that examines the portfolio of activities in the DT methodology that problem-solvers and their teams choose to use at the project level. The activities associated with DT are not unique to the DT methodology, and are rooted in decades of managerial practice and research. The management literature has yet to address the question of the relationships between the degrees to which managers specify their targeted problems and their chosen use of the DT phases. In order to address this gap, the following research study proposes and tests hypotheses about the relationship between the problem to be solved, and the impact on the teams of utilizing DT tools as they relate to the portfolio of tools used during the innovation process. Specifically, this research investigates the following questions:

Question 1) to what extent does the level of specifications that practitioners include in their problems relate to the practitioners' selection of DT tools and phases?

Question 2) to what extent does practitioners' selective use of DT tool and phases relate to their perception of cooperation in their team?

1.2 Organization

This paper proceeds by introducing the background and context of the research study in chapter one. Chapter two provides the main concepts of DT and theoretical foundations of problem specificity and perceived team cooperation that support the generation of the hypotheses central to this study. Chapter three provides a detailed explanation of the training program that provides data for the study and how the design of the study addresses the hypotheses. Chapter four outlines the results of the data analysis, and chapter five discusses the results and their implications for future research and practitioners.

1.3 Background and context

> *The natural sciences are concerned with how things are...design on the other hand is concerned with how things ought to be.*

(Simon, 1988)

1.3.1 Design as the core of Design Thinking

The concept of "design" defies containment into a simple definition (Buchanan, 1992). Engineers use design as a noun that describes how individuals combine knowledge with physical objects to create artifacts that serve specific purposes (Ralph & Wand, 2009). Design is also a verb. Simon's (1996) use of the term embraces the essence of design in his exposition of design as the process of human creation within the bounds of the natural environment. In other words, design is ubiquitous in the world – from architecture all the way to institutions. These are but two of many concepts of the processes that human designers undertake when they create something new.

Design's original roots embed it in the physical world (Margolin, 1989), and are concerned with the activities of creation. In the mid-20th century, theoreticians started viewing design process as more malleable and applicable across the world of human endeavor. Herbert Simon is considered a vanguard of that position:

> *Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state. 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.*
>
> (Simon, 1988)

Liedtka and Mintzberg (2006) highlight that design is action-oriented around foundational principles. They assert that "the basic attributes of successful designing are well-known—the process is synthetic, future-focused, hypothesis-driven, and opportunistic. It involves observation, the use of frameworks, and prototyping" p.16. Buchanan (2001) provides an encompassing definition of design that benefits the foundations of design thinking. He defines design as "…the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes." (p.9) These design activities— such as conceiving, planning, and building—are process steps focused on providing structure for achieving knowledge milestones along a continuum between an identified problem and its satisfactory solution (Bertola & Teixeira, 2003; Wynn & Clarkson, 2005). Organizations and businesses use such activities to develop sustainable value propositions that solve existing problems. However, design is a broad field filled with a broad selection of activities, and DT narrows the approaches to a compact set of principles and activities.

1.3.2 Design Thinking

DT is a distillation of the complex and interdependent activities embedded within the broader field of design (Dorst, 2011) that combines the tasks, activities, and mindsets that designers use in the process of designing solutions to complex problems (Dorst, 2006; Dunne & Martin, 2006). DT extends beyond general design through its increased focus on three factors (Liedtka, 2017): DT encourages that practitioners empathize with stakeholders and end-users in order to understand their perspectives which inform the development of impactful solutions; include and work directly with a broad range of stakeholders in the solution creation process; and use a wide range of activity-based tools that support the generation of the knowledge needed to develop technologically feasible and desirable solutions to the problem at hand. Gruber, et al. (2015) define DT as a "human-centered approach to innovation that puts the observation and discovery of often highly nuanced, even tacit, human needs right at the forefront of the innovation process." These descriptions evolved from earlier conceptualizations of DT as a problem-solving methodology that emphasizes empathy, a focus on users, team collaboration, and recursive thinking (Brown, 2008; Liedtka, 2014).

DT uncovers customers' unexpressed needs by giving practitioners a set of varied tools that focuses their attention on their customers' whole human-ness—their emotions, ambitions, perceptions, and actions rather than solely on their articulated desires (Norman, 2013). While focusing on customers' explicit desires may elicit the early adoption of those targeted solutions, DT helps uncover new and innovative solutions that are both economically viable and practical for both practitioners and end-users, and not obvious at the outset of the solution-creation process (Brown, 2008).

DT's core objective is to provide a framework for practitioners to acquire new information about users' needs, analyze that information and transform it into actionable goals, and test the utility of those goals. DT's phases encourage practitioners to work through a number of iterative activities generally understood to 1) use empathy to discover the problem, 2) synthesize insights and hypotheses about the problem, 3) ideate solutions, 4) prototype potential solutions, and 5) test the ideal solutions. The activity-based tools at the core of DT include ethnography (Hammersley & Atkinson, 2007), mind-mapping (Buzan & Buzan, 1996), brainstorming (Osborn, 1953), rapid-prototyping (Thomke, 1998), and testing (Luchs, Griffin, & Swan, 2015).

Considering that these phases have different roles to play in problem-solving, scholars and practitioners alike can benefit from an increased understanding of the circumstances that affect the use of DT tools. Research has shown that DT is a challenging method to use thoroughly (Cross, 2004). Case studies have shown that practitioners’ implementation of DT tools varies greatly in environments where the concept has been newly introduced (Rauth, Carlgren, & Elmquist, 2014). This study indicates that these differences are also due to the nature of problems that the practitioners chose. Similar research by Seidel & Fixson (2013) looks at how the early use of DT unfolds, and finds evidence of high variance of DT tool usage across problems with a varying range of goals.

These studies indicate that differences between the topic areas of the problems that DT practitioners choose to take on influences the portfolio of tools that they choose to deploy. However, the literature focuses on specific categories of strategic problems, from new product development, to process improvement and change management. This focus fails to address how the practitioners’ chosen level of problem specificity influences their use of the DT methodology, or the extent to which they use the entire sequence of phases.

DT's association with ill-defined problems that lack concise specifications is well established. Nevertheless, many problems that organizations face are well-defined with high levels of specification. Combined with the growing urge organizations have to use DT across many types of projects, many practitioners are likely to apply the DT methodology to problems that are well-defined. Hence, it is important to compare the implications of using DT on problems that are well-defined versus ill-defined. One way to categorize problems on the spectrum of ill-defined through well-defined is through the concept of problem-specificity.

1.3.3 Problem specificity

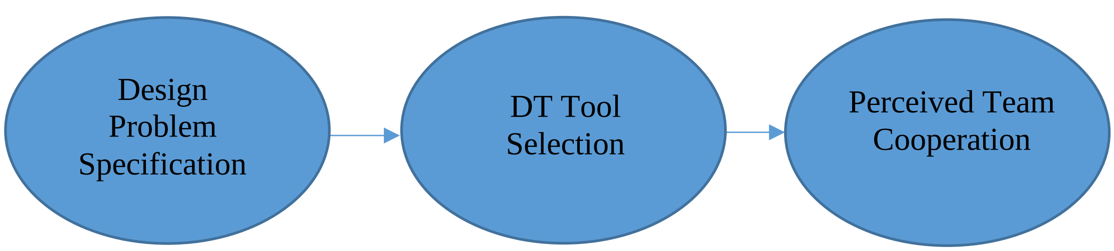
Problems that organization face and wish to overcome in many forms, and the way leaders in organizations articulate, specify, and bound these problems, influences the way these leaders and their teams solve them (Camillus, 2008; Hsieh et al., 2007; Lyles & Thomas, 1988). Dorst (2015) conceptualizes problems as having systemic borders that delineate the information that should be ignored from what is useful. Specifications establish these boundaries. The specificity within the problem plays a powerful role in determining which problems receive focus, and ultimately the degree to which the solutions address the symptoms or the source of the underlying problems (Mitroff & Featheringham, 1974; Simon, 1973; Volkema, 2009; Volkema, 1983). As DT's implementation moves beyond new product development to more strategic level problem-solving (Cooper, Junginger, & Lockwood, 2009; Liedtka, 2000), research has not maintained pace with this evolution, and investigated whether the specificity of these problems influences practitioners' use of DT tools to solve problems. Building on confirmatory search theory, this research hypothesizes that practitioners who work on problems with low levels of specificity are likely to use more DT tools, as well as the tools that encourage practitioners to search broadly for unanticipated solutions, than practitioners who work on problems with high levels of specificity.

1.3.4 Perceived team collaboration

Solving strategically important problems is rarely done in isolation, and usually teams work together to develop solutions (Amason, 1996; Bantel & Jackson, 1989). Teams require a minimum amount of cooperation and shared vision to successfully work together in the demanding environment of innovation (De Dreu & Weingart, 2003; De Dreu, 2006). However, teams working within the areas of innovation, with its associated risks of failure and communication breakdowns due to ambiguous goals, often struggle with internal conflict (De Dreu & West, 2001; Wall Jr & Callister, 1995). Teams using DT to tackle innovation problems face these hazards by default.

Although some research has proposed links between DT and team collaboration and cooperation (Cross, 2011; Liedtka, 2015), research has yet to investigate the relationship between the specific DT phases and its practitioners' subsequent perceptions of team collaboration. Given the differing functions of the DT phases, it is expected that certain phases relate positively to the practitioners perceiving team cooperation.

Figure 1.1 Model of hypothesized relationships



1.4 Contributions of this study

This research connects the design thinking and work-team management literatures through its investigation of the processes that problem-solvers use to solve complex problems. As DT continues to spread as a methodology for organizations to solve problems and innovate, it is important to isolate factors that influence practitioners and their teams' use of the tools in the method. Firstly, by using the concept of specificity to put boundaries on the range of possible solutions to targeted problems, this research illuminates which DT tools in the subsequent problem-solving steps that practitioners consider important when trying to generate novel value. Secondly, by investigating practitioners' perceptions of team collaboration, this research suggests factors that influence practitioners' ability to integrate their work teams when they engage with complex problems.

2 Design Thinking Methodology, Problem Specificity, and Perceived Team Cooperation

2.1 Design and the Design Thinking Methodology

2.1.1 DT's roots in design

Design, in its most abstract definitional form, encompasses all of the human decision processes and actions that lead to something new that natural processes have yet not created (Cross, 2001). Most scholars agree that design is the process by which people move from a *problem space* to a *solution space* by way of developing and applying an intervention in the form of an artefact (Simon, 1996). The problem space is the area where the current reality and desired expectations do not coincide, whereas the solution space is where desired expectations and reality overlap. Take, for example, a bare, vacant city lot as a problem space—a prime location that is underutilized and not adding adequate value commensurate with its potential. The solution space is the completed skyscraper that houses organizations, generates rents, and accentuates that city's urban skyline. However, designing a solution that eliminates the gap between problem spaces and solutions spaces can take many forms, and, as such, design is a broad topic that has defied succinct definitions (Jones, 1977).

The modern design literature has evolved from the "Design Methods Movement" that emerged in the 1960's and 1970's with such works by Hall (1962), Asimow (1962), and Broadbent (1973). These seminal books examine the design methods that engineers and architects apply when they design solutions. The engineering and architectural fields developed their own design method versions that reflect the type of problems that they tend to solve, and the distinctive approaches in each field for solving complex problems (Cross, 2004).

Asimow (1962) theorized about the design process in terms of activities set within stages. Stages can be set in a linear pattern as well as in a cyclical pattern. The sequential process steps are in the *morphological dimension*, and the iterative and reflective activities are in the *problem-solving dimension*. Lawson (1979) conducted research comparing the problem-solving and design strategies that architects and scientists used. The findings from this research highlighted that the scientists' approach tended to focus on rigorously applying sequential process steps of the scientific method to identify systematic rules that would help isolate the ideal solution. Contrastingly, the architects tended to start exploring potential solutions iteratively until they found one that would "satisfice" (Simon, 1972).

The "try it and see" approach that the architects used can produce solutions that are satisfactory enough to bridge the gap between the problem and solution spaces. However, they likely fall short of the optimal solutions, especially where the optimal solution requires high levels of search beyond one that satisfices. The satisficing approach is consistent with March's (1976) observation that design relies on abductive reasoning to create novelty, while science investigates what already exists. Abductive reasoning—a central tenet of design (Dunne & Martin, 2006b; Kolko, 2010)—is a reasoning method (akin to induction and deduction) that serves as the source of new hypotheses through creative and generative thought spurred by observation and pattern finding (Peirce, 1974). Abduction is the mechanism by which creators make novel inferences from incomplete data, or data that contravenes expectations that arise from either induction and deduction. These novel inferences are wholly new. DT encourages practitioners to develop hypotheses using abductive logic through the methodology's synthetic activities—activities that require practitioners to process and reflect on knowledge and experiences salient to the problem and solution spaces (Kolko, 2010). Design activities focus on cognitive activities that help generate more information in order to achieve the milestones of problem-solving (Hubka & Eder, 2012). Examples include: developing finely structured problem descriptions; synthesizing information; searching for solutions; and evaluating solutions. These activities are sequential, yet allow for iteration if a stage's activities produce unsatisfactory knowledge or results.

Each of these activities can be deconstructed into smaller steps, though these sub-steps are not harmonized across the field of design. The DT methodology builds on the tenets of design, and is a process based on many of design’s most important features (Carlgren, Rauth, & Elmquist, 2016). The following section describes DT, and compares some of the most popular permutations.

2.1.2 Design Thinking methodology

Like design, DT has a plethora of definitions, and its evolution continues to defy falling under a succinct umbrella as presaged by Buchanan’s (1992, p. 5) sentiment that:

> *No single definition of design, or branches of professionalized practice such as industrial or graphic design, adequately covers the diversity of ideas and methods gathered together under the label. Indeed, the variety of research reported in conference papers, journal articles, and books suggests that design continues to expand in its meanings and connections, revealing unexpected dimensions in practice as well as understanding. This follows the trend of design thinking in the twentieth century, for we have seen design grow from a trade activity to a segmented profession to afield for technical research and to what now should be recognized as a new liberal art of technological culture.*

Tim Brown, the founder of IDEO and famed for popularizing DT’s use in businesses, and other organizations not usually associated with design practices, has described DT methodology as “a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business can convert into customer value and market opportunity" (Brown, 2009). Similarly, Plattner, Meinel, & Weinberg (2009, p. xiv) contend that:

> *[DT's] human-centric methodology integrates expertise from design, social sciences, engineering, and business. It blends an end-user focus with multidisciplinary collaboration and iterative improvement to produce innovative products, systems, and services. Design thinking creates a vibrant interactive environment that promotes learning through rapid conceptual prototyping.*

While many scholars debate the precise nature of DT, they tend to agree that DT is a problem-solving methodology that allows designers to maintain their focus on end-users, and generate new knowledge that leads to novel solutions (Patnaik, 2009).

2.1.2.1 Design Thinking mechanisms

DT's foundational characteristics support practitioners' ability to contribute to a spectrum of positive qualities at the project and organizational levels (Elsbach & Stigliani, 2018). These qualities, as outlined in a literature review by Elsbach and Stigliani (2018), include focus on user-centricity, openness to ambiguity and risk-taking, interdisciplinary team collaboration, and increased creativity. Management and design studies referenced below associate these qualities with increased organizational and project performance.

User-centricity produces positive outcomes to organizations through focusing attention on customers' needs, which increases the probability that organizations will produce new products that customers want and readily adopt; limits the need for product redesign due to lack of customer interest; and increases the likelihood of developing products that provide maximal user utility (Kurtmollaiev, Pedersen, Fjuk, & Kvale, 2018; Veryzer & Borja de Mozota, 2005). Several recent studies suggest that DT fosters user-centricity, and the subsequent positive effects on organizations (Bailey, 2012; Beverland, Wilner, & Micheli, 2015; Bjögvinsson, Ehn, & Hillgren, 2012; Dijksterhuis & Silvius, 2017; Rau, Zbiek, & Jonas, 2017; Venkatesh, Digerfeldt-Månsson, Brunel, & Chen, 2012; Ward, Runcie, & Morris, 2009; Wilkinson & De Angeli, 2014).

Openness to ambiguity and risk-taking are cognitive characteristics of individuals and teams that lead to the development of new products and exploring opportunities for further development (Büschgens, Bausch, & Balkin, 2013; Chandy & Tellis, 1998). Firms including Google, Apple, and IBM aggressively foster these characteristics in their management. The studies by Büschgens, et al. (2013), and by Chandy and Tellis (1998) conclude that openness to ambiguity fosters the freedom to experiment with untested ideas, generate new knowledge, and develop opportunities. Several further studies have tested the concept that the DT methodology advances the positive effects associated with risk-taking in the course of problem-solving (Ben Mahmoud-Jouini, Midler, & Silberzahn, 2016; Fixson & Rao, 2014; Gornick, 2008; Liedtka, 2011; Sutton & Hargadon, 1996).

Studies have shown that interdisciplinary teams increase projects' technical quality, speed to completion, and budget efficiency due in large part to the members' diverse networks, and knowledge resources that they contribute to project progression (Edmondson & Nembhard, 2009; Keller, 2001). Further research concluded that interdisciplinary teams working with ad hoc operation and collaboration procedures tend to experience more inefficiencies (e.g. reduced creativity and slower decision-making cycles) compared to those working within established procedures (West, 2002). These findings provide a foundation for subsequent research investigating DT's proclivity to foster interdisciplinary team collaboration (Carlgren, Rauth, & Elmquist, 2016b; Dalton & Kahute, 2016; Kolko, 2015; Kumar, Lodha, Mahalingam, Prasad, & Sahasranaman, 2016; Liedtka, 2011; Liedtka, 2014; Liedtka, 2017; Mintrom & Luetjens, 2016; Olsen, 2015; Seidel & Fixson, 2013).

Finally, creativity, in the form of novel idea generation and problem-solving, is a source of competitive advantage (Somech & Drach-Zahavy, 2013; West, 2002; Zhou & Shalley, 2003). Recent studies show that DT methodology fosters creativity through its systematic combination of activity-based tools that help practitioners access the knowledge and engagement of stakeholders involved in the process (De Mozota & Kim, 2009; Filson & Lewis, 2000; Goffin & Micheli, 2010; Ignatius, 2015; Kurtmollaiev, Pedersen, Fjuk, & Kvale, 2018b; Rauth, Köppen, Jobst, & Meinel, 2010; Wattanasupachoke, 2012).

2.1.2.2 Design Thinking versus other methodologies

This methodology differs from traditional rational-analytical problem-solving perspectives (Kepner & Tregoe, 1965; Newell & Simon, 1972) often espoused as the fundamental method for decision-making in business (Hitt & Tyler, 1991). However, this rational-analytical perspective has proven less successful at supporting the exploratory learning and divergent thinking that are valuable for creating sustainable competitive advantages through affective and experiential analysis (Behling & Eckel, 1991; March, 1991). DT's unique approach enables practitioners to develop new value through its focus on advancing practitioners' learning and divergence from status quo options

(Beckman & Barry, 2007). The DT methodology incorporates activities designed to repeatedly engage multiple people involved with problem-solving and is a team-oriented, reflexive activity (Plattner, Meinel, & Leifer, 2012; West, 2000). Stakeholders provide information that elaborates the problem's context within the broader environment. The design team can then share that information and build up collective models of solutions (Van Knippenberg, De Dreu, & Homan, 2004) through reflexive activities. These are activities that focus team members' attention on their objectives, and towards adapting those objectives to dynamic circumstances. These reflexive activities allow practitioners to focus on end-users' needs as they become known, as well as increase tolerance for ambiguity, team and stakeholder collaboration, and creativity (Elsbach & Stigliani, 2018).

These factors contribute to positive organizational and project outcomes through a number of mechanisms. User-centricity is associated with intensely understanding the needs of customers in order to develop products and services that are readily adopted by customers, and that limit the development of products with lower-than-expected demand (Seidel & Fixson, 2013). Tolerance of ambiguity, a trait normally associated with individuals, can emerge as an attribute of organizational culture, and encourages boundary spanning that aids discovering opportunities obscured by environmental uncertainty, or indeterminate factors (Dollinger, 1984). Collaboration can accelerate task completion rates and is crucial for access to diverse knowledge (Edmondson & Nembhard, 2009). Creativity is also crucial for organizations to overcome obstacles and generate novel, sustainable value propositions (Amabile, Conti, Coon, Lazenby, & Herron, 1996; George & Zhou, 2002).

DT, as a process, is not unique in its ability to facilitate the development of new knowledge and solutions to complex problems. Other well-developed process concepts exist in the management literature that support decision-making in complex and uncertain environments. For example, effectuation (Read, Sarasvathy, Dew, & Wiltbank, 2016; Sarasvathy, 2001) is a tools-based concept that has gained acceptance in the entrepreneurship literature. Recently, the Lean Startup methodology has helped entrepreneurs and innovative managers with decision-making in new ventures (Ries, 2011). Total Quality Management offers another integrated set of practices that support practitioners' capabilities to solve organizational problems and inefficiencies (Deming, 1986; Powell, 1995). Each of these management innovations (Birkinshaw, Hamel, & Mol, 2008) seeks to further organizational goals, although they do prioritize different goals in the process of making decisions that support managers' ability to solve the organizations' problems, and ensure sustainable operations.

These methods, like DT, have their unique philosophical foundations that instill certain mindsets, and nudge the direction of practitioners' decisions. Effectuation encourages its practitioners to rely as much as possible on resources that are readily available rather than overextend resources that incur excessive costs (Sarasvathy, 2001). The Lean Startup method supports the building of continuous feedback loops with customers in order to avoid the often venture-destroying costs of creating products with minimal demand or with unsustainable costs (Ries, 2011). Total Quality Management takes a comprehensive view of operational procedures in organizations and supports its practitioners in the decision process of how to cull inefficient and unnecessary costs (Powell, 1995). These management innovations encourage their practitioners to prioritize certain decisions through their portfolios of activities with proscriptive and prescriptive rules. DT's approach to decision-making diverges from these other options due, in part, to the magnitude of its focus on creatively, and pragmatically incorporating stakeholder feedback throughout the process while prioritizing end-user needs. This factor makes DT a useful methodology to study in the context of problems with low levels of specificity and within teams with varying levels of cooperation.

Table 2.1 Common problem-solving methodologies.

	Design Thinking (Carlgren et al., 2016a)	Effectuation (Sarasvathy, 2001)	Lean Startup (Ries, 2011)	Agile (Cockburn & Highsmith, 2001)	TQM (Powell, 1995; Samson & Terziovski, 1999)
Goal	Creative problem solving	New venture creation	New venture creation	Innovative software	Business process efficiency
Scope, focus	General innovations	Innovations for startups	Innovations for startups	Accelerate and improve software development	Eliminate inefficiency in business operations
Uncertainty	High levels of uncertainty	High levels of uncertainty	Unclear levels of uncertainty	Low levels of uncertainty	Low levels of uncertainty
Insight generation	Abductive	Leverage resources	Hypothesis driven	React and adapt	Predictive analysis
Testing	Deliberate hypothesis generation and experimentation	Purposeful experimentation	Purposeful experimentation	Quick tests	Comprehensive throughout process
Iteration	Yes	Yes	Yes	Yes	Limited
Ideation	Crucial cross-functional process	Embedded throughout each phase	Ideation precedes lean startup processes. Lean startup builds existing visions	Ideate process refinements across all team members	Knowledge sharing across management levels
Quantitative methods	Minor focus	Minor focus	Strong focus for testing hypotheses	Strong focus	Strong focus
Qualitative methods	Strong focus	Strong focus	Minor focus	Minor focus	Minor focus
Typical methods and tools	Ethnographic interviews, pattern finding, hypothesis development, brainstorming, synthesis, prototyping	Improvisation, entrepreneurial ask, reciprocity with stakeholders	Need mapping, business model Canvas, innovative accounting, A/B testing, prototyping, and funnel metrics	Affinity mapping, historical data analytics, collaborative design, customer journey maps, prototype testing	Run charts, control charts, Pareto diagrams, brainstorming, stratification, tree diagrams, histograms, scatter diagrams, force-field analysis
Target audience	End-users and associated stakeholders	Customers that advance profitability	Customers that advance profitability	End-users via collaboration among developers	Internal operations teams

Source: Müller & Thoring, 2012 and author's contributions (Müller & Thoring, (2012) established the categories and descriptions for Lean Startup, and DT attributes. The author compiled attributes for Effectuation, Agile, and TQM attributes)

2.1.2.3 Design Thinking phases

DT is also a management innovation with a set of practices rooted in its own philosophical foundation. While some of the individual practices of DT might be similar to those in the methods above (e.g. qualitative interviews and rapid prototyping), the basic attributes of successful DT process centers on synthesis, future-focus, hypotheses, and opportunism (Liedtka & Mintzberg, 2006). It involves observation, the use of frameworks, and prototyping (Brown, 2009). A recent definition of DT defines it as a methodology of applying a portfolio of activities that approximate the process that designers utilize to refine and solve problems (Dorst, 2011). Design thinking experts largely agree that the process includes two main phases: the *problem* phase and the *solution* phase (Buchanan, 1992; Simon, 1996).

The problem phase focuses on designers understanding the system in which the problem exists, and is known at the *problem space* (Simon, 1996). The designers analyze the problem space, and develop specifications for the problem during the problem definition phase. Subsequently, designers then synthesize the information gathered about the diverse elements that exist within the problem space. The designers then carefully balance these elements in the form of a viable solution during the solution phase. Solutions exist in the *solution space* (Simon, 1996).

Following Buchanan (1992), Dunne & Martin (2006), and Brown (2009), the methodology has a number of elements that address the problem and solution spaces. First, the methodology starts with the designers collecting information about the problem and its context in order to build a holistic understanding of the problem and the system in which it sits. Next, the designers synthesize the collected information in order to generate hypotheses about the problem, and develop the boundaries of the problem that constrain the range of possible solutions. These two phases focus on the problem space while the subsequent steps move the focus to the solution space. The following phase requires the refinement of ideas that aim towards a range of viable solutions that fit within the established boundaries. The penultimate phase places emphasis on prototyping possible solutions in order to refine viable options that can effectively solve the problem. Finally, designers test their hypotheses about the problem by actively implementing their solutions in the problem-space, and observing whether the outcomes confirm, or disconfirm the hypotheses generated in the earlier phases.

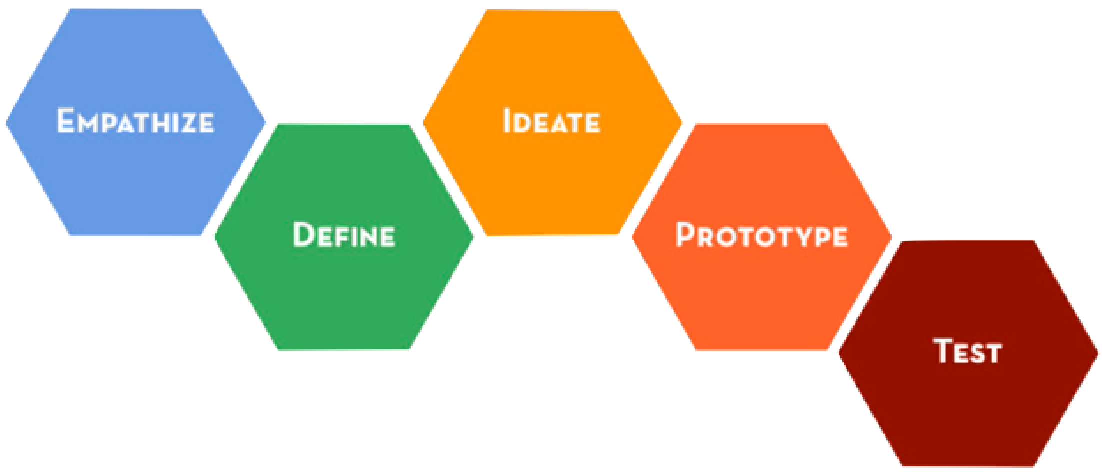
Different models of Design Thinking

There are several popular models that practitioners reference which include the models from the Hasso Plattner Institute of Design at Stanford University, also known as the Stanford d.School, the design consultancy IDEO, and Designing for Growth (Ogilvie & Liedtka, 2011). This study relies on the Designing for Growth model due to its recency and utility with problems of varying types and levels of specificity. The authors of this version of DT designed the methodology for managers who wish to solve pressing business problems and not only new products—as some methodologies do. The authors relied on extensive research of existing methodologies and consultations with leading experts in the field. These factors make the Designing for Growth model an ideal candidate for this study. The description and comparison in the following sections confirms that this model is appropriate for this study.

Stanford d.School model of Design Thinking

The Stanford d.School's model is often taught to interdisciplinary students at Stanford University, and shared widely in both educational and organizational settings (Lindberg, Meinel, & Wagner, 2011). The d.School offers extensive tutorials online for helping students and aspiring practitioners learn this version of the design thinking methodology. The d.School model has fives phases as represented below figure 2.1.

Figure 2.1 Stanford d.School design thinking phases

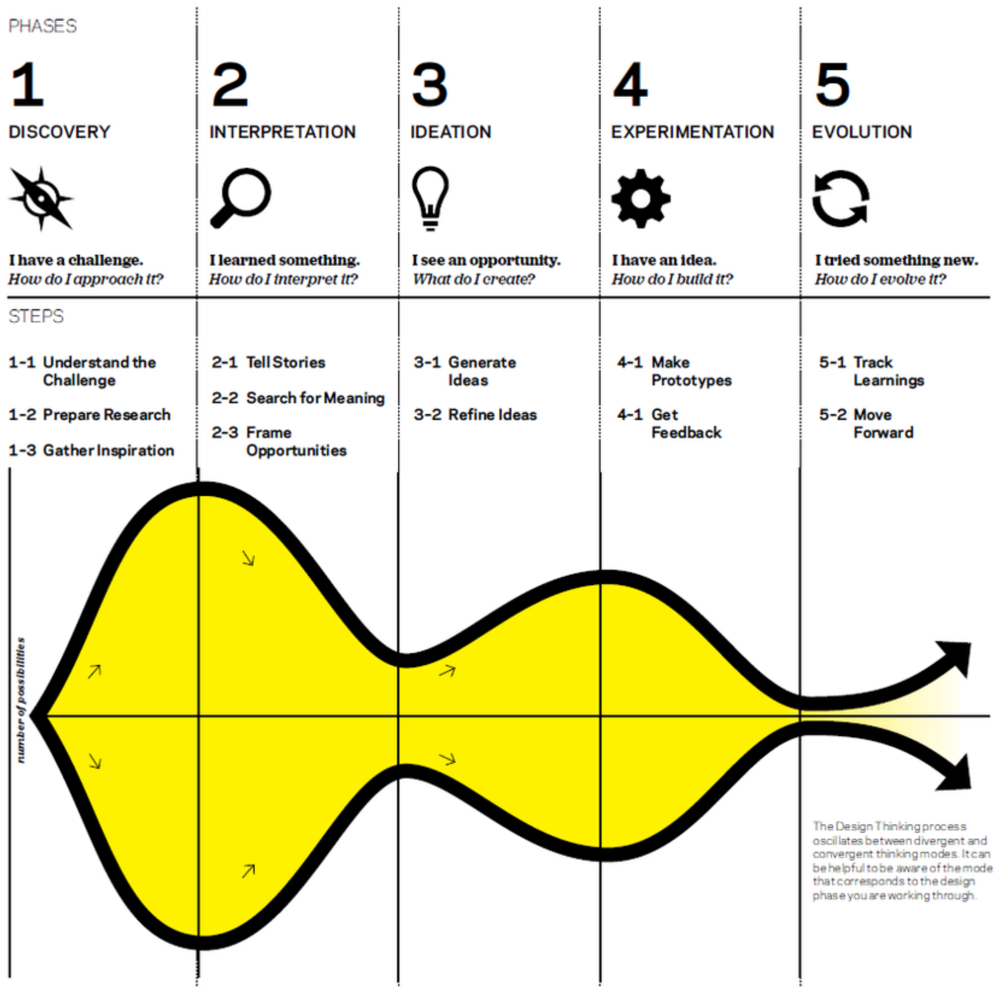


Source: https://dschool-old.stanford.edu/groups/k12/wiki/17cff/images/5af04.png#1346x454

IDEO Model of Design Thinking

The IDEO version shares similarities with the d.School and highlights comparable attributes of the DT process (KELLEY, 2001). IDEO refined and synthesized its professional model into a version that is often taught to grade school and college students. Figure 2.2 below shows how this design firm depicts its version of DT in five phases.

Figure 2.2 IDEO Design Thinking model



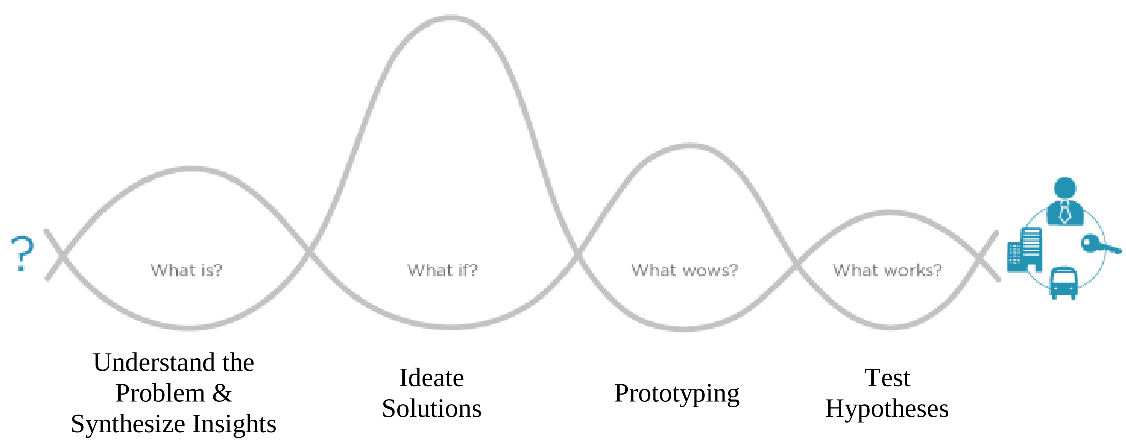
Design Thinking for Educators (IDEO & Riverdale, 2012)

Source: https://designthinkingforeducators.com/toolkit/

Designing for Growth Model of Design Thinking

A contemporary version of the DT methodology, articulated by Ogilvie and Liedtka in “Designing for Growth” (2011), is a synthesis and interpretation of the activities that are found other commonly accepted DT models. This model includes specific tools organized into the phases consistent with the d.School and IDEO models shown above, with additional attention to articulating assumptions, specifying explicit design criteria, and designing and conducting marketplace experiments. The authors equate the five phases of DT to questions in this version.

Figure 2.3 Ogilvie and Liedtka (2011) Design Thinking Model



Comparing these models' phases indicates that while the models approach the DT methodology similarly, they differ in terminology, as shown below in Table 2.1

Table 2.1 Stanford d.School, IDEO, Designing for Growth model comparison

DT Phases	d.School	IDEO	Designing for Growth
Understand the Problem	Empathize	Discovery	What is?
Synthesize Insights	Define	Interpretation	What is?
Ideate Solutions	Ideate	Ideation	What if?
Prototype Solutions	Prototype	Experiment	What wows?
Test Assumptions	Test	Evolution	What works?

The IDEO and Designing for Growth models highlight how each phase either expands or contracts the number of possibilities available, as represented by the undulating line chart moving from left to right. Earlier phases broaden the possibilities available while subsequent phases synthesize and focus attention on the possibilities with the most promise. While not graphically represented above, the Stanford d.School model also encourages the expansion and contraction of possibilities as practitioners move through the subsequent phases. All models present a stepwise process that encourages returning to previous steps as new information becomes available, and include a number of activity-based tools to support practitioners in their achievement of the phases' goals.

2.1.3 Design Thinking activity-based tools

DT uses a set of activity-based tools to help practitioners meet the key objectives of the aforementioned phases which are: understand the problem and its context; synthesize insights from newly acquired information; ideate possible solutions that build on the insights; and prototype those solutions: and test idealized solution and its associated assumptions (Brown, 2009). The methodology allows for designers to recursively visit activities as their knowledge about the problem and solution spaces increases (Brown, 2009). DT's activity-based tools serve as structured guides for generating and processing new knowledge (Goldschmidt & Rodgers, 2013), sensemaking (Klein, Moon, & Hoffman, 2006; Kolko, 2010), and ultimately creating new alternatives with that knowledge (Simon, 1996).

The specific tasks and activities as conceptualized by Ogilvie and Liedtka (2011) and (Liedtka, Ogilvie, & Brozenske, 2014) are as follows.

Understand the Problem (What is?)

- Direct Observation
- Ethnographic Interviews
- Journey Mapping
- Job to be Done

Synthesize Insights (What is?)

- Personas
- Gallery Walk
- Mind Mapping
- Design Criteria

Ideate Solutions (What if?)

- Brainstorming
- Concept Cluster
- Forced Connection

Prototype Solutions (What wows?)

- Identifying Assumptions
- Prototyping
- Storytelling

Test Hypotheses (What works?)

- Co-creation
- Learning Launch Experiments

Detailed explanations of these tools are in Appendix 6.1. These sixteen tools focus practitioners' thinking processes throughout the problem-solving process. They help practitioners collect a wide array of pertinent data, facilitate their ability to articulate ideas within their own minds, communicate reciprocally with their stakeholders, and overcome biases that can obscure useful knowledge (Liedtka, 2015; Tschimmel, 2012). This portfolio of tools provides activities that encourage practitioners to search for information and knowledge that may disconfirm their expectations (Liedtka, 2015; Shepherd et al., 2012). The "Understand the Problem" has five tools that aid in collecting data about the problem-space from stakeholders. These activities encourage practitioners to uncover the nuances of the people and systems involved in the problem space. These tools help uncover the experiences and expectations of the stakeholders. These tools prioritize the acquisition of new knowledge about the problem space and the perspectives of the stakeholders involved. The "Synthesize Insights" phase has three tools that focus on finding patterns within the newly created data set. These tools help practitioners understand elements in the problem space that drive stakeholders' expectations and experiences. These tools encourage carefully converting the data into useful patterns, and extrapolating the foundation of new solution-oriented ideas. The three tools in the "Ideate Solutions" focus practitioners on marrying the newly discovered patterns with ideas that can convert the growing knowledgebase into solutions that meet the expectations of the stakeholders. These tools are useful in expanding practitioners' creativity. The five tools in the ‘Test Hypotheses” phase aids in the process of applying the new knowledge to refine the quality of potential solutions, and assess their sustainable viability through working with stakeholders.

Taken together, the sixteen tools provide practitioners with a structure to collect information, analyze that information, extrapolate possible solutions from that information, and test the quality of those solutions. In essences, these DT tools guide practitioners through a series of activities that helps them with knowledge acquisition, conversion, and application (Gold, Malhotra, & Segars, 2001).

2.1.4 Knowledge Acquisition, Sharing, and Application

The effectiveness of DT is higher when used within teams versus using it in solitude (Sonalkar, Mabogunje, Pai, Krishnan, & Roth, 2016). Teams offer their members the benefit of multiple perspectives because members have different perspectives of their environments which are rooted in their personal repertoires, and assumptions of their environment (Boland & Tenkasi, 1995; Brown & Duguid, 2000). Assumptions about stakeholders’ perspectives drive individuals to use heuristics to expedite decisions based on their assumptions about what stakeholders are thinking (Tversky & Kahneman, 1974). The reliance on these heuristics can lead to errors in judgement due to a lack of shared knowledge.

In order for the team to take advantage of their multiple perspectives, team members need to make their perspectives and supporting foundations explicit. As described by Pyrko, Dörfler, & Eden (2016), sharing perspectives is a team activity that hinges on team members collectively engaging problem spaces combined with their inclination to share and debate their personal knowledge about that space. Failure to share the knowledge and understand team members' perspectives has been associated with the failure of product development projects (Purser, Pasmore, & Tenkasi, 1992). The DT process encourages the teams to share their diverse information and perspectives, then simplify and push those perspectives towards cohesive and specified structures useful for problem-solving (Kolko, 2007). Specifically, the DT process focuses on these activities after the knowledge acquisition phase—during the knowledge sharing phase. Knowledge that is not equally distributed across the teams is shared primarily during the "Synthesize Insights" and "Ideate Solutions" phases. The tools in these phases encourage practitioners to make ideas explicit, share them, and discuss their utility in context of the problem and solution spaces.

2.1.4.1 Reflexivity

Designers and their teams engage in specific DT activities that encourage reflexivity (Seidel & Fixson, 2013). Reflexivity is the team-oriented activity where the group members analyze, question and digest past events and new knowledge, reflect on objectives, and adapt the decisions to dynamic environmental circumstances (West, 1996). Team reflexivity is defined as "the extent to which group members overtly reflect upon, and communicate about the group's objectives, strategies, and processes, and adapt them to current or anticipated circumstances" (West, Garrod, & Carletta, 1997) p. 296). Team reflexivity centers on open-minded dialog within one's group that fosters sensemaking of what has already been observed (Easterby-Smith & Malina, 1999; Hoegl & Parboteeah, 2006). The DT activities that encourage reflexivity occur throughout the DT methodology. However, there are varying degrees of focus on reflexivity across the portfolio of DT phases and their associated tools. Some phases focus practitioners' attention on gathering new information, while other phases focus on working with that information in an explicitly reflexive manner to gain new insights.

The phases at the beginning and end of the DT process—"Understand the Problem," "Prototype Solutions," and "Test Hypotheses"—focus on gathering information from stakeholders about the problem and solution spaces. Tools in the "Understand the Problem" phases demand a limited degree of reflexivity. For example, Ethnographic Interviews and Job to be Done phases encourage practitioners to adapt reflexively to the information they recently received to better direct their and gather pertinent new information from stakeholders. Tools used toward the end of the DT process are also similar in their use of reflexivity. The activities in "Prototype Solutions" rely on knowledge gained in earlier phases to create physical manifestations of solutions to the problem. Prototyping is reflexive in that it requires practitioners to use the knowledge gained so far in the process and translate that into a proof-of-concept with which stakeholders can interact. The main goals of the phase are to gain knew information in the form of tests of the solution's practicality in the physical world and feedback from stakeholders. The final phase, "Test Hypotheses" also prioritizes gathering information from stakeholders while relying to a limited degree on reflexivity to create a minimum viable concept that stakeholders can use to solve their problems.

Reflexivity happens more consistently in the middle phases of the DT methodology. The tools in the "Synthesize Insights" and "Ideate Solutions" phases. The activities in these two phases foster reflexivity through their focus on encouraging design teams to share and assess the diverse information gathered about the problem space (Schippers, West, & Dawson, 2015; West, 1996). In terms of DT activities, Gallery

Walk, Mind Mapping, Brainstorming, Concept Clustering, and Forced Connections all require that practitioners and their teams look back over the information that they have collected, and refine their insights in order to further develop a vision of an acceptable portfolio of testable solutions. These phases focus on working with the information that already exists in order gain obscured insights. This process of looking back and refining insights, is a hallmark of reflexivity, and is consistent with findings by Seidel and Fixson (2013).

2.1.4.2 Creative Abrasion

Creative abrasion is also a reflexive mechanism for sharing and generating new knowledge (Leonard & Sensiper, 1998; Leonard-Barton, 1995). Creative abrasion is the phenomenon where interpersonal debate around differing ideas stimulates the generation of novel ideas. Giving voice to the different perspectives that team members offer, and carefully managing the potential conflict and power dynamics constructively in the service of sharing new knowledge, can generate novel insights (Contu, 2014; Leonard & Straus, 1997). Many of the DT tools encourage creative abrasion (Dunne & Martin, 2006; Lockwood, 2009). According to the activity descriptions above in section 2.1.3 and Appendix section 6.1, creative abrasion happens among the designers and their teams in each of the DT activities in the Synthesize Insights and Ideate Solutions phases where open sharing, debate, and idea generation are crucial objectives.

2.1.4.3 Tools for addressing problems

DT practitioners strive to move from problem spaces to solution spaces that contain viable solutions that stakeholders will value. The DT methodology and its activity-based tools increase the probability that practitioners can generate a diverse set of high-quality possible solutions, and refine them into a viable solution (Kolko, 2015). Recent research (Martelaro, Ganguly, Steinert, & Jung, 2015) found that practitioners' use of DT tools positively influences their focus on generating novel solutions when they worked on a problem-oriented project versus a project looking for a concrete solution to a specific problem. Sharing information about a problem space that is initially less well-understood, collectively making sense of that information, and developing cohesive knowledge about that problem space, helps identify the applicable specifications of both the problem space as well as the solution space.

Considering that these tools support the generation of new information and synthesize it into new knowledge, it is important to understand the magnitude of the problem at hand. The breadth of the problem space that practitioners choose to engage affects the amount of knowledge that practitioners must acquire, share, and apply. As problem spaces grows, so too does practitioners' need for tools that help them focus on acquiring pertinent knowledge. Therefore, it is important to understand problems in terms of their breadth, also known as problem specificity.

2.2 Problem Specificity

Problems, according to March & Simon (1958) emerge when managers realize that their organizations are not using resources optimally. Problems and their formulation are a well-established activity for organizations' strategic planning (Baer, Dirks, & Nickerson, 2013; Quinn, 1980). Research suggests that identifying instances where performance fails to meet aspirations stimulates organizational action to solve the problem (Miller & Ireland, 2005). Determining how to describe a problem greatly influences which problem receives attention, and subsequently, the solutions' ability to ameliorate the symptoms of the problem (Churchman, 1971; Volkema, 1983). Management scholars have also shown that the formulation of problems impacts managerial behavior and organizational outcomes (Lyles & Mitroff, 1980; Weick, 1995). These attributes of problems make them an important subject to study in terms of organizations' ability to sustain themselves in dynamic environments.

Agre (1982) defines problems as situations that are undesirable yet solvable while Pounds (1965) describes problems as "a difference between some existing situation and some desired situation." Baer, et al. (2013) define a problem as "a deviation from a desired set of specific or a range of acceptable conditions resulting in a symptom or a web of symptoms recognized as needing to be addressed." Dewey (1958) explains that problems exist in the form of tension between desired expectations and reality. These undesirable situations require translation into common language in a process known in the problem-solving literature as problem formulation (Volkema, 1983a; Von Hippel & Von Krogh, 2015). Formulation requires a priori specification of the problem space which subsequently sets boundaries around the solution space (Le Masson, Weil, & Hatchuel, 2010), and subsequently limits the range of the possible solutions uncovered in the design process (Schön, 1983).

Problems, as abstractions, are subject to multiple interpretations, misinterpretation, and exist on a spectrum between well-defined and ill-defined (Reitman, 1964b; Simon, 1973). Well-defined problems implicitly direct problem-solvers toward a limited range of solutions, while ill-defined problems contain solutions over a comparatively wider range of options (Newell & Simon, 1972; Simon, 1973). The current problem literature has not come to a consensus for a clear classification of ill-versus well-defined problems. There is consensus that problems that do not delineate clear right or wrong outcomes have the hallmark characteristics of ill-defined problems (Rittel & Webber, 1973). Primary attributes of well-defined problems include goal states that can be represented a priori, and clear criteria to test the efficacy of solutions. Ill-defined problems, on the other hand, include a higher level of uncertainty and unpredictability characterized by a lack of concise goal states, and criteria for successful outcomes are unclear. These unclear measures of success can often arise from ill-defined problems' likelihood to include many stakeholders with values and expectations with not much overlap (Mason & Mitroff, 1973). Formulating a problem with ill- or well-defined parameters significantly affects how the problem-solvers search for solutions (Choo, 2014; Nickerson & Zenger, 2004). Poorly formulated problems can lead to Errors of the First Kind (accepting an incorrect solution for a problem) and Second Kind (rejecting an acceptable solution to a problem). Careful formulation is also crucial for practitioners to avoid solving the wrong or suboptimal problems also known as Errors of the Third Kind (Volkema, 2010).

Problem specifications are boundaries placed onto the problem space in order to mitigate the risks of uncertainty during the subsequent process of problem-solving (Hendry, 2002). Specifications move problems from the range of ill-defined to well-defined, and play an important role in problem formulation and subsequent problem-solving activities. As specifications within problems increase, the range of solutions decreases (Cartwright, 1973). Locke and Latham (1990) address this concept of specificity as *domain restriction* in their corollary work on goals. Highly specified problems include clear vectors between the goals of the problem-solving initiatives and the solutions (Rijsdijk & van den Ende, 2011; Salomo & Mensel, 2001). These vectors imply that the manager formulating the problem already possesses a high understanding of the underlying causes of the problems' existence. Ultimately, highly specified problems tightly define the solution space and imply highly predictable solutions.

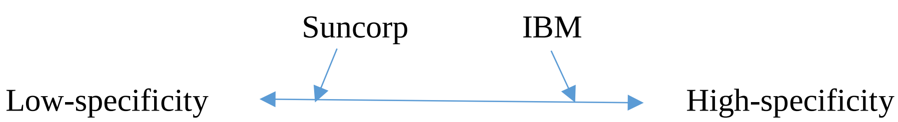
2.2.1 Problem Specificity – example stories IBM / Suncorp

As individuals and organizations discover DT's utility, they are expanding their use of DT to a wide breadth of organizational problems (Dorst, 2011). For example, (Liedtka, King, & Bennett, 2013) describe how two organizations in separate industries used DT to solve two different problems. In the first example, IBM used DT to revamp its customer engagement strategy at large trade shows. The IBM team observed customer interactions at regular conference stands; they developed insights that helped them substantially redesign their stand design, flow, and how IBM ambassadors built a rapport with visitors. The second example explains how the bank, Suncorp, used DT to merge two culturally different businesses into one operationally consistent business. In this case, multiple teams were cooperating in understanding the breadth of challenges that different divisions and locations faced during the initial phases of the merger. Through many iterations of understanding the environment and hypothesizing solutions, the two organizations converged on a new culture that fit the old cultures.

2.2.2 Problems with low and high specificity

In both examples, practitioners' use of DT tools salient to the targeted problems helped generate novel value that was not readily apparent at the outset of the problem-solving process. Both of these examples started with problems with varying degrees of specificity: IBM – How to design a large event strategy to improve customer engagement? Suncorp – How to integrate two separate work cultures? These problems sit on a spectrum:

Figure 2.4: Problem specificity spectrum



The problem the designers choose to tackle in the IBM example sits closer to the well-defined end of the spectrum than the Suncorp example. This is because the problem space for IBM—conference events—is relatively contained versus Suncorps' space of merging two entire businesses. Moreover, the specifications of the desired outcomes for the two projects diverge on the specificity spectrum as well. The need for IBM to increases customer engagement at conference events, while not necessarily a simple task, is a goal set within a tighter operational venue versus Suncorps' requirement to instill cultural unity across all divisions in two companies.

2.2.3 Problem Specificity – map analogy

To better understand the variance between lowly-specified and highly-specified problems, consider the analogy of problems in terms of a map of the world where every location on the map represents a possible solution. In this analogy, a problem's level of specificity is akin to the problem that includes map coordinates defining an area on the map where the problem-solver can find the solution (Fleming & Sorenson, 2004). A problem with low specifications includes coordinates that cover an entire continent. (e.g. The solution is somewhere in Australia.) A moderately well-defined problem includes coordinates that targets a particular city. (The solution is in Sydney.) And a truly highly specified problem directs the solver to a specific address. (The solution is at 23/45 Clarence St, Sydney NSW 2000, Australia.)

The value of a solution for a problem with low specifications implies that solutions at the continent level depend on the underlying assumptions that the practitioner has embedded within the problem. Would a solution anywhere within that continent be as useful as any other, or does that problem benefit from targeting a solution at the city or even block level? Researchers at the Rand Corporation have a complementary analogy for problems with high and low levels of specificity (Treverton & Gabbard, 2008). They suggest that broader problems, where the information and knowledge to generate viable solutions does not yet exist, are a mystery. The onus on the problem-solver is to discover information and generate novel knowledge that lays the foundations for successful solutions. Puzzles are at the other end of the specificity spectrum. Puzzles are where the information and knowledge already exist, and the problem-solvers must simply acquire that knowledge, and use it to stitch the pieces together into a cohesive solution.

A tangible example of a problem in a business setting with low specifications, is the case where profits at the fictional company, Tharsis, are falling quarter after quarter. Solutions for declining profits include coordinates across the map. The company could seek to reduce the cost of goods sold, raise prices, and diversify products into higher margin segments, etc. The list includes many options that are at the continent level using the map analogy. An example problem with high specificity at Tharsis could be that cost of goods increases have directly reduced profits. That problem implies that solutions are in the supply chain – a city level solution analogically speaking. A problem with higher specifications could target links within the supply chain—profits have declined in sync with Tharsis' supplier's five percent increase on the price on product Z. The solution implied in the problem points problem-solvers to a specific block on the map of potential solutions price—conduct price negotiations for product Z with the supplier, or pass the price onto customers.

Assumptions that imply specifications of problems are often taken for granted or never articulated (Shrivastava & Mitroff, 1984). One way in which DT helps problem solvers start to innovate acceptable solutions for a problem with low levels of specificity, is through application of different types of activities that help problem-solvers and their teams uncover unarticulated assumptions and knowledge (Fixson & Read, 2012; Liedtka, 2015). Many of the DT activities encourage discussion to make those assumptions explicit in several different ways. Once the teams have identified and codified the assumptions, they can develop hypotheses around those assumptions. Armed with those hypotheses, the teams can develop tests of the hypotheses' accuracy in order to isolate potential solutions that adequately solve the targeted problem.

Specifications change problems from an ill-defined state, to a well-defined state. Buchanan (1992) highlights the idea that highly-specified problems require a different approach than those with lower levels of specifications. Low levels of specifications leaves room for exploration, reflection, and the embodiment of solutions that did not exist before problem-solving process began. Whereas, problems with higher levels of specifications reduce the degrees of freedom for divergent exploration solution. Guindon (1990) and Lloyd and Scott (1994) study the relationship between DT and the context from the specification perspective. Guindon's (1990) research suggests that specificity emerges from opportunistic discovery of new information about the problem and solution spaces. Specifications that exist a priori mitigate this discovery. Lloyd and Scott (1994) show that the individual designer's repertoire of experience influences their ability to explore broadly in and around the problem space in the absence or inclusion of specific boundaries in the problem. The boundaries limit this exploration and subsequently the acquisition of serendipitous new knowledge. These findings gird Schön's (1983) observations about the creative power of improvising in the face of ambiguity, and the role of repertoire. Problems with low levels of specifications allow for reflecting on the many intricacies of the current initiative, and vary the direction of future action inducing innovations that did not exist at the outset of the initiative.

Dorst & Cross (2001) go on to find that designers -or decision-makers in general-, facing arbitrary boundary limits on the defined problem-space, fit their solutions within the boundaries even when those boundaries exclude otherwise optimal solutions. Kruger & Cross (2006) extend those studies by finding that designers who build more specifications into their problems early on tend to truncate iterations of the design methodology. Similar research by Erat & Krishnan (2012) finds that higher problem specification decreases search behavior within problem spaces. Given that solutions are a result of a generative search process, practitioners can overlook viable solutions in situations when factors in the problem constrain search (Simon, 1996).

2.2.4 Problem Specificities' effects on other methodologies

Problem-specificity effects are not limited to the DT methodology. Practitioners who use other methodologies are likely to modify their application of those methodologies based on the specificity of the problem at hand. Research in total quality management (TQM) shows that highly specified problems affect the decisions of its practitioners. For example, highly specified problems focus problem solvers' attention toward a singular solution irrespective of underlying factors that may exacerbate the problems' negative consequence beyond the short-term (Deming, 1986). Sitkin, Sutcliffe, and Schroeder (1994) espouse that individuals must search "outside the box" of highly specified problems to create solutions that provide lasting value. Victor, Boynton, and Stephens-Jahng (2000) also find evidence that employees tasked with highly specified quality management objectives eschew the search for improvements outside of the specifications. This aligns with findings that solution criteria already embedded into the targeted problems limits solution search (Erat & Krishnan, 2012).

These findings support Hendry's (2002) earlier proposition that initial specifications which include possible solutions – essentially a co-mingling of the problem and solution spaces – limits problem-solvers' initiative to search comprehensively for solutions. This concept is also known as multitasking, and is used to reduce the risk of generating outcomes to problems that are outside of an expected range (Holmstrom &

Milgrom, 1991). The result of the bounded search allows the problem-solver to limit the uncertainty within the problem-space – i.e. focus the search at the city level instead of the continent level. However, avoiding that uncertainty subsequently means that problem-solvers avoid searching for solutions beyond the specified bounds – i.e., the specifications limit the solution to one city on the map when a better solution may well be in another city.

Von Hippel & Von Krogh (2015) find that decision makers can so highly specify their problem that they spontaneously generate a solution without a search. Given that the problems' level of specificity restrains search and can direct problem solvers to solutions, it is therefore possible to codify the problems' level of specificity in terms of the problem formulation that defines a solution. Here specification essentially bridges the gap between the problem space and the solution space, and limits the need for the innovation of building the bridge between the two spaces.

2.2.5 DT Tools and Problem Specificity

As mentioned earlier, the DT methodology is prized for its ability to help practitioners better understand the nuances and complexities of problem spaces, and contribute to developing useful and sustainable solutions to problems. However, DT is itself a complex process with many activity-based tools distributed among the primary problem-solving phases. Each of these tools contributes to building a better understanding of the problem spaces, and translating that understanding into actionable solutions. As specifications of the problem increase, the uncertainty of the problem and subsequent solution decreases. As a result, it is expected that:

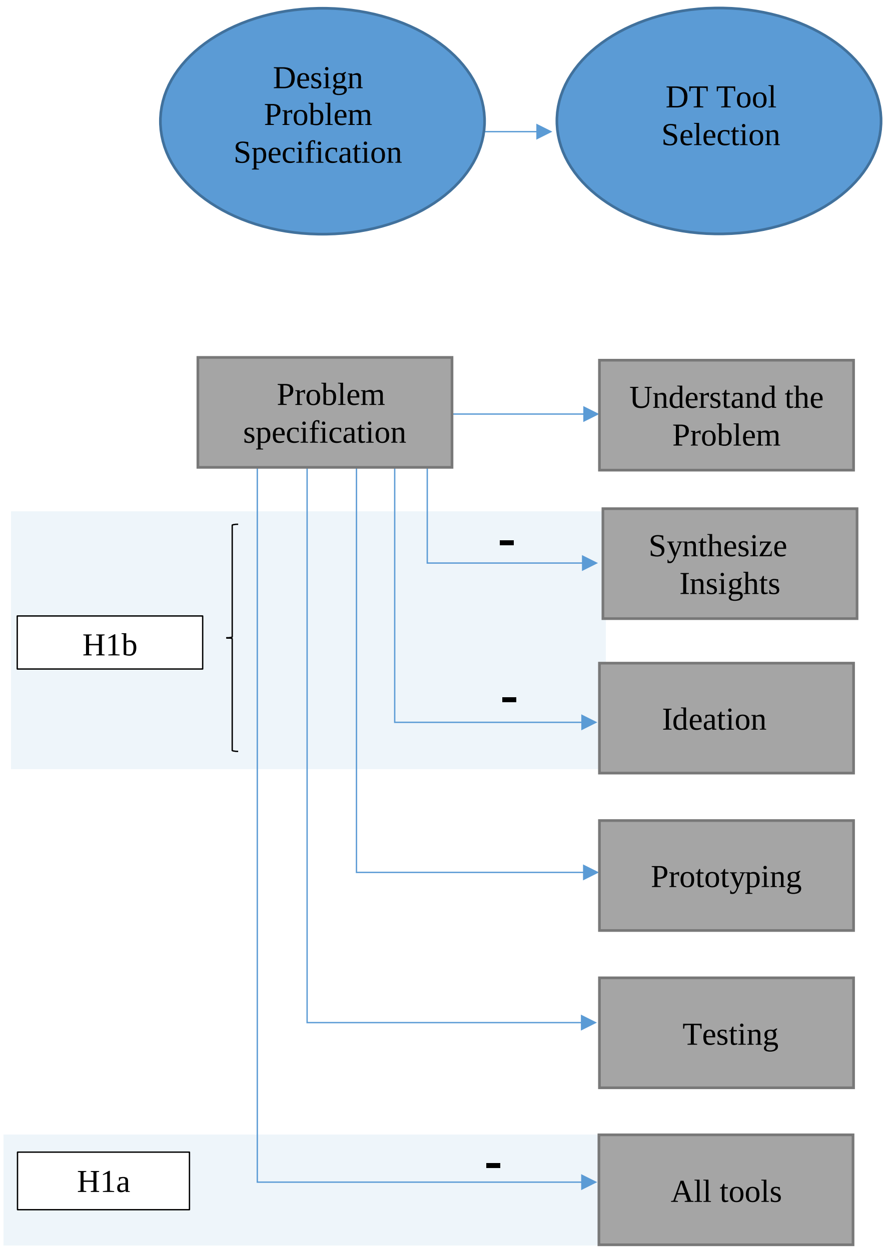
H1a: Problem specificity relates negatively to practitioners' total use of DT tools.

Each of the phases in the DT process (Understand the Problem, Synthesize Insights, Ideate Solutions, Prototype, and Test) focus on different aspects of the problem-solving process. The tools in the Synthesize Insights and Ideate Solutions phases focus on converting unarticulated knowledge into explicit and actionable knowledge by synthesizing teams' diverse perspectives of the problem space. These activities help practitioners and their teams bridge the gap between the problem and solutions spaces. When problems are highly specified, the metaphorical bridge already exists. Consequently, it is expected that:

H1b: Problem specificity relates negatively to practitioners' use of tools in the DT phases that focus on reflexivity.

Figure 2.2 below graphically represents the relationships between practitioners' chosen level of specificity in their problems and the DT phases that they use during process of developing solutions to their problem. As problem specificity increases, it is expected that both total tool usage and use of the Synthesize Insights and Ideate Solutions phases decreases.

Figure 2.2 Model for H1a and H1b



2.3 Perceived Team Cooperation

Solving challenging problems generally improves in quality when conducted in teams versus in solitude (Hirst, Van Knippenberg, & Zhou, 2009), and DT is commonly used among teams (Sonalkar et al., 2016). Cooperation among team members on problem-solving projects is cited as one of the most important factors for project success (De Dreu & West, 2001; Pinto, Pinto, & Prescott, 1993). However, teams require cooperative effort from their members to become and remain effective (Edmondson & Nembhard, 2009). Lack of cooperation imperils projects' progress due, in part, to the disagreement on goals among team members, and insufficient amount of communication to achieve tasks (De Dreu & West, 2001).

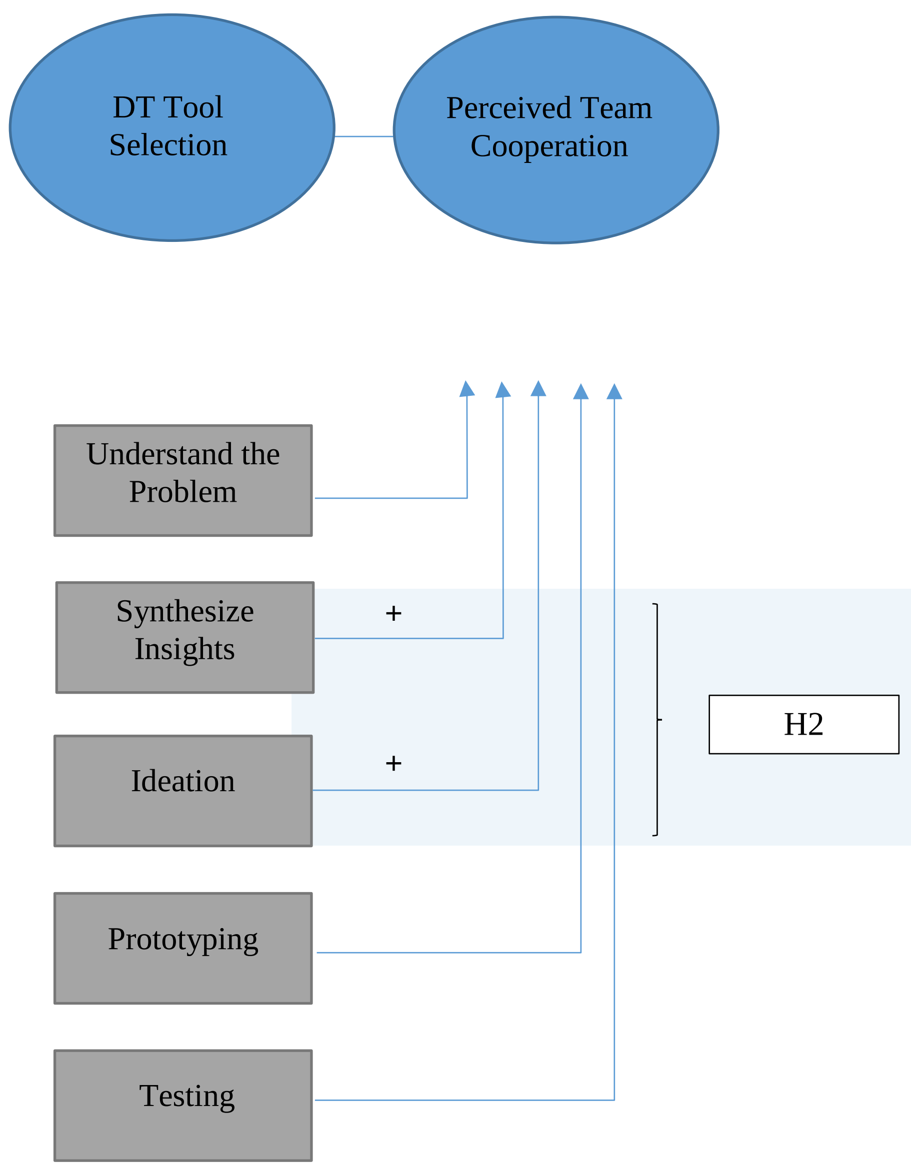
The team innovation literature agrees that reflexivity in teams reduces the likelihood that team members will disagree on goals and fail to communicate sufficiently (Hirst et al., 2009). Moreover, Paulus (2000) suggests that reflexive incubation and attention to idea exchange is highly influential in problem-solving within teams. Studies have shown that reflexive tasks increase cooperation in teams, in part, through goal alignment (Tjosvold, Tang, & West, 2004) and information sharing (De Dreu, 2007). Teams that reflect on the relevance and utility of the new knowledge that they have gained and shared are prepping themselves for further learning (Argyris & Schon, 1996) and build trust within a team (De Jong & Elfring, 2010). As mentioned earlier in section 2.1.4.1, the DT methodology encourages its practitioners to reflexively process information and knowledge to advance mutual goal attainment. The DT phases with activities that encourage reflexivity are Synthesize Insights and Ideate Solutions. Therefore, it is hypothesized that:

H2: Teams' use of Synthesize Insights and Ideate Solutions activities relates positively to practitioners' perceptions of team cooperation.

This is an important potential contribution of DT activities, considering teams facing innovation problems are especially prone to experiencing less integration due to the unharmonious goals that can lead to functional and emotional conflict (Janssen, 2003). New teams can get disillusioned with the design process early in the process, and chafe against slow movement toward value generating results (Carlgren, et al 2013). Process oriented activities have been shown to support team functions. Research by Mohammed & Angell (2004) successfully tested hypotheses that process-orientation reduces team conflict and simultaneously improves perceptions of team performance for teams that utilized more of the prescribed methodology.

According to Faraj & Xiao (2006), teams facing the uncertainty associated with novel problems are prone to less integration, though those that are more integrated react faster and with better overall results. For example, different factions that the team members represent can exacerbate conflict points (Li & Hambrick, 2005). Factions of team members can form within teams and constrain knowledge flows across the whole teams. Such teams are then likely to become less effective than those teams with better knowledge flows (Barki & Hartwick, 2001). If we consider that reflexive activities in the DT methodology seek to harmonize goals, increase knowledge flows, and subsequently constrain uncertainty, then DT's focus on reflexivity, which fosters cooperation, can counteract the negative consequences of working within innovation spaces. Thus, the relationship between team cooperation and the formal procedures of the DT methodology benefits from understanding the practitioners' selective use of DT activities their perception of their teams' cooperation.

Figure 2.3 Model of H2



3 Research Design

In order to examine the hypotheses presented in Chapter 2, we gathered data from assignments and surveys completed by participants who completed a DT training program (the Program) run at the fictitiously named global multinational corporation, Tharsis Inc. These data include 1) the organizational problems that program participants wish to solve in their own words collected at the beginning of the training program; and 2) the participants' answers to a survey collected at the end of the DT training program. In this survey, participants listed which DT tools they actively used in their attempts to solve their self-selected problems, and identified successful outcomes that they achieved during the problem-solving process. The following chapter provides details about the company where the program took place, the DT training program structure, and the variables used in this study.

3.1 The Company and DT training program

The company, Tharsis Inc. (a fictional name of a real company) where the DT training program took place, is a Fortune 100 company headquartered in the United States of America, with revenues of exceeding USD 30 billion in 2016. Founded in the early 20th century, Tharsis has a long history of growth and has built diverse product divisions based around the world that include pre-packed foods for human and animal consumption as well as life sciences services and products.

Tharsis offers internal management training programs to its employees to secure its pipeline of managerial talent. One of these programs focused on teaching managers the principles of DT and how to use DT's many tools. The company chose to provide DT training to its mid-level managers to improve their ability to manage complexity and ambiguity. Tharsis selected the Designing for Growth model of the DT methodology developed by Liedtka & Ogilvie (2011) outlined in section 2.1.2 and Appendix 6.1. Tharsis chose this model because its generalizability to many types of problems including change management, service design, as well as new product development. Participants for the DT training program (the Program) were from the company's middle management levels and worked in diverse divisions located in the USA, Canada, China, Hong Kong, Australia, Europe, and the Middle East. The Program was the second part in a three-part portfolio of training courses aimed at improving managers' capabilities to lead divisions within the company. The first part introduced managers early in their career to basic management and communication skills. The third part of the portfolio provided training on how to manage large staffs, with many reports who themselves ran complex operations.

The Program was a project-based training includes three phases:

1. problem-identification phase,
2. classroom learning phase, and
3. application phase.

The first phase required that participants identify a relevant, human-centered, strategic problem that they had the authority to address directly in the business unit where they worked. The problem-identification phase concluded when participants completed a document called a "Challenge Brief," a blank version of which is in appendix, section 6.2 The Challenge Brief helped participants identify important attributes of their chosen problem in a report that defined their objectives for the project that they worked on throughout the training program. The participants then attended a five-day residential program that introduced the DT methods and tools, and allowed them to practice using the tools in the context of a company-specific case, as well as their own and their classmates' strategic problems. Following the classroom phase, they moved to the application phase when they returned to the workplace and utilized the DT tasks and activities (i.e., tools), as they saw fit to solve their identified problem. The following section goes into more detail about these activities and the collected data.

3.2 DT Training Program and Survey Data

The ongoing training program had graduated 1007 participants at the point when data was collected for this research project. These participants took part in the program from 2014-2016. Data collected from participants included their initial problem statement and a post-program follow-up survey. Of the 1007 participants, 305 answered the follow-up survey. This population of 305 participants constitutes the entire dataset for this research project.

Participants developed problem statements during the problem identification phase of the program. Participants were given a form with questions to help them identify important aspects of the problem they chose. Guidance for filling out the form included descriptions of human-centered problems that require innovation to limit participants' chances of selecting a technology-centered problem. The participants were asked make sure their problems (also referred to as challenges) met these criteria when deciding on a problem to solve:

- Are about creating value for an identifiable group or groups of people that you can interview. Whether the challenge is customer-facing or is about associates, suppliers, or others, your [ ] challenge must have a human-centered component.

- Defy known solutions. In other words, you don't already have an answer and breakthrough thinking is needed to overcome the challenge's complexity.

- Involve others. The successful solution is beyond your individual capability to develop and requires the collaboration and different perspectives of other people.

- Require you and others to be flexible and innovative throughout the process.

- Are within your current scope of work. Your challenge should be something you have some ownership over, with some degree of influence over the process and organization en route to overcoming it.

- Have potentially significant business impact for Tharsis.

- Will interest and motivate you to work on the issue now and over the next several months.

The problem statements were generated in response to the following question: "What is your business problem or opportunity? Describe the challenge in a few sentences, as you would in an elevator pitch." This open-text free-form response allowed participants to describe their problem in as much or as little detail as they wished. All participants filled out the same form, a copy of which is in Appendix 6.2. As a part of the training, participants could receive coaching from the program trainer in the development of their problem. The participants also were encouraged to work with their line manager in developing a problem statement that is important to the division and the participant's role. The participants referenced their problem statement during the classroom training sessions and were expected to continue to work on that problem, or a version thereof, after they returned to their business unit during the subsequent application phase.

The classroom phase was a five-day residential program where groups of 20 to 25 participants from various divisions across Tharsis worked with a team of DT trainers. A consistent team of DT consultants provided training to all of the participants in this program. The participants in this course were individual managers from various regions around the world. They were not joined by their team or subordinates. Part of the training focused on helping the managers teach their teammates, who were not in the training, the basic tenants of DT during the subsequent application phase of the Program. The participants received training materials in the form of books and workbooks that outlined DT. These materials included descriptions of DT and its tools, cases with examples of design thinking in business settings, and checklists to help the participants apply DT to their self-selected problem, as well as other operational problems that they may face. Specifically, these materials included the book “Designing for Growth” (Ogilvie & Liedtka, 2011), as well as a supplementary workbook containing selections from “The Designing for Growth Field Book” (Liedtka et al., 2014). The book’s intention is to “cover the mindset, techniques, and vocabulary of design thinking, unpack the mysterious connection between design and growth, and teach managers in a straightforward way how to exploit designs’ exciting potential” (Ogilvie & Liedtka, 2011). The training materials and training program remained the same throughout the classroom phase for all groups of participants.

The application phase followed this classroom phase. This phase officially lasted three months starting when the participants returned to their regular jobs after the classroom phase. The application phase portion of the Program allowed the participants to apply the tools that they learned during the classroom phase to the problem that they had selected to solve in a real-world operational setting. During the application phase, the participants were expected to apply DT tools to their problem, with the aim of developing a succinct action plan for deploying a viable solution. Each of the participants had the opportunity to receive 3 hours of coaching from the training staffs throughout the application phase. The coaches offered feedback about what the participant had achieved and they discussed plans including which of the tools to use in the future. Throughout the application phase, it was expected that the participants would include their organizational team members in the process of applying these tools. These team members typically included employees who reported directly to the Program participants, the participants' line managers, and stakeholders associated with the problems.

Participants were asked to complete a survey at the conclusion of the training program—three months after the classroom phase. This survey is found in Appendix 6.4. Three hundred five participants submitted completed surveys, and these survey responses were matched directly with the participants' problem statements. Two areas of the survey provide insights to the participants' use of DT, and the benefits that they perceived from using DT to solve their self-selected problem. First, the survey requested that the participants identify each of the DT tasks and activities which they used during the application phase from a list of the 16 derived from the training materials and explained in section 2.1.4 above. They were presented with a list of all tools, and were given the option to check off whether they had used each tool or not. Second, the participants provided an open-ended statement that explained positive outcomes they achieved during the project. The survey specifically asked, “What do you consider one of your greatest successes in your work on your challenge?” Participants could write as little or as much as they pleased in response to this open-ended question. The survey also posed questions about which elements of the training they found useful, as well as areas for improving the training program. The survey questions are in the Appendix, section 6.4.

These three data points: 1) text of the initial problem statements, 2) quantitative lists of DT tools utilized, and 3) text of participants’ self-defined success factors, were combined into a database for further analysis.

3.3 Testing H1a and H1b

3.3.1 Independent Variable: Problem specification

We are interested in understanding the degree to which initial specifications included in the problem statement influenced the use of DT tools. The following section details the test of hypotheses H1a and H1b which are:

H1a: Problem specificity relates negatively to practitioners’ total use of DT tools.

and

H1b: Problem specificity relates negatively to practitioners’ use of tools in the DT phases that focus on reflexivity.

For the following analysis, we focused on the written problem statements that the training participants generated before beginning the classroom phase, matched with the corresponding surveys that each participant completed at the end of the program. Out of the 1007 participants, 305 completed both the problem statement form and survey. The instructions that the participants received for developing their problem did not rigidly define the structure of the problem statement. As a result, participants' problem statements varied in their level of specificity. Some participants wrote broad problem statements with few specifications, while others were inclined to include many specifications. For example, the following problem statement from the data provided minimal specifications as to what a possible solution may be:

> *How can we prepare our organization to face the future leadership needs? [Our region] is an emerging market which has been growing in an accelerated pace. Demands of an increasingly complex business environment have changed performance requirements for leaders, and the leadership benches are not equipped to meet these expectations. The succession management process has not kept pace with the changing demands while the supply of candidates is unstable as well having as a result fragile pipelines.*

The problem statement above suggested that leaders were under stress to make decisions in a dynamic operating environment, and that there were relatively few candidates capable of filling management roles with such demands. The problem-solver included minimal specifics in the problem statement, and a third-party reader is unlikely to identify a particular solution from the problem's formulation.

Other participants relied heavily on specifications in their problem statements. Below is an example of a problem statement with a high degree of specification that indicated a likely solution embedded into the problem statement:

> *Business opportunity is to expand [Tharsis's] food portfolio (xx.x% $ share) to successfully compete with [our biggest competitor] who is almost 2X our size (xx.x% $ share). The challenge within this opportunity is to determine the right strategic and tactical moves to enable us to successfully expand the portfolio without overwhelming our current resources and supply chain. The dog food category is contracting -2.5% in 2015 driven by a decline in dog ownership and an increase in small dog ownership who consume less food than large dogs. Therefore the portfolio expansion must focus on premiumization to sell the declining volume at a higher cost/lb to unlock category growth.*

Specifications in the above problem statement above pointed to an idealized solution. For instance, the participant said that the current sales volume was too small ("compete with [our biggest competitor] who is almost 2X our size"), the target market was shrinking ("dog food category is contracting"), and the supply chain was at capacity ("expand the portfolio without overwhelming our current resources and supply chain"). These specifications of the problem helped bolster the participant's idealized solution which was to "focus on premiumization to sell the declining volume at a higher cost/lb to unlock category growth."

To operationalize the concept of problem specification, we relied on independent raters external to the Program to judge whether or not a problem statement included a high degree of specifications that indicated a desired solution. Following fully crossed data categorization procedures (Glaser & Strauss, 2017; Larsson, 1993), three doctoral-level trained researchers independently coded the 305 problem statements into one of two nominal categories: 1) the problem includes a high degree of specifications, or 2) the problem includes a low degree of specifications. Prior research suggests that two or more raters are sufficient to code qualitative data into nominal categories (Cooper, Schindler, & Sun, 2006; Larsson, 1993); (Baer, Leenders, Oldham, & Vadera, 2010; Junni, Sarala, Taras, & Tarba, 2013).

The instructions for classification were: "Problems that include discrete scenarios that prescribe specific actions and / or include specification that indicate a desired solution are considered to be highly specified. Otherwise, they are considered not highly specified." Five examples of each category were included with the instructions. These instructions rely on the concept of needs-solution pairs (Von Hippel & Von Krogh, 2015), and pop-up solutions (Novick & Sherman, 2003) where problem specifications drive rapid solution generation within the process of formulating the problem.

Checking for interrater reliability is an important step in establishing the validity of the categorization outcome (Landis & Koch, 1977; LeBreton & Senter, 2008). One of the most commonly accepted tests for interrater reliability is Cohen's kappa coefficient (Cohen, 1968; Orwin & Vevea, 2009; Perreault & Leigh, 1989; Stahl & Voigt, 2008), which removes the probability of chance reliability in categorization procedures. Cohen's kappa coefficients at or above 0.7 are considered an acceptably high level of interrater reliability (Cohen, 1968; Landis & Koch, 1977; Viera & Garrett, 2005). Comparing the two raters' coding produces a Cohen's kappa coefficient of 0.71. The two raters discussed the discrepancies, agreed on a single code for each discrepancy, and incorporated the agreed upon code into the final analyses in alignment with common practice.

A third rater coded the entire set of 305 problem statements. The Cohen's kappa for this rater's codes compared to the harmonized categorization codes, agreed upon by the other two raters, produced a score of 0.83. The Cohen's kappas for the third rater's codes compared to the other two raters' separate codes were 0.73 and 0.76, respectively. These scores provided evidence that the coding of the categories aligned sufficiently across the raters.

Table 3.2 Cohen's Kappa correlations for high versus low specifications

	Final Categories	Coder 1	Coder 2
Coder 1	0.81		
Coder 2	0.89	0.71	
Coder 3	0.83	0.73	0.76

Intraclass correlation coefficient (ICC) is another useful method for testing interrater reliability among multiple raters (LeBreton & Senter, 2008). Employing ICC2 for this coding exercise among the three raters produced a coefficient of 0.73 at a significance level of <0.001, which reaffirms the interrater reliability among these raters.

3.3.1.1 Descriptive statistics: problem statement specification categories

A total of 305 problem statements were available for analysis that matched directly with participants' program exit surveys. The training cohorts sampled included 1007 participants representing a response rate of 30.3 percent. The problem statements range in length from eight to 188 words, have an average length 93.4 words, and a standard deviation of 39.9 words. Independent coding revealed that 164 challenges had low specifications, and 141 had high specifications representing 53.8 percent and 46.2 percent, respectively.

3.3.2 Dependent variables: DT tools

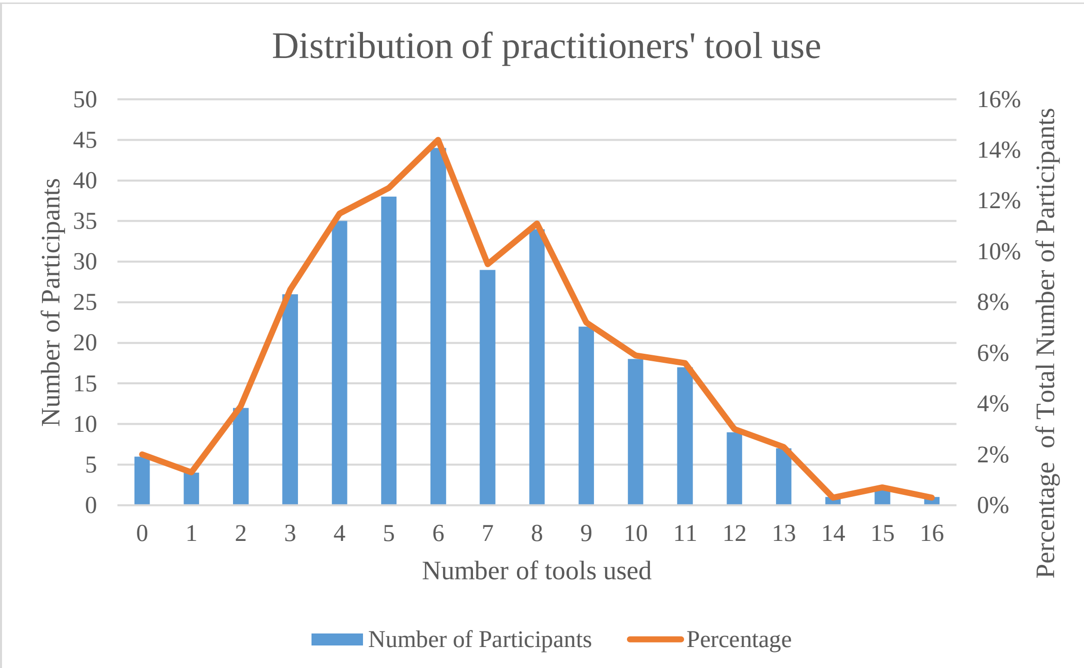
The dependent variables of interest for H1 and H1b are the DT tools that the participants indicated they had used in the end-of-program survey. Participants marked which tasks and activities from the list of 16 (as outlined in section 2.1.4) they had used in the course of solving their problem during the three-month application phase of the training program. For the following analyses, the tools were categorized into the five buckets: Understand the Problem, Synthesize Insights, Ideate Solutions, Prototype Solutions, and Test Hypotheses (as outlined in section 2.1.4).

3.3.2.1 Descriptive statistics: DT tool usage

On average, participants applied 6.55 tasks and activities out of the 16 available. The median number of the tasks and activities applied is 6. The distribution of the participants' tool usage is shown in the more detailed breakdown in Figure 3.1 below. This figure shows that that almost half of the practitioners (145) used five to eight tools, with very few using ten or more tools.

Figure 3.1 Practitioners' DT Tool Usage Regardless of DT Phase

Percentages represent the proportion of the total population (N=305)



Looking at tool usage by phases shows that more participants used tools in the initial phases of the DT methodology. The breakdown by phase below shows that probability of usage of each subsequent phase decreases.

283 participants (92.8 percent) applied at least one Understand the Problem tool;

238 participants (88.0 percent) applied at least one Synthesize Insights tool;

228 participants (74.8 percent) applied at least one Ideate Solutions tool;

221 practitioners (72.5 percent) applied at least one Prototype Solutions tool; and

159 participants (52.1 percent) applied at least one Test Hypotheses tool.

(For Test Hypotheses, 42.3 percent used Co-creation and 19.3 percent used Learning Launches marking a distinct imbalance between the two tools)

Table 3.3. shows the distribution of tool usage across all of the phases. Usage evolves as expected where usage decreases, with each subsequent tool in each phase. The exception is that more participants used two Understand the Problem tools (113 participants) than those who used only one tool (78 participants).

Table 3.3 Tool Usage by DT Phase (*N=305)*

	Number of participants (percentage of total number of participants)				
Number of Tools Used	Understand the Problem	Synthesize Insights	Ideate Solutions	Prototype Solutions	Test Hypotheses
0	22 (7.2%)	67 (22%)	77 (25.2%)	84 (27.5%)	146(47.9%)
1	78 (25.6%)	87 (28.5%)	116 (38%)	119 (39%)	130 (42.6%)
2	113 (37%)	73 (23.9%)	77 (25.2%)	75 (24.6%)	29 (9.5%)
3	69 (22.6%)	60 (19.7%)	35 (11.5%)	27 (8.9%)	N/A
4	23 (7.5%)	18 (5.9%)	N/A	N/A	N/A

Table 3.4 shows the average number to tools that participants used in each phase. On average, participants used fewer than 50 percent of available tools in each phase, with three phases around 40 percent usage.

Table 3.4 Average Number of Tools by Participants by DT Phase

DT Activities	Average tool usage (max)	Percentage of max	S.D.
Understand the Problem	1.98 (4)	49.5%	1.04
Synthesize Insights	1.59 (4)	39.8%	1.20
Ideate Solutions	1.23 (3)	41.0%	.96
Prototype Solutions	1.15 (3)	38.3%	.93
Test Hypotheses	0.62 (2)	31.0%	.65
Total tools	6.55 (16)	40.9%	3.09

Table 3.5 shows the breakdown of tool usage by phases. Both Direct Observation and Brainstorming were used by more than 50 percent of the participants and their teams. Fewer than 20 percent used Forced Connections and Learning Launch Experiments.

Table 3.5 Individual Tool Usage by DT Phase (*N=305*)

DT Activities	Number of Participants	Percentage	DT Phase
Direct Observation	154	50.50%	Understand the Problem
Ethnographic Interviews	239	78.40%	
Journey Mapping	137	44.90%	
Job to be done	73	23.90%	
Personas	114	37.40%	Synthesize Insights
Gallery Walk	134	43.90%	
Mind Mapping	108	35.40%	
Design Criteria	129	42.30%	
Brainstorming	216	70.80%	Ideate Solutions
Concept Clustering	101	33.10%	
Forced Connection	58	19%	
Identifying Assumptions	112	36.70%	Prototype Solutions
Prototyping	126	41.30%	
Storytelling/Storyboarding	112	36.70%	
Cocreation	129	42.30%	Test Hypotheses
Learning Launch Experiments	59	19.30%	

3.4 Test of H2

The following section covers the test of H2, which is:

Teams' use of Synthesize Insights and Ideate Solutions activities relates positively to practitioners' perceptions of team cooperation.

In order to test H2, we rely on the participants' survey responses collected at the end of the program following the application phase and discussed in section 3.2.

3.4.1 Independent variables: tool usage

The dependent variables used in the test of H1 and H1b use of specific tasks and activities—are the independent variables in the test of H2. These variables, which are described in section 3.3.2, are the participants' survey responses indicating whether they used certain tasks and activities during the application phase of their project.

3.4.2 Dependent variable: success outcomes

Participants answered the open-ended question, "What do you consider one of your greatest successes in your work on your challenge?" A preliminary analysis of all 305 responses revealed that success, defined by the individual innovation leaders, ranged from the discrete accomplishment of solving the defined problem, to expanding their innovation project management capabilities. These assessments also included perceived team cooperation.

To follow the same categorization procedure as for the problem statements, three doctoral-level trained raters independently categorized the answers to this question into two nominal categories: 1) the participant's success statement included identifying attributes of team behavioral integration by mentioning positive examples of the operational team sharing information, contribution to the tasks at hand, and/or collaborative creativity as a critical success outcome (Hambrick, 1995; Simsek, Veiga, Lubatkin, & Dino, 2005), or 2) does not include perceived team cooperation outcomes. The raters were instructed to determine if the success statements indicated that the operational team that the training program participant supervises "engages in mutual and collaborative interaction," (Hambrick, 1994), and included any of the following elements from: collaborative behavior within the operational team, information exchange among operational team members, joint decision-making, and collaborative task interactions.

The first two raters' categorization of the entire list of 305 statements produced a Cohen's kappa coefficient of .79, which suggests substantial inter-rater reliability (Landis & Koch, 1977; Viera & Garrett, 2005). As in the previous section, discrepancies were discussed, harmonized, and included in the final analysis. A third rater coded the entire list of 305 success statements. These scores were compared to the harmonized ratings agreed upon by the first two coders as well as the codes provided by the other two raters. The Cohen's kappa of 0.83 also suggest a high inter-rater reliability. The Cohen's kappa between the third rater and the first two raters were 0.84 and 0.74, respectively. The ICC2 among the three raters is 0.79 at a significance <0.001 which reaffirmed an acceptable level of interrater reliability.

Table 3.6 Cohen's Kappa coefficient for perceived team cooperation

	Final Code	Coder 1	Coder 2
Coder 1	0.90		
Coder 2	0.84	0.79	
Coder 3	0.83	0.84	0.74

Table 3.7 below provides details of the major themes that practitioners identified as success factors at the conclusion of the six-month DT training program. The top category after team cooperation, "use of specific tools," denotes each time a practitioner mentioned that he or she used a tool or tools by name as a success factor in their project. "Stakeholder participation and focus" indicates when practitioners said that they considered that they had included stakeholders in the process and focus on their needs as a success factor. "Ability to bring people along on the process/alignment of the process or

ideas" designates the cases where practitioners said that they were able to use the DT process to engender alignment within their team and/or stakeholders in order to make progress on viable solutions

Table 3.7 Project Success Factors mentioned by practitioners in final survey

Identified success factors:	#
Team cooperation	75
Use of specific tools (tools mentioned by name)	71
Stakeholder participation and focus	60
Ability to bring people along on the process/alignment of the process or ideas	45
Gaining broader perspectives regarding problem to be solved	36
Tool use in general (no tools mentioned by name)	27
Gained new knowledge / ideas / opportunity possibilities	24
Personal/leadership development in general	18
Change in mindset regarding innovation	17
Time and energy dedicated to problem solving	15
General project momentum that would be difficult to generate otherwise	15
Networking	10
Feedback on ideas / plans	7
Deployed an innovative solution	7
Development through coaching	6

3.4.2.1 Descriptive statistics: Perceived Team Cooperation

75 participants (24.6 percent) included attributes of perceived cooperation in their success assessments

4 Results

The following chapter describes the results of the analyses of problem statements, and the post-program survey from the 305 observations described in chapter 3. Section 4.1 presents a preliminary analysis of the variables in the study. Section 4.2 in this chapter details the main analysis of hypotheses 1a and 1b. Section 4.2 shows the results of the analysis for hypothesis 2.

4.1 Preliminary Analysis

Table 4.1 below presents the descriptive statistics and Pearson correlations for the variables within the complete dataset of the participants' problem statements and follow up surveys. Rows 1-6 show the mean number of tools used in each DT phase, and the numbers in the parentheses indicate the total number of tools available in each phase. Row 7 (Low Specifications) is a dummy variable predictor for hypotheses 1a and 1b, where a score of one indicates that the practitioner chose to solve a problem with Low Specifications. Row 8 (Perceived Team Cooperation) is a dummy variable for the outcome predicted in hypothesis 2, where a score of one indicates that the practitioner indicated Perceived Team Cooperation.

Table 4.1 Descriptive Statistics and Correlations

	Mean (total)	S.D.	1.	2.	3.	4.	5.	6.	7.
1. Understand the Problem	1.98 (5)	1.04	1						
2. Synthesize Insights	1.59 (3)	1.20	.210**	1					
3. Ideate Solutions	1.23 (3)	0.96	.251**	.459**	1				
4. Prototype Solutions	1.15 (3)	0.93	.261**	.245**	.252**	1			
5. Test Hypotheses	0.62 (2)	.654	.186**	.185**	.183**	.376**	1		
6. Total Tools Used	6.55 (16)	3.09	.613**	.714**	.685**	.643**	.518**	1	
7. Low Specifications	0.56	0.50	0.038	.216**	.123*	0.034	-0.004	.142*	1
8. Perceived Team Cooperation	0.25	0.43	-0.009	.196**	.262**	-0.042	0.009	.139*	0.107

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

These correlations highlight the relationships between the phases that the practitioners used. The scores for the individual phases as well as the total number of tools correlate showing no biases in the distribution of tool usage. The positive correlations in row seven highlight relationships predicted in hypotheses 1a and 1b where the Synthesize Insights and Ideate Solutions phases as well as Total Tools Used are positively related to problems with Low Specifications. Two of the positive correlations in row 8 were predicted in hypothesis 2, where the Synthesize Insights and Ideate Solutions phases are positively related to Perceived Team Cooperation.

4.2 Tests for H1a and H1b

H1a hypothesizes that problem-solvers working on problems with low specifications are likely to use more DT tools than those working on highly-specified problems. Similarly, H1b hypothesizes that problem-solvers working on problems with low specifications are likely to use more tools from the Synthesize Insights and Ideate Solutions phases.

In the case of these hypotheses, there are two discrete populations: program participants working on a problem with low specificity versus those working on problems with high specificity. The dependent variable for H1a is the total tool count for each of these two categories. The individual dependent variables for H1b are the number of tools that the participants used in each of Synthesize Insights and Ideate Solutions phases.

A comparison of the mean tool usage between the two categories of problem specificity showed that participants working on problems with low specificity use, on average, more tools in each DT phase as well as generally as detailed in Table 4.2:

Table 4.2 Mean tool usage across levels of problem specificity

	Mean tool usage				Cooperation Perceived - not Perceived	Percentage
	Team Coop. Perceived	s.d.	Team Coop. Not Perceived	s.d.	Difference	Difference
Understand the Problem	1.96	.979	1.98	1.06	-0.02	-1.0%
Synthesize Insights	2.00	1.23	1.46	1.16	0.54	27.0%
Ideate Solutions	1.67	0.84	1.09	0.95	0.58	34.7%
Prototype Solutions	1.08	0.85	1.17	0.95	-0.09	-8.3%
Test Hypotheses	0.63	0.65	0.61	0.66	0.02	3.2%
Total tools	7.31	2.77	6.31	3.15	1.00	13.7%

Formal analysis of normality (Shapiro & Wilk, 1965) revealed that the observations in the H1a and H1b are not normally distributed as evidenced by all variables having Shapiro-Wilk *p*-scores less than 0.001. Additionally, the Fisher skewness coefficient exceeded 2 in all but one case (Understand the Problem) further substantiating that these data have non-normal distributions (Doane & Seward, 2011). Therefore, using a non-parametric test provides higher reliability than parametric tests (Siegel, 1957).

The Mann-Whitney U-test (Mann & Whitney, 1947; Palepu, 1985; Etzion & Pe'er, 2014) is an appropriate test for these hypotheses as it is a rank-order tests of the difference between the distributions of two independent populations that are not normally distributed. The Mann-Whitney relies on ranking scores in the two populations and compares the resultant distributions. Consequently, it also detects differences in the rank-order means. The test of H1a revealed a statistically significant difference between Total Tools used by participants working on problems with low specifications versus those working on highly-specified problems at the ($z = 2.093$, $p < 0.05$) level. The test of H1b also showed statistically significant differences between participants focused on problems with low specificity and their use of the tools in the Synthesize Insights ($z = 2.889$, $p < 0.005$) and Ideate Solutions ($z = 2.144$, $p < 0.05$) phases versus those who focused on highly specified problems. No significant relationships were detected between problem specificity level and the other DT phases where p levels exceeded 0.05. These results support rejecting the null hypotheses for both H1a and H1b. The remaining phases were not significantly different between the two categories of specificity.

4.2.1 Replication of H1a and H1b with linear regression

A linear regression between two populations can serve as a backup analysis despite its assumption of normality. Linear regression loses sensitivity to abnormal distributions as the population grows, especially beyond 80 observations (Lumley, Diehr, Emerson, & Chen, 2002). Regressing problem specificity and tool usage for each of the DT phases, independently, based on the formula below, produced similar p-scores to the Mann-Whitney U test.

Tools(i) = a + B(i)*Low Specification(i) + e(i)

The regression for H1a shows that participants, who focused on problems with low-specifications, tended to use more tools in total ($B = 0.882$, $p < .05$) than participants who focused on highly-specified problems. Problem specificity, while statistically significant between groups with high and low levels, has a small impact on total tool usage as evidenced by the low effect size. The independent regressions for each of the DT phases indicated that participants were likely to use more tools in the Synthesize Insights ($B = 0.520$, $p < .001$) and Ideate Solutions ($B = 0.236$, $p < .05$) phases. The remaining phases showed no significant relationships.

Table 4.3 Low Specifications: Results of linear regressions

	Understand the Problem	Synthesize Insights	Ideate Solutions	Prototype Solutions	Test Hypotheses	Total Tools
Independent Variable:						
Low Specifications						
B	0.079	0.520**	0.236*	0.063	-0.005	0.882*
R^2	0.001	0.047	0.015	-0.001	0.000	0.020

*   p < 0.05
** p < 0.001

4.2.2 Replication of H1b with independent samples t-test

H1b hypothesizes that participants who work on problems with low specifications are likely to use more reflexive tools (Synthesize Insights and Ideate Solutions) than those working on highly-specified problems. While the distribution of the tool usage within the phases is not normal, the independent samples t-test is less sensitive to non-normality when n exceeds 60 observations (Sawilowsky & Blair, 1992). The t-test of H1b produced similar results to the Mann-Whitney test. The test reconfirmed the hypothesis that participants working on problems with low specificity use Synthesize Insights (t = 3.917, $p < 0.005$) and Ideate Solutions (t = 2.176, $p < 0.05$) more often than peers working on problems with high specificity.

The relationship between problem specificity and tool usage suggests that, in spite of the statistical significance in the case of the Total Tools Used, Synthesize Insights and Ideate Solutions, the magnitude of these relationships is slight, as evidenced by the low effect sizes evidenced in the three tests.

4.3 Hypothesis 2

H2 hypothesizes that use of tools included in the Synthesize Insights and Ideate Solutions phases is positively associated with perceived team cooperation as a project success outcome. In order to test this hypothesis, the success factors that practitioners entered into their program completion surveys were coded into two discrete groups. The first group included observations that included perceived team cooperation while the second group included all of the observations that do not mention perceived team cooperation. Looking at mean tool usage difference between the two groups showed that there was a tendency for the group that mentioned perceived team cooperation to use more tools than the other group. These differences were greatest in the Synthesize Insights and Ideate Solutions phases. Table 4.4 shows the variance in mean tool usage between the two groups across the different phases.

Table 4.4 Mean tool usage variance between groups where the practitioner perceived team cooperation versus did not perceive team cooperation

	Mean tool usage				Cooperation Perceived - not Perceived	Percentage
	Team Coop. Perceived	s.d.	Team Coop. Not Perceived	s.d.	Difference	Difference
Understand the Problem	1.96	.979	1.98	1.06	-0.02	-1.0%
Synthesize Insights	2.00	1.23	1.46	1.16	0.54	27.0%
Ideate Solutions	1.67	0.84	1.09	0.95	0.58	34.7%
Prototype Solutions	1.08	0.85	1.17	0.95	-0.09	-8.3%
Test Hypotheses	0.63	0.65	0.61	0.66	0.02	3.2%
Total tools	7.31	2.77	6.31	3.15	1.00	13.7%

The Shapiro-Wilk formal test of normality revealed that the distribution of the categories of perceived team cooperation are significant ($p < 0.001$) and kurtosis and skewness standard errors exceed the respective statistics by more than two. As above, these scores indicated that the Mann-Whitley U test is an appropriate analysis tool to analyze the data for H2. The results of this analysis indicated that participants who used more tools in the Synthesize Insights ($p < 0.001$) and Ideate Solutions ($p < 0.001$) phases had a statistically significant higher probability of perceiving team cooperation as a success outcome than participants working on problems with higher specificity. The tool usage from the remaining DT phases did not have significant relationships with perceived team cooperation and $p > 0.5$ in both cases. However, Total Tools Used ($p \leq 0.01$) did have a statistically significant relationship with perceived team cooperation.

4.3.1 H2 Replication with independent samples t-test

As mentioned above in section 4.2.2, the independent samples t-test is an acceptable secondary analysis of this hypothesis due to the high number of observations ($n = 305$). The following analysis compared Synthesize Insights and Ideate Solutions tool usage scores in relationship with perceived team cooperation. The analysis indicated that practitioners who used more tools in the Synthesize Insights ($t = 3.475$ $p = .001$) and Ideate Solutions ($t = 4.716$ $p < .001$) phases had a statistically significant positive relationship with perceived team cooperation compared to those who used fewer of the tools in these categories. Further analysis of the relationship between tool usage in each of the remaining phases revealed no statistically significant relationship with perceived team cooperation.

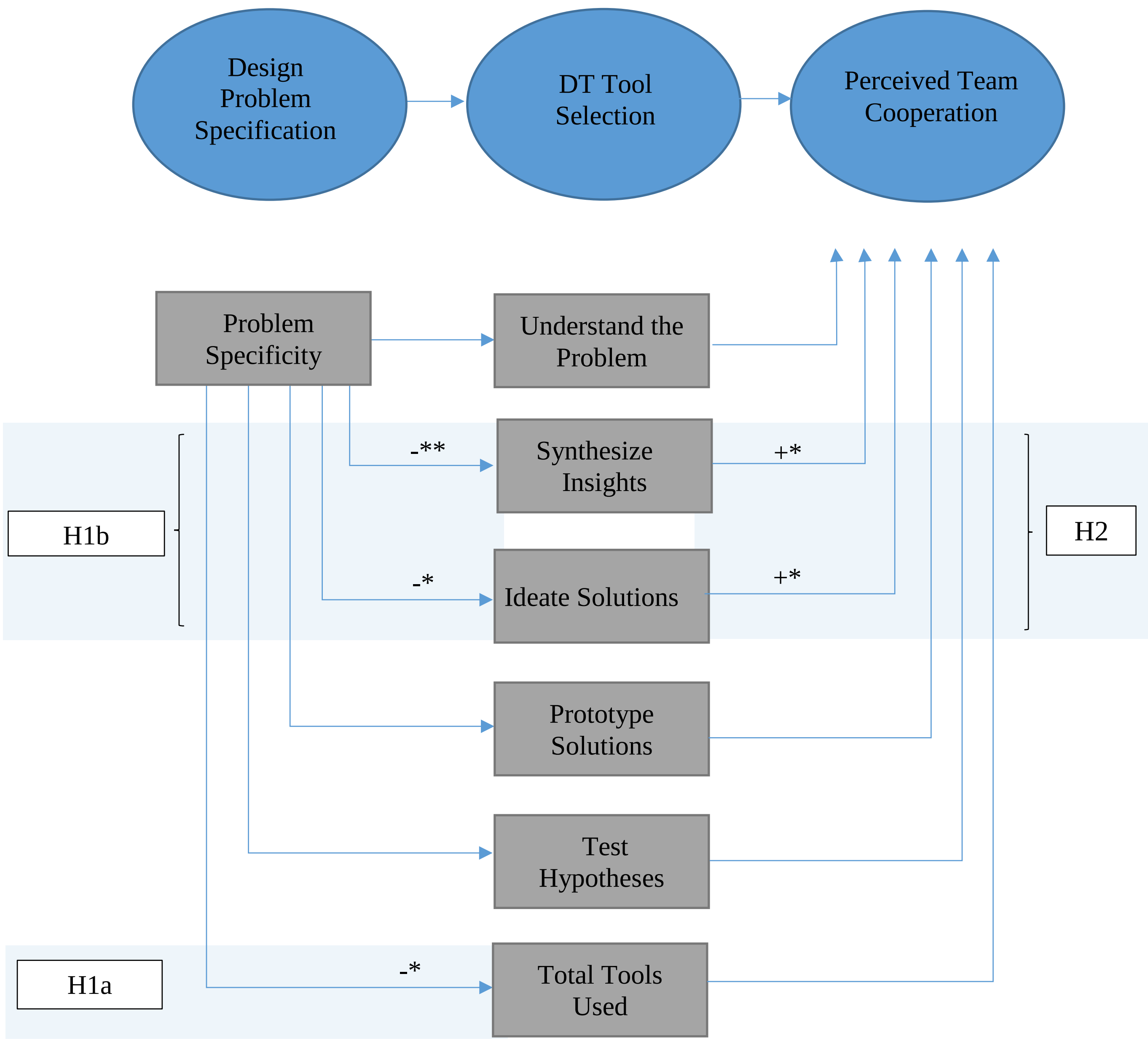
Table 4.5 Independent Samples t-test Results for H1a, H1b, and H2

	Understand the Problem	Synthesize Insights	Ideate Solutions	Prototype Solutions	Test Hypotheses	Total tools
t(df)						
Low Specifications	0.665(295)	3.917(300)**	2.176(295)*	0.596(289)	-0.071(292)	2.556(302)*
Perceived Team Cooperation	-0.17(135)	3.37(120)**	5.007(140)*	-0.769(139)	0.157(126)	2.62(142)

4.4 Cumulative results

Overall, these results agree with hypothesized relationships. Figure 4.1 below represents the full model and relationships that problem specificity and perceived team cooperation have with practitioners' use of tools in the five DT phases as well as their total tool use. The left side of the figure shows that, as problem-specificity increases, practitioners' use of all tools and reflexive tools (Synthesize Insights and Ideate Solutions) decreases as predicted in H1a and H1b, respectively. The other phases had no statistically significant relationships with problem-specificity. Similarly, the left side of the figure shows the positive relationship with practitioners' use of reflexive tools and practitioners' perception of team cooperation.

Figure 4.1: Statistical relationships between problem specificity, DT phase tool use, and perceived team cooperation



Mann Whitney * $p < .05$ ** $p < .001$

5 Discussion

5.1 Key Findings

This research investigated questions on two sets of relationships within the problem-solving process when practitioners apply DT. The first question examined the extent to which the level of specification in the problems that practitioners choose to solve using DT related to practitioners' selection of DT tools. The second question examined the extent to which practitioners' selective use of DT tools and phases related to the practitioners' perception of cooperation with their teams.

This research has three key findings that contribute to the DT literature, specifically in the areas of problem formulation and team cooperation. Firstly, design teams working on problems with low levels of specificity were more likely to use a higher number of tools across the phases of DT methodology. Secondly, the evidence suggested that practitioners and their teams were likely to use more tools in the Synthesize Insights and Ideate Solutions phases than those teams that worked on problems with high levels of specification. Thirdly, practitioners whose design teams used more tools in the Synthesize Insights and Ideate Solutions phases were more likely to perceive team cooperation than those practitioners who used fewer tools in those two phases.

DT's facilitation of the problem-solving process is important to understand due to problems' dynamic, future-focused attributes for creating new value propositions (Foss, Frederiksen, & Rullani, 2016). These findings contribute to DT theory through their extension of previous research on tool usage in organizational settings (Seidel & Fixson, 2013). One of DT's strengths is its ability to support practitioners with uncovering end-users' needs (Beckman & Barry, 2007) and deploying viable solutions (Liedtka, 2017). This research indicates that problem specificity relates to practitioners' selective use of the DT tool portfolio. The problem specificity perspective contributes to DT theory by providing a mechanism to examine practitioners' choices when implementing the DT methodology. The problem specificity perspective also provides insights into the different phases of the DT methodology that practitioners prioritize when facing problems with varying degrees of specificity. In the case where the problem has a low level of specificity, and the solution space includes a broad range of options, practitioners tend to give more priority to the tools that focus on reflexivity within the DT methodology (Synthesize Insights and Ideate Solutions), that facilitate practitioners' ability to process new information, and use those new insights and ideas in subsequent problem-solving activities. The results of this research suggest that a problem's level of specificity may influence the amount of effort practitioners invest in using DT tools to explore the breadth of the problem and solution spaces.

5.1.1 Problem specificity and Design Thinking tools

Practitioners' use of the tools in the Synthesize Insights and Ideate Solutions phases showed a significant relationship with practitioners' level of specificity in their problem formulation. Each of the tools within the phases were not used equally among the practitioners in the program. Appendix 6.3.3 shows the variation in practitioners' and their teams' use of tools within the phases. Two of the sixteen total tools had a statistically significant relationship with the level of specificity in practitioners' problems. Gallery Walk and Design Criteria. Within the Synthesize Insights phase, practitioners used the Gallery Walk (134) tool the most followed by the other three, Design Criteria (129), Personas (114), Mind Mapping (108). The tools in this phase have different functions that spark reflexivity in the design team and add specifications to the problem space (as described in Appendix 6.1.2). The Personas and Mind Mapping tools provide methods for the design teams to generate insights that subsequently inform the activities prescribed by the Gallery Walk and Design Criteria tools. Design teams using Personas and Mind Mapping parse out the nuances of and find patterns in the information gathered during the Understand the Problem phase.

The Gallery Walk is a multi-stage activity that requires practitioners, their teams, and stakeholders to synthesize information gathered using other DT tools and develop several clusters of insights that highlight questions around the problem environment. The design team then creates graphic representations of these insights and displays them in a place where stakeholders can review and discuss the scenarios. The design team can use the outputs from the collective discussions to generate new ideas in subsequent DT phases. Beyond its reflexive characteristics, the Gallery Walk marks an important milestone in the problem-solving process—its value hinges on the ability of the design team to develop realistic insights that tease out the nuances of a problem space and engage the stakeholders. These activities provide concrete details about complex problem spaces that can become specifications on which the design team can make future decisions. These specifications provide increasing levels of clarity around the problem space.

The Ideate Solutions phase includes three tools that received varying degrees of use by the practitioners. Practitioners used Brainstorming (216) the most, followed by Concept Clustering (101) and Forced Connections (58). These tools encourage practitioners and their teams to engage with what they know about the problem space in a creative manner (as described in Appendix 6.1.2). Brainstorming establishes guidelines that push team members to generate and share many ideas iteratively without the need to defend those ideas in the moment (Fisher & Fisher, 1998). Each of the team members' perspectives and iterative engagement with the problem space holds the possibility to move the team from a problem with broad parameters towards a defined solution space. In contrast to a problem with high specifications, the team is less likely to need to refine the solution space if that space already exists at the outset of the problem-solving process.

While, the tools in the Synthesize Insights and Ideate Solutions phases are highly reflexive, they are not the only tools in the DT methodology that leverage the power of reflexivity. For example, the prototyping tool in the Prototyping Solutions phases requires practitioners and teams to draw on ideas gained from the Ideate Solutions phase in order to generate prototypes with which stakeholders can engage. The primary difference between the use of reflexivity in the tools of Synthesize Insights and Ideate Solutions phases and the Testing Hypotheses phase is that prototyping ultimately encourages practitioners to seek and gain new information—e.g. does the stakeholder use the prototype in the expected way and derive enough value from it? Whereas Synthesize Insights and Ideate Solutions focus the practitioner and their teams on taking existing information and analyzing primarily through dialog to generate new insights that inform later phases.

The findings of this study that focused on the unique nature of the Synthesize Insights and Ideate Solutions phases contribute to the management literature's interest in opportunities that entrepreneurs and business leaders leverage. Problems give rise to opportunities for new value propositions (Simon & Hayes, 1976; Tversky & Kahneman, 1981). Such opportunities can emerge as a result of iterative communications processes where problem-solvers and the problems' stakeholders exchange and integrate each other's perspectives (i.e., intersubjectivity; Davidson, 2001; Suddaby, Bruton, & Si, 2015; Venkataraman, Sarasvathy, Dew, & Forster, 2012). Much of the research to date has focused on delineating the process of intersubjective communications, however does not discuss the mechanisms that elicit intersubjectivity have received considerably less attention. The findings of the current study contribute to this gap in knowledge by providing concrete suggestions for facilitating intersubjective processes during opportunity identification and actualization. For instance, the earlier example of Gallery Walks is a mechanism for intersubjective communication because it encourages practitioners to distill and share stakeholders' perspectives with the aim of gaining refined understanding of the problem space and nascent ideas for opportunities value propositions.

5.1.2 Design Thinking tools and perceived team cooperation

The empirical results of this research extend theories within the team cooperation literature. These findings indicated that there is a positive relationship between practitioners' and their teams' use of DT phases comprised of reflexive activities and the practitioners' perception of team cooperation during their projects' lifecycle. Cooperation within teams has been shown to improve the probability of project outcomes (Pinto,

Pinto, & Prescott, 1993). This research has shown a link between the DT tools that prioritize reflexivity and the team leaders' perceptions of heightened team cooperation. The team reflexivity-oriented tools in the Synthesize Insights and Ideate Solutions phase encourage dialog among team members and prescribe methods that elicit the participation of all team members and simultaneously reduce the risk of sharing ideas that are not yet fully formed within the work team. Tools in the Ideate Solutions phase push practitioner and their teams to creatively combine their existing knowledge and find ideas that construct useful solutions spaces. For example, research by (Kavadias & Sommer, 2009) indicates that in the case of problems with low specifications, brainstorming teams produce more ideas. This suggests that brainstorming sessions where teams work with low specifications engenders more engagement, which is likely to contribute to the practitioners' perception of cooperation within the team. Similar rules exist for the other tools in this phase. If the teams use these tools, the likelihood is higher that practitioners will have the opportunity to observe more cooperation among their teams.

5.1.3 Independence of antecedents (problem specificity) and consequences (perceived team cooperation) of applying DT phases and tools

Practitioners' selective use of the prescriptive process that DT phases and tools relates to both problem specificity and subsequent perceptions of team collaboration. There is the possibility of a direct relationship between problem specificity and perceived team cooperation. However, exploratory analysis of direct relationships between practitioners' chosen level of problem specificity and their subsequent perceptions of team cooperation revealed no statistically significant relationships (Pearson correlation = -0.107; $p > 0.06$). The observed lack of relationship is consistent with research by Aram and Morgan (1976) that task orientation (high specifications) and exploration of opportunities (low specifications) can foster individual collaborative behaviors during innovative projects. Further research by Gebert, Boerner, and Kearney (2010) indicates that teams have the capacity to cooperate effectively when facing tasks that encourage knowledge integration (high specifications) and knowledge generation (low specifications) concurrently. These studies are corroborated by research by Pinto et al (1993) that team processes are more important for team cooperation than goals. The results in this study further support these findings by connecting problem specificity with team cooperation outcomes through the mediating impact of the use of DT tools. Since no independent impact of specificity on team cooperation is indicated, the results suggest that it is the problem-solving process by which the two are linked.

5.1.4 Design Thinking tools that are not phase specific

Part of the power assigned to DT is its iterative nature (Brown & Katz, 2011; Liedtka, 2015). Practitioners, when using DT to its fullest, constantly return to earlier tools as necessary to assure that they increasingly improve their assessment of their current reality. Additionally, practitioners can use some of the DT tools throughout the problem-solving process. One such tool is Co-creation, which is associated with the final phase, Testing Hypotheses, of the linear model applied in this research project. The Co-creation tool embodies the ethos for the practitioners to work closely with their stakeholders, to develop solutions together, and maximize the knowledge and resources that the stakeholders can contribute to the final solution. Table 3.5 on page 66 indicates that 42.3 percent of practitioners used Co-Creation versus 19.3 percent who used the other Testing Assumptions tool, the Learning Launch. The Co-Creation tool is paired with Learning Launch tool because of the close work required between practitioners and stakeholders particularly during the final testing phase. However, its utility is important throughout the DT process.

Analysis of the survey responses revealed no significant correlations between the co-creation responses on the survey and problem specificity ($p > 0.4$) and perceived team cooperation ($p > 0.7$). Additional analysis also revealed no significant correlations between the Learning Launch tool and either problem ($p > 0.4$) specificity or perceived cooperation ($p > 0.9$).

5.2 Practical Implications

This study yielded insights for DT practitioners and those who wish to start using DT to solve problems. Firstly, this research detected that practitioners use the portfolio of DT tools differently. Managers of such practitioners should be aware that the DT process is unlikely to unfold in the same way across multiple projects. Particularly, the practitioners sampled in this research generally prioritized the earlier exploratory phases of the DT methodology including Understand the Problem, Synthesize Insights and Ideate Solutions. The activities in these phases encourage practitioners and their project teams to acquire, share, and process information with other project stakeholders. This sample indicated lower focus on the subsequent testing phases – Prototype Solutions and Testing Hypotheses – which are integral phases of the holistic DT methodology. While it is beyond the scope of this research to identify reasons why practitioners made these choices, these findings do show that practitioners presumably face obstacles that reduce their likelihood of testing the solutions they develop during the exploratory phases.

Additionally, this research uncovered a relationship between reflexive DT tools and practitioners' perceptions of cooperation within their teams. This perception can continue to bolster trust in teams. Innovation is often a challenge and can hinder a teams' ability to cooperate effectively (Miron-Spektor, Erez, & Naveh, 2011), while cooperation generally fosters trust and helps teams remain productive (Mayer, Davis, & Schoorman, 1995). This research suggests that practitioners are likely to use more tools in certain phases of the DT methodology when they face problems that lack specifications and obvious solutions. Knowing ahead of time whether idealized solutions exist or not, may help practitioners predict the amount of effort they anticipate spending on activities that focus on synthesizing insights and ideating new solutions. An ancillary consideration for practitioners regarding their choice of specifications in their problems is also their ability to redefine the problem as more information about the problem space becomes available. A constrained search of a highly specified problem may uncover disconfirming data which supports redefining the problem. However, highly specified problems can be difficult to renegotiate due to sunk costs and path dependence. (Thrane, Blaabjerg , & Møller, 2010). Practitioners and their managers should consider the possibility that renegotiation of problem parameters may be necessary after any of the DT phases.

This study also highlights implications for trainers introducing DT to leaders who wish to incorporate DT into their repertoires. This study focused on teaching new practitioners the tenets of DT using their self-selected projects. The practitioners who chose problems with high levels of specificity, on average, chose to practice fewer tools. Trainers who work within the bounds of self-selected problems should be aware of the possibility that their students may practice a limited number of tools across the phases.

Trainers should also consider that new practitioners may underestimate how the phases in the DT methodology reinforce themselves in the pursuit of solutions that meet their stakeholders' needs.

5.3 Limitations

This study offers insights on the implementation of DT tools and associated outcomes. This research explores practitioners' use of the full portfolio of design thinking tools in real-world project situations over an extended time horizon. This time horizon gives practitioners time to make significant progress on their individual projects. The practitioners in this research study were all from the same company, Tharsis Inc., and had roughly the same level of experience and seniority at the company. The practitioners participated in a complex training program that was delivered with consistency across the many cohorts of practitioners. While the basic program remained the same throughout, each participant had different experiences throughout the six-month training program based on realities of operations in organizations. These real-world observations provide insights to how practitioners apply the DT methodology when they face realistic obstacles. This is a useful study due to its large sample size and consistency in delivery of the training program in a single company.

The strengths of this study exceed its limitations. All of the practitioners in the program received the same training experience and used their training in their own work environment. They received the same preparation materials that helped them choose their problem. Their experiences reflect how DT can unfold in a corporate setting where there is no widespread familiarity with DT principles or processes. With 305 participants included in the analysis, this dataset has a high-level of statistical relevance. This research provides an important view of the DT problem-solving methodology in a globally significant company, and provides a foundation on which to build future research using the problem specificity, team cooperation, and reflexivity lenses.

There are limitations to this study that constrain its generalizability. These data were not initially collected for rigorous scholarly analysis. This required the development of proxies for problem specificity and perceived team cooperation rather than use of established scales. High interrater reliability scores of these proxies achieved using standard practice increases the validity of these proxies. While this study detected several significant effects, this research does not imply a causal relationship between the practitioners' choice of tools, their formulated problem specificity, or their perceptions of team cooperation. The data used in this research tested the hypotheses through the measurement of variances within the entire population that received the same DT training. Testing hypotheses based on within population variance is in line with similar research by Ployhart & Vandenberg (2010).

The data collection period for each of the practitioners covered approximately six months, which exposed the practitioners to various environmental factors. The individual projects that practitioners focused on as part of the training process allowed them to translate the conceptual learning into real-time and real-world experiments that facilitated learning through experience. However, the environmental uncertainty between practitioners' unique circumstances affect their ability to practice the full spectrum of DT tools (Mohammed & Angell, 2004).

These data exclude other team members' perceptions of their experiences during the projects. Reliance on a sole practitioner's perceptions of the team environment has precedence in studies, including Anderson, Hellriegel, & Slocum Jr. (1977), and contributes to understanding team leaders' sense of their teams' ability to cooperate and collectively move towards aspired goals.

5.4 Future Directions

This research makes contributions that lay the foundation for future research on problem specificity, team cooperation, and methodology-based innovation. This research has identified relationships that deserve further investigation. Firstly, in order to test the relationships in H1a, H1b, and H2 for causality, future research should include control groups that receive other interventions for example training in effectual logic, TRIZ, and Lean Startup methods as well as no other interventions. Comparing practitioners' use of these methodologies, along the problem specificity and team cooperation dimensions, contributes to the generalizability of the hypotheses in this research. Secondly, in order to further refine the generalizability of these findings, future research should consider the views of other team members as well as the teams' overall project performance in order to generate objective assessment of team cooperative behaviors. A broader range of performance metrics offers the possibility of identifying the tools that return higher value for the effort invested.

As process-oriented innovation continues to flourish in organizations, it is important to consider how such processes drive behaviors that ultimately deliver useful solutions to challenging problems. As mentioned earlier, the intersubjective nature of the

DT methodology overall and the Synthesize Insights and Ideate Solutions phases specifically warrants further investigation. The DT tools that may encourage intersubjective communication provides discrete environments for investigating the mechanisms that foster the development of new opportunities and subsequent value propositions. The DT process would be a useful testbed for tracking the evolution of problem-identification, opportunity identification, and solution development. Further research should consider the degree to which intersubjective communication influences outcomes of problem-based projects, both in terms of objective performance and team cooperation.

Future research should consider the extent to which practitioners utilize the DT methodology completely. Descriptive statistics showed that few practitioners (19.3 percent) used the Learning Launch testing tool, which is an important step for verifying the utility and viability of the proposed solution. Future studies should consider the degree to which practitioners advance their initiatives using selective tools in the DT methodology portfolio.

5.5 Summary

This study has exposed some of the inner mechanisms of DT that contribute to its use in organizations. These findings advance DT theory through the problem-formulation and team cooperation perspectives. These two perspectives offer an improved understanding of the distinct mechanisms within the DT methodology beyond what prior research has achieved. This research indicates that practitioners' choices in problem formulation relate to the degree to which they subsequently utilize the DT methodology, providing DT theory with an improved ability to predict tool utilization. These findings also highlight the relationship between reflexive tools and team cooperation, which provides theorists with an improved understanding of which tools in the DT toolkit relate to team-oriented outcomes. The team cooperation perspective remains salient for organizations as teams become more diverse in skills, expertise, and task motivation.

References

Agre, G. P. (1982). The concept of problem. *Educational Studies, 13*(2), 121-142.

Al′tshuller, G. S. (1999). *The innovation algorithm: TRIZ, systematic innovation and technical creativity* Technical Innovation Center, Inc.

Alexander, L., & Van Knippenberg, D. (2014). Teams in pursuit of radical innovation: A goal orientation perspective. *Academy of Management Review, 39*(4), 423-438.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal, 39*(5), 1154-1184.

Amason, A. C. (1996). Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management teams. *Academy of Management Journal, 39*(1), 123-148.

Anderson, C. R., Hellriegel, D., & Slocum Jr, J. W. (1977). Managerial response to environmentally induced stress. *Academy of Management Journal, 20*(2), 260-272.

Aram, J. D., & Morgan, C. P. (1976). The role of project team collaboration in R&D performance. *Management Science,* 22(10), 1127-1137.

Archer, L. B. (1979). Whatever became of design methodology. *Design Studies, 1*(1), 17-18.

Argyris, C. (1993). *Knowledge for action: A guide to overcoming barriers to organizational change*. Jossey-Bass Inc., Publishers, 350 Sansome Street, San Francisco, CA 94104.

Argyris, C. & Schön, D. (1996). Organizational learning II: Theory, method and practice. *Massachusetts: Addison-Wesley Publishing Company*.

Asimow, M. (1962). *Introduction to design* Prentice-Hall.

Baer, M., Dirks, K. T., & Nickerson, J. A. (2013). Microfoundations of strategic problem formulation. *Strategic Management Journal, 34*(2), 197-214.

Baer, M., Leenders, R. T. A., Oldham, G. R., & Vadera, A. K. (2010). Win or lose the battle for creativity: The power and perils of intergroup competition. *Academy of Management Journal, 53*(4), 827-845.

Bantel, K. A., & Jackson, S. E. (1989). Top management and innovations in banking: Does the composition of the top team make a difference? *Strategic Management Journal, 10*(S1), 107-124.

Bazerman, M. H., & Moore, D. A. (2009). Improving decision making. *Judgement in managerial decision making*, 179-199.

Beckman, S. L., & Barry, M. (2007). Innovation as a learning process: Embedding design thinking. *California Management Review, 50*(1), 25-56.

Behling, O., & Eckel, N. L. (1991). Making sense out of intuition. *Academy of Management Perspectives, 5*(1), 46-54.

Bertola, P., & Teixeira, J. C. (2003). Design as a knowledge agent: How design as a knowledge process is embedded into organizations to foster innovation. *Design Studies, 24*(2), 181-194.

Birkinshaw, J., Hamel, G., & Mol, M. J. (2008). Management innovation. *Academy of Management Review, 33*(4), 825-845.

Boland Jr, R. J., & Tenkasi, R. V. (1995). Perspective making and perspective taking in communities of knowing. *Organization Science, 6*(4), 350-372.

Broadbent, G. (1973). *Design in architecture: architecture and the human sciences*. London, New York: John Wiley & Sons.

Brown, J., & Duguid, P. (2000). Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. *Knowledge and communities* (pp. 99-121) Elsevier.

Brown, T. (2009). *Change by design: How design thinking creates new alternatives for business and society*. Collins Business.

Brown, T., & Katz, B. (2011). Change by design. *Journal of Product Innovation Management, 28*(3), 381-383.

Brown, T. (2008). Design Thinking. *Harvard Business Review, 86*(6), 84.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues, 8*(2), 5-21.

Buchanan, R. (2001). Design research and the new learning. *Design Issues, 17*(4), 3-23.

Büschgens, T., Bausch, A., & Balkin, D. B. (2013). Organizational culture and innovation: A meta-analytic review. *Journal of Product Innovation Management, 30*(4), 763-781.

Buzan, T., & Buzan, B. (1996). *The mind map book: How to use radiant thinking to maximize your brain's untapped potential* Plume New York.

Camillus, J. C. (2008). Strategy as a wicked problem. *Harvard Business Review, 86*(5), 98.

Carlgren, L. (2013). *Design thinking as an enabler of innovation: Exploring the concept and its relation to building innovation capabilities* Chalmers University of Technology.

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing design thinking: The concept in idea and enactment. *Creativity and Innovation Management, 25*(1), 38-57.

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing design thinking: The concept in idea and enactment. *Creativity and Innovation Management, 25*(1), 38-57.

Cartwright, T. J. (1973). Problems, solutions and strategies: A contribution to the theory and practice of planning. *Journal of the American Institute of Planners, 39*(3), 179-187.

Chandy, R. K., & Tellis, G. J. (1998). Organizing for radical product innovation: The overlooked role of willingness to cannibalize. *Journal of Marketing Research,* , 474-487.

Choo, A. S. (2014). Defining problems fast and slow: The u-shaped effect of problem definition time on project duration. *Production and Operations Management, 23*(8), 1462-1479.

Churchman, C. W. (1971). The design of inquiring systems basic concepts of systems and organization.

Cockburn, A., & Highsmith, J. (2001). Agile software development, the people factor. *Computer, 34*(11), 131-133.

Cohen, J. (1968). Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit. *Psychological Bulletin, 70*(4), 213.

Contu, A. (2014). On boundaries and difference: Communities of practice and power relations in creative work. *Management Learning, 45*(3), 289-316.

Cooper, D. R., Schindler, P. S., & Sun, J. (2006). *Business research methods* McGraw-Hill Irwin New York.

Cooper, R., Junginger, S., & Lockwood, T. (2009). Design thinking and design management: A research and practice perspective. *Design Management Review, 20*(2), 46-55.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design Issues, 17*(3), 49-55.

Cross, N. (2004). Expertise in design: An overview. *Design Studies, 25*(5), 427-441.

Cross, N. (2011). *Design thinking: Understanding how designers think and work* Berg.

Cross, N. (2018). 21 expertise in professional design. *The Cambridge Handbook of Expertise and Expert Performance*, 372-388.

Cross, N., & Cross, A. C. (1995). Observations of teamwork and social processes in design. *Design Studies, 16*(2), 143-170.

De Dreu, C. K. (2007). Cooperative outcome interdependence, task reflexivity, and team effectiveness: a motivated information processing perspective. *Journal of Applied Psychology*, 92(3), 628.

De Dreu, C. K. (2006). When too little or too much hurts: Evidence for a curvilinear relationship between task conflict and innovation in teams. *Journal of Management, 32*(1), 83-107.

De Dreu, C. K., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology*, *88*(4), 741.

De Dreu, C. K., & West, M. A. (2001). Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology*, *86*(6), 1191.

De Jong, B. A., & Elfring, T. (2010). How does trust affect the performance of ongoing teams? the mediating role of reflexivity, monitoring, and effort. *Academy of Management Journal, 53*(3), 535-549.

Deming, W. E. (1986). Out of the crisis. massachusetts institute of technology. *Center for Advanced Engineering Study, Cambridge, MA, 510*

Dewey, J. (1958). *Experience and nature* Courier Corporation.

Doane, D. P., & Seward, L. E. (2011). Measuring skewness: A forgotten statistic? *Journal of Statistics Education, 19*(2)

Dollinger, M. J. (1984). Environmental boundary spanning and information processing effects on organizational performance. *Academy of Management Journal, 27*(2), 351-368.

Dorst, K. (2006). Design problems and design paradoxes. *Design Issues, 22*(3), 4-17.

Dorst, K. (2011). The core of ‘design thinking’ and its application. *Design Studies, 32*(6), 521-532.

Dorst, K. (2015). Frame innovation: Create new thinking by design. MIT Press.

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem–solution. *Design Studies, 22*(5), 425-437.

Drucker, P. F. (1984). Converting social problems into business opportunities: The new meaning of corporate social responsibility. *California Management Review (Pre-1986), 26*(000002), 53.

Dunne, D., & Martin, R. (2006). Design thinking and how it will change management education: An interview and discussion. *Academy of Management Learning & Education, 5*(4), 512-523.

Easterby-Smith, M., & Malina, D. (1999). Cross-cultural collaborative research: Toward reflexivity. *Academy of Management Journal, 42*(1), 76-86.

Edmondson, A. C., & Nembhard, I. M. (2009). Product development and learning in project teams: The challenges are the benefits. *Journal of Product Innovation Management, 26*(2), 123-138.

Elsbach, K. D., & Stigliani, I. (2018). Design thinking and organizational culture: A review and framework for future research. *Journal of Management, 44*(6), 2274-2306.

Erat, S., & Krishnan, V. (2012). Managing delegated search over design spaces. *Management Science, 58*(3), 606-623.

Etzion, D., & Pe'er, A. (2014). Mixed signals: A dynamic analysis of warranty provision in the automotive industry, 1960–2008. *Strategic Management Journal, 35*(11), 1605-1625.

Fisher, K., & Fisher, M. D. (1998). *The distributed mind: Achieving high performance through the collective intelligence of knowledge work teams* Amacom New York.

Fixson, S. K., & Read, J. M. (2012). Creating innovation leaders: Why we need to blend business and design education. *Design Management Review, 23*(4), 4-12.

Fleming, L., & Sorenson, O. (2004). Science as a map in technological search. *Strategic Management Journal, 25*(8-9), 909-928.

Foss, N. J., Frederiksen, L., & Rullani, F. (2016). Problem-formulation and problem-solving in self-organized communities: How modes of communication shape project behaviors in the free open-source software community. *Strategic Management Journal, 37*(13), 2589-2610.

George, J. M., & Zhou, J. (2002). Understanding when bad moods foster creativity and good ones don't: The role of context and clarity of feelings. *Journal of Applied Psychology, 87*(4), 687.

Gebert, D., Boerner, S., & Kearney, E. (2010). Fostering team innovation: Why is it important to combine opposing action strategies? *Organization Science*, 21(3), 593-608.

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research* Routledge.

Gold, A. H., Malhotra, A., & Segars, A. H. (2001). Knowledge management: An organizational capabilities perspective. *Journal of Management Information Systems, 18*(1), 185-214.

Goldschmidt, G., & Rodgers, P. A. (2013). The design thinking approaches of three different groups of designers based on self-reports. *Design Studies, 34*(4), 454-471.

Gruber, M., De Leon, N., George, G., & Thompson, P. (2015). Managing by design. *Academy of Management Journal, 58*(1), 1-7.

Guindon, R. (1990). Designing the design process: Exploiting opportunistic thoughts. *Human-Computer Interaction, 5*(2), 305-344.

Hall, A. D. (1962). A methodology for systems engineering.

Hambrick, D. C. (1994). Top management groups: A conceptual integration and reconsideration of the" team" label. *Research in Organizational Behavior, 16*, 171-171.

Hambrick, D. C. (1995). Fragmentation and the other problems CEOs have with their top management teams. *California Management Review, 37*(3), 110-127.

Hammersley, M., & Atkinson, P. (2007). *Ethnography: Principles in practice* Routledge.

Harry, M., & Schroeder, R. (2006). *Six Sigma: The breakthrough management strategy revolutionizing the world's top corporations* Crown Business.

Hendry, J. (2002). The principal's other problems: Honest incompetence and the specification of objectives. *Academy of Management Review, 27*(1), 98-113.

Hirst, G., Van Knippenberg, D., & Zhou, J. (2009). A cross-level perspective on employee creativity: Goal orientation, team learning behavior, and individual creativity. *Academy of Management Journal, 52*(2), 280-293.

Hitt, M. A., & Tyler, B. B. (1991). Strategic decision models: Integrating different perspectives. *Strategic Management Journal, 12*(5), 327-351.

Hoegl, M., & Parboteeah, K. P. (2006). Team reflexivity in innovative projects. *R&D Management, 36*(2), 113-125.

Holmstrom, B., & Milgrom, P. (1991). Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics, & Organization, 7*, 24-52.

Hsieh, C., Nickerson, J. A., & Zenger, T. R. (2007). Opportunity discovery, problem solving and a theory of the entrepreneurial firm. *Journal of Management Studies, 44*(7), 1255-1277.

Hubka, V., & Eder, W. E. (2012). *Design science: Introduction to the needs, scope and organization of engineering design knowledge* Springer Science & Business Media.

Jones, G. R., & Butler, J. E. (1992). Managing internal corporate entrepreneurship: An agency theory perspective. *Journal of Management, 18*(4), 733-749.

Jones, J. C. (1977). How my thoughts about design methods have changed during the years. *Design Methods and Theories, 11*(1), 48-62.

Junni, P., Sarala, R. M., Taras, V., & Tarba, S. Y. (2013). Organizational ambidexterity and performance: A meta-analysis. *The Academy of Management Perspectives, 27*(4), 299-312.

Katila, R., & Ahuja, G. (2002). Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal, 45*(6), 1183-1194.

Kavadias, S., & Sommer, S. C. (2009). The effects of problem structure and team diversity on brainstorming effectiveness. *Management Science, 55*(12), 1899-1913.

Keller, R. T. (2001). Cross-functional project groups in research and new product development: Diversity, communications, job stress, and outcomes. *Academy of Management Journal, 44*(3), 547-555.

KELLEY, T. A. (2001). *The art of innovation: Lessons in creativity from IDEO, america's leading design firm* Broadway Business.

Kepner, C. H., & Tregoe, B. B. (1965). *The rational manager: A systematic approach to problem solving and decision making* McGraw-Hill.

Klayman, J., & Ha, Y. (1987). Confirmation, disconfirmation, and information in hypothesis testing. *Psychological Review, 94*(2), 211.

Klein, G., Moon, B., & Hoffman, R. R. (2006). Making sense of sensemaking 1: Alternative perspectives. *IEEE Intelligent Systems,* (4), 70-73.

Kolko, J. (2010). Abductive thinking and sensemaking: The drivers of design synthesis. *Design Issues, 26*(1), 15-28.

Kolko, J. (2015). Design thinking comes of age. *Harvard Business Review, 93*(9), 66-71.

Kruger, C., & Cross, N. (2006). Solution driven versus problem driven design: Strategies and outcomes. *Design Studies, 27*(5), 527-548.

Kurtmollaiev, S., Pedersen, P. E., Fjuk, A., & Kvale, K. (2018). Developing managerial dynamic capabilities: A quasi-experimental field study of the effects of design thinking training. *Academy of Management Learning & Education, 17*(2), 184-202.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics,* , 159-174.

Larsson, R. (1993). Case survey methodology: Quantitative analysis of patterns across case studies. *Academy of Management Journal, 36*(6), 1515-1546.

Lawson, B. R. (1979). Cognitive strategies in architectural design. *Ergonomics, 22*(1), 59-68.

Le Masson, P., Weil, B., & Hatchuel, A. (2010). *Strategic management of innovation and design* Cambridge University Press.

Leavy, B. (2010). Design thinking–a new mental model of value innovation. *Strategy & Leadership, 38*(3), 5-14.

LeBreton, J. M., & Senter, J. L. (2008). Answers to 20 questions about interrater reliability and interrater agreement. *Organizational Research Methods, 11*(4), 815-852.

Leonard, D., & Sensiper, S. (1998). The role of tacit knowledge in group innovation. *California Management Review, 40*(3), 112-132.

Leonard, D., & Straus, S. (1997). Putting your company's whole brain to work. *Harvard Business Review, 75*, 110-122.

Leonard, D. (1995). *Wellsprings of knowledge* (p. 65). Boston: Harvard Business School Press.

Liedtka, J. (2000). In defense of strategy as design. *California Management Review, 42*(3), 8-30.

Liedtka, J. (2014). Innovative ways companies are using design thinking. *Strategy & Leadership, 42*(2), 40-45.

Liedtka, J., King, A., & Bennett, K. (2013). *Solving problems with design thinking: Ten stories of what works* Columbia University Press.

Liedtka, J., & Mintzberg, H. (2006). Time for design. *Design Management Review, 17*(2), 10-18.

Liedtka, J., Ogilvie, T., & Brozenske, R. (2014). *The designing for growth field book: A step-by-step project guide* Columbia University Press.

Liedtka, J. (2015). Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction. *Journal of Product Innovation Management, 32*(6), 925-938. doi:10.1111/jpim.12163

Liedtka, J. (2017). Evaluating the impact of design thinking in action. Paper presented at the *Academy of Management Proceedings, , 2017*(1) 10264.

Lindberg, T., Meinel, C., & Wagner, R. (2011). Design thinking: A fruitful concept for it development? *Design thinking* (pp. 3-18) Springer.

Lloyd, P., & Scott, P. (1994). Discovering the design problem. *Design Studies, 15*(2), 125-140.

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance.* Prentice-Hall, Inc.

Lockwood, T. (2009). Transition: How to become a more design-minded organization. *Design Management Review, 20*(3), 28-37.

Lockwood, T. (2010). *Design thinking: Integrating innovation, customer experience, and brand value*. Simon and Schuster.

Luchs, M. G., Griffin, A., & Swan, S. (2015). *Design thinking: New product development essentials from the PDMA* John Wiley & Sons.

Lumley, T., Diehr, P., Emerson, S., & Chen, L. (2002). The importance of the normality assumption in large public health data sets. *Annual Review of Public Health, 23*(1), 151-169.

Lyles, M. A., & Mitroff, I. I. (1980). Organizational problem formulation: An empirical study. *Administrative Science Quarterly,* 102-119.

Lyles, M. A., & Thomas, H. (1988). Strategic problem formulation: Biases and assumptions embedded in alternative decision-making models. *Journal of Management Studies, 25*(2), 131-145.

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics,* , 50-60.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science, 2*(1), 71-87.

March, J. G., & Simon, H. A. (1958). Organizations. Wiley. New York.

March, L. (1976). *The architecture of form* Cambridge University Press.

Margolin, V. (1989). *Design discourse: History, theory, criticism* University of Chicago Press.

Martelaro, N., Ganguly, S., Steinert, M., & Jung, M. (2015). The personal trait myth: A comparative analysis of the innovation impact of design thinking tools and personal traits. *Design thinking research* (pp. 41-57) Springer.

Martin, R. L. (2009). *The design of business: Why design thinking is the next competitive advantage* Harvard Business Press.

Mason, R. O., & Mitroff, I. I. (1973). A program for research on management information systems. *Management Science, 19*(5), 475-487.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review, 20*(3), 709-734.

McGrath, R. G. (1999). Falling forward: Real options reasoning and entrepreneurial failure. *Academy of Management Review, 24*(1), 13-30.

Miller, C. C., & Ireland, R. D. (2005). Intuition in strategic decision making: Friend or foe in the fast-paced 21st century? *Academy of Management Perspectives, 19*(1), 19-30.

Mintzberg, H. (1990). Strategy formation: Schools of thought. *Perspectives on Strategic Management, 1968*, 105-235.

Mintzberg, H. (2004). *Managers, not MBAs: A hard look at the soft practice of managing and management development* Berrett-Koehler Publishers.

Miron-Spektor, E., Erez, M., & Naveh, E. (2011). The effect of conformist and attentive-to-detail members on team innovation: Reconciling the innovation paradox. *Academy of Management Journal, 54*(4), 740-760.

Mitroff, I. I., Emshoff, J. R., & Kilmann, R. H. (1979). Assumptional analysis: A methodology for strategic problem solving. *Management Science, 25*(6), 583-593.

Mitroff, I. I., & Featheringham, T. R. (1974). On systemic problem solving and the error of the third kind. *Behavioral Science, 19*(6), 383-393.

Mohammed, S., & Angell, L. C. (2004). Surface-and deep-level diversity in workgroups: Examining the moderating effects of team orientation and team process on relationship conflict. *Journal of Organizational Behavior, 25*(8), 1015-1039.

Müller, R. M., & Thoring, K. (2012). Design thinking vs. lean startup: A comparison of two user-driven innovation strategies. *Leading through Design, 151*

Newell, A., & Simon, H. A. (1972). *Human problem solving* Prentice-Hall Englewood Cliffs, NJ.

Newell, S. (1990). Collaborative learning in engineering design. *Journal of College Science Teaching, 19*(6), 359-362.

Nickerson, J. A., & Zenger, T. R. (2004). A knowledge-based theory of the firm—The problem-solving perspective. *Organization Science, 15*(6), 617-632.

Norman, D. (2013). *The design of everyday things: Revised and expanded edition* Constellation.

Novick, L. R., & Sherman, S. J. (2003). On the nature of insight solutions: Evidence from skill differences in anagram solution. *The Quarterly Journal of Experimental Psychology Section A, 56*(2), 351-382.

Ogilvie, T., & Liedtka, J. (2011). *Designing for growth: A design thinking toolkit for managers* Columbia University Press.

Orwin, R. G., & Vevea, J. L. (2009). Evaluating coding decisions. *The Handbook of Research Synthesis and Meta-Analysis, 2*, 177-203.

Osborn, A. F. (1953). Applied imagination. Oxford, England: Scribner's

Owens, D. A. (2000). Structure and status in design teams: Implications for design management. *Academic Review, 1*(1), 55-63.

Palepu, K. (1985). Diversification strategy, profit performance and the entropy measure. *Strategic Management Journal, 6*(3), 239-255.

Patnaik, D. (2009). *Wired to care: How companies prosper when they create widespread empathy* Ft Press.

Paulus, P. (2000). Groups, teams, and creativity: The creative potential of idea-generating groups. *Applied Psychology, 49*(2), 237-262.

Peirce, C. S. (1974). *Collected papers of Charles Sanders Peirce.* Harvard University Press.

Perreault, W. D., & Leigh, L. E. (1989). Reliability of nominal data based on qualitative judgments. *Journal of Marketing Research, 26*(2), 135.

Peterson, B. K., & Wong-On-Wing, B. (2000). An examination of the positive test strategy in auditors' hypothesis testing. *Behavioral Research in Accounting, 12*, 257.

Pinto, M. B., Pinto, J. K., & Prescott, J. E. (1993). Antecedents and consequences of project team cross-functional cooperation. *Management Science, 39*(10), 1281-1297.

Pinto, M. B., Pinto, J. K., & Prescott, J. E. (1993). Antecedents and consequences of project team cross-functional cooperation. *Management Science, 39*(10), 1281-1297.

Plattner, H., Meinel, C., & Leifer, L. (2012). *Design thinking research* Springer.

Plattner, H., Meinel, C., & Weinberg, U. (2009). *Design thinking* Springer.

Ployhart, R. E., & Vandenberg, R. J. (2010). Longitudinal research: The theory, design, and analysis of change. *Journal of Management, 36*(1), 94-120.

Pounds, W. F. (1969). The Process of Problem Finding. *Sloan Management Review,* 11(1), 1.

Powell, T. C. (1995). Total quality management as competitive advantage: A review and empirical study. *Strategic Management Journal, 16*(1), 15-37.

Purser, R. E., Pasmore, W. A., & Tenkasi, R. V. (1992). The influence of deliberations on learning in new product development teams. *Journal of Engineering and Technology Management, 9*(1), 1-28.

Quinn, J. B. (1980). Managing strategic change. *Sloan Management Review (Pre-1986), 21*(4), 3.

Ralph, P., & Wand, Y. (2009). A proposal for a formal definition of the design concept. *Design requirements engineering: A ten-year perspective* (pp. 103-136) Springer.

Read, S., Sarasvathy, S., Dew, N., & Wiltbank, R. (2016). *Effectual entrepreneurship* Routledge.

Reitman, W. R. (1964). Heuristic decision procedures, open constraints, and the structure of ill-defined problems. *Human Judgments and Optimality,* , 282-315.

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses* Crown Books.

Rijsdijk, S. A., & van den Ende, J. (2011). Control combinations in new product development projects. *Journal of Product Innovation Management, 28*(6), 868-880.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*(2), 155-169.

Salomo, S., & Mensel, N. (2001). Front-end idea generation for innovation: Empirical evidence from german industrial corporations. Paper presented at the *Management of Engineering and Technology, 2001. PICMET'01. Portland International Conference On,* 117-123.

Samson, D., & Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management, 17*(4), 393-409.

Sarasvathy, S. D. (2001). Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. *Academy of Management Review, 26*(2), 243-263.

Sawilowsky, S. S., & Blair, R. C. (1992). A more realistic look at the robustness and type II error properties of the t test to departures from population normality. *Psychological Bulletin, 111*(2), 352.

Schippers, M. C., Edmondson, A. C., & West, M. A. (2014). Team reflexivity as an antidote to team information-processing failures. *Small Group Research, 45*(6), 731-769.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. Routledge.

Seidel, V. P., & Fixson, S. K. (2013). Adopting design thinking in novice multidisciplinary teams: The application and limits of design methods and reflexive practices. *Journal of Product Innovation Management, 30*(S1), 19-33.

Senge, P. (1990). The fifth discipline: The art and science of the learning organization. *New York: Currency Doubleday,*

Shepherd, D. A., Haynie, J. M., & McMullen, J. S. (2012). Confirmatory search as a useful heuristic? testing the veracity of entrepreneurial conjectures. *Journal of Business Venturing, 27*(6), 637-651.

Shrivastava, P., & Mitroff, I. I. (1984). Enhancing organizational research utilization: The role of decision makers' assumptions. *Academy of Management Review, 9*(1), 18-26.

Siegel, S. (1957). Nonparametric statistics. *The American Statistician, 11*(3), 13-19.

Simon, H. A. (1972). Theories of bounded rationality. *Decision and Organization, 1*(1), 161-176.

Simon, H. A. (1973). The structure of ill structured problems. *Artificial Intelligence, 4*(3-4), 181-201.

Simon, H. A. (1988). The science of design: Creating the artificial. *Design Issues,* 67-82.

Simon, H. A. (1996). *The sciences of the artificial* MIT press.

Simon, H. A., & Hayes, J. R. (1976). The understanding process: Problem isomorphs. *Cognitive Psychology, 8*(2), 165-190.

Simsek, Z., Veiga, J. F., Lubatkin, M. H., & Dino, R. N. (2005). Modeling the multilevel determinants of top management team behavioral integration. *Academy of Management Journal, 48*(1), 69-84.

Smith, G. F. (1989). Defining managerial problems: A framework for prescriptive theorizing. *Management Science, 35*(8), 963-981.

Somech, A., & Drach-Zahavy, A. (2013). Translating team creativity to innovation implementation: The role of team composition and climate for innovation. *Journal of Management, 39*(3), 684-708.

Sonalkar, N., Mabogunje, A., Pai, G., Krishnan, A., & Roth, B. (2016). Diagnostics for design thinking teams. *Design thinking research* (pp. 35-51) Springer.

Stahl, G. K., & Voigt, A. (2008). Do cultural differences matter in mergers and acquisitions? A tentative model and examination. *Organization Science, 19*(1), 160-176.

Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams-an analysis of team communication. *Design Studies, 23*(5), 473-496.

Sutton, R. I., & Hargadon, A. (1996). Brainstorming groups in context: Effectiveness in a product design firm. *Administrative Science Quarterly,* 685-718.

Thomke, S. H. (1998). Managing experimentation in the design of new products. *Management Science, 44*(6), 743-762.

Thrane, S., Blaabjerg, S., & Møller, R. H. (2010). Innovative path dependence: Making sense of product and service innovation in path dependent innovation processes. *Research Policy*, 39(7), 932-944.

Tippmann, E., Sharkey Scott, P., & Parker, A. (2017). Boundary capabilities in MNCs: Knowledge transformation for creative solution development. *Journal of Management Studies, 54*(4), 455-482.

Tjosvold, D., Tang, M. M., & West, M. (2004). Reflexivity for team innovation in china: The contribution of goal interdependence. *Group & Organization Management, 29*(5), 540-559.

Treverton, G. F., & Gabbard, C. B. (2008). *Assessing the tradecraft of intelligence analysis* Rand Corporation.

Tschimmel, K. (2012). Design thinking as an effective toolkit for innovation. Paper presented at the *ISPIM Conference Proceedings,* 1.

Tushman, M., & Nadler, D. (1986). Organizing for innovation. *California Management Review, 28*(3), 74-92.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124-1131.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211*(4481), 453-458.

Ucbasaran, D., Westhead, P., & Wright, M. (2009). The extent and nature of opportunity identification by experienced entrepreneurs. *Journal of Business Venturing, 24*(2), 99-115.

Vaghely, I. P., & Julien, P. (2010). Are opportunities recognized or constructed?: An information perspective on entrepreneurial opportunity identification. *Journal of Business Venturing, 25*(1), 73-86.

Van Knippenberg, D., De Dreu, C. K., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*(6), 1008.

Veryzer, R. W., & Borja de Mozota, B. (2005). The impact of user-oriented design on new product development: An examination of fundamental relationships. *Journal of Product Innovation Management, 22*(2), 128-143.

Victor, B., Boynton, A., & Stephens-Jahng, T. (2000). The effective design of work under total quality management. *Organization Science, 11*(1), 102-117.

Viera, A. J., & Garrett, J. M. (2005). Understanding interobserver agreement: The kappa statistic. *Family Medicine, 37*(5), 360-363.

Volkema, R. (2009). Natural language and the art and science of problem/opportunity formulation: A transportation planning case analysis. *Journal of the Operational Research Society, 60*(10), 1360-1372.

Volkema, R. J. (1983). Problem formulation in planning and design. *Management Science, 29*(6), 639-652.

Volkema, R. J. (1988). Problem complexity and the formulation process in planning and design. *Behavioral Science, 33*(4), 292-300.

Volkema, R. J. (2010). Designing effective projects: Decision options for maximizing learning and project success. *Journal of Management Education, 34*(4), 527-550.

Von Hippel, E., & Von Krogh, G. (2015). Crossroads—identifying viable "Need–solution pairs": Problem solving without problem formulation. *Organization Science, 27*(1), 207-221.

Wall Jr, J. A., & Callister, R. R. (1995). Conflict and its management. *Journal of Management, 21*(3), 515-558.

Weick, K. E. (1995). *Sensemaking in organizations* (Vol 3) Sage.

West, M. A., Beyerlein, M., Johnson, D., & Beyerlein, S. (2000). Reflexivity, revolution and innovation in work teams. *Advances in interdisciplinary studies of work teams,* 5.

West, M. A. (2002). Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups. *Applied Psychology, 51*(3), 355-387.

West, M., Garrod, S., & Carletta, J. (1997). Group decision-making and effectiveness: Unexplored boundaries. 293-317

Wynn, D., & Clarkson, J. (2005). Models of designing. *Design process improvement* (pp. 34-59) Springer.

Zhou, J., & Shalley, C. E. (2003). Research on employee creativity: A critical review and directions for future research. *Research in personnel and human resources management* (pp. 165-217) Emerald Group Publishing Limited.

6 Appendix

6.1 Design Thinking Activities Description

6.1.1 Stanford d.School

The d.School offers the following brief guidance for the process:

> *EMPATHIZE: Work to fully understand the experience of the user for whom you are designing. Do this through observation, interaction, and immersing yourself in their experiences.*
>
> *DEFINE: Process and synthesize the findings from your empathy work in order to form a user point of view that you will address with your design.*
>
> *IDEATE: Explore a wide variety of possible solutions through generating a large quantity of diverse possible solutions, allowing you to step beyond the obvious and explore a range of ideas.*
>
> *PROTOTYPE: Transform your ideas into a physical form so that you can experience and interact with them and, in the process, learn and develop more empathy.*
>
> *TEST: Try out high-resolution products and use observations and feedback to refine prototypes, learn more about the user, and refine your original point of view.*

Source: http://web.stanford.edu/group/cilab/cgi-bin/redesigningtheater/the-design-thinking-process/

6.1.2 Designing for Growth tools description

6.1.2.1 Understand the Problem

Direct observation focuses on "stepping into the user's 'native habitat' and capturing the full context without interpretation or judgement." This task encourages the design thinker to carefully capture the nuances of the users' activities without making inferences about what may or may not be driving their choices and actions. Specific activities include observing users, their environment, their interactions, and their behavior, and recording these observations without interpretations.

Ethnographic interviews are rooted in the scholarly practice of understanding human culture. These interviews help design thinkers "capture the full context of [users'] experience, including behaviors, attitudes, beliefs, and cultural meaning," with the aim to build a deep understanding of the environment, and to isolate compelling options to solve the users' problems. Ethnographic interviews with users or stakeholders benefit from an interview guide with open ended questions, long interviews of an hour or more, to develop deep understanding around the problem at stake, and capture notes diligently in order to help find patterns.

Journey Mapping focuses on graphically representing users' individual experiences as they work to accomplish tasks or meet goals. A journey map is a longitudinal chart that chronologically lists the tasks users undertake in the process of achieving a goal. The maps can track activities as well as users' emotional energy throughout the time they spend working on activities. These maps help to highlight differences between idealized workflows and actual workflows, as well as users' individualized solutions to problems where the idealized and actual workflows are not congruent, also commonly referred to as "workarounds." Capturing the users' emotional journey can also shine a spotlight on areas ripe with opportunities for improvements.

Job to be Done focuses on understanding the users' underlying needs. The purpose of investigating the job to be done helps design thinkers make the connection between users' expression of need ("I need a hammer and nail.") to the underlying purpose of the need ("I want to hang clocks above every workstation to keep everyone synchronized.") Jobs to be done help highlight motivation for undertaking certain tasks and help the design thinking find connections between needs and goals.

6.1.2.2 Synthesize Insights:

Personas are archetypal representations of categories of users. These personas are based on the amalgamated discoveries in the earlier data gathering activities. These personas help categorize different types of users into manageable groups in terms of their experiences, needs, and motivation. Design thinkers using the personas task will create realistic representations of people who occupy different categories of users with names, pictures, brief bios, and comments about the problem area. The realism helps connect design thinkers with the realities of the situation and move their frame of reference from a high-level abstraction of the problem to granular and specific details of the problem.

The Gallery Walk is a process where design thinkers aggregate and share findings accumulated during the previous activities. The technique relies on design thinkers and their teams to create upwards of two dozen posters that include the pertinent findings so far. For example, posters could include all of the quotes from the Ethnographic Interviews that typify a specific pain point, each Persona could have a poster with corresponding Journey Maps, or anecdotes from the Direct Observations are all typical topics for posters. The next step is to hang all of the posters together and invite team members, users, and stakeholders to contemplate the large amount of data in order to add nuance, correct any inconsistencies, and begin the process of making connections in the next step.

Mind Mapping is the process of looking for connections among the large amounts of data available. Mind Mapping encourages design thinkers, their teams, and stakeholders to carefully consider the data collected to date and briefly write down any insights or new learnings that have the potential to inform novel ideas and possible solutions. Mind Mapping can take place in conjunction with the Gallery Walk. Users and stakeholders can use the Gallery Walk experience to increase their understanding of the problem space and other stakeholders' perceptions of the problem space and offer insights captured in writing. The design thinkers and their teams can use the large amount of data uncovered in the earlier activities which are visible in the poster form as well as the stakeholders' insights to make further refined insights and group their insights and those of others into common themes.

Design Criteria is the process of identifying ideal conditions that ameliorate the concerns and pain points that the users and stakeholders experience in the existing and unaltered problem space. Design thinkers and their team often spark the process with the sample question, "If anything were possible, our design would…" The criteria generated can inform the process of creatively generating solutions.

6.1.2.3 Ideate Solutions:

Brainstorming is the process where design thinkers and their teams generate fresh ideas that attempt to address problems revealed in the earlier activities as well as the Design Criteria activity. Brainstorming is a team-focused activity designed to trigger novel ideas that build on one another. Several methods for brainstorming exist (Sutton & Hargadon, 1996) and typically include private ideation, sharing with the group, brief discussion and further ideation in successive rounds. (Liedtka et al., 2014) offer five brainstorming techniques that require design thinkers and their team members to synthesize the disparate data collected during the earlier activities.

Concept Clustering is a group activity that focuses on taking the ideas generated during the brainstorming and arranging them in thematic groups. The best ideas begin to define prominent themes around the problem space and solution space. These clusters inform the most salient specifications for options to test in later stages of the DT methodology.

Forced connections is a group activity focused on finding unexpected links between concepts that have been articulated in the earlier tasks. This task requires creatively stretching the links between concepts to reveal unforeseen insights. The activity focuses the group's attention on taking ideas and concepts from the Brainstorming and Concept Clustering and creatively generating links between seemingly unrelated concepts. The objective is to spur creativity while suspending biases that constrain ideation.

6.1.2.4 Prototype Solutions:

Identifying Assumptions is the process of memorializing the many tacit assumptions that emerged organically during the earlier activities. Assumptions in this context are akin to hypotheses. In order to complete this task effectively, the design thinkers and their teams need to carefully identify and assess the tacit assumptions (Senge, 1990) that they have surfaced in the course of the earlier activities. Once the tacit assumptions become explicit, the design thinkers and their teams can formalize the assumptions in the form of hypotheses about how potential solutions ameliorate the problem spaces.

Storytelling is intended to help fit all of the pieces of a problem and potential solutions together into cohesive, shareable vignettes that can engage users and those implementing solutions. The aim is to help people involved build a mental image of the problem and how the proposed solution ameliorates the problem. If the story is not cohesive enough, it can highlight the possible solution's deficiencies, and spark ideas for refinement before jumping into creating a solution that is less than optimal.

Prototyping is the activity that design thinkers use to create a sort of low fidelity experiential manifestation of possible solutions that test their hypotheses. These manifestations can be in the form of simple visualizations that help users imagine using the new solutions. They can also be physical mock-ups of solutions that give users hands on experiences with the possible solutions. Prototypes are useful because they can help design thinkers get immediate feedback from users quickly and cheaply.

6.1.2.5 Test Hypotheses

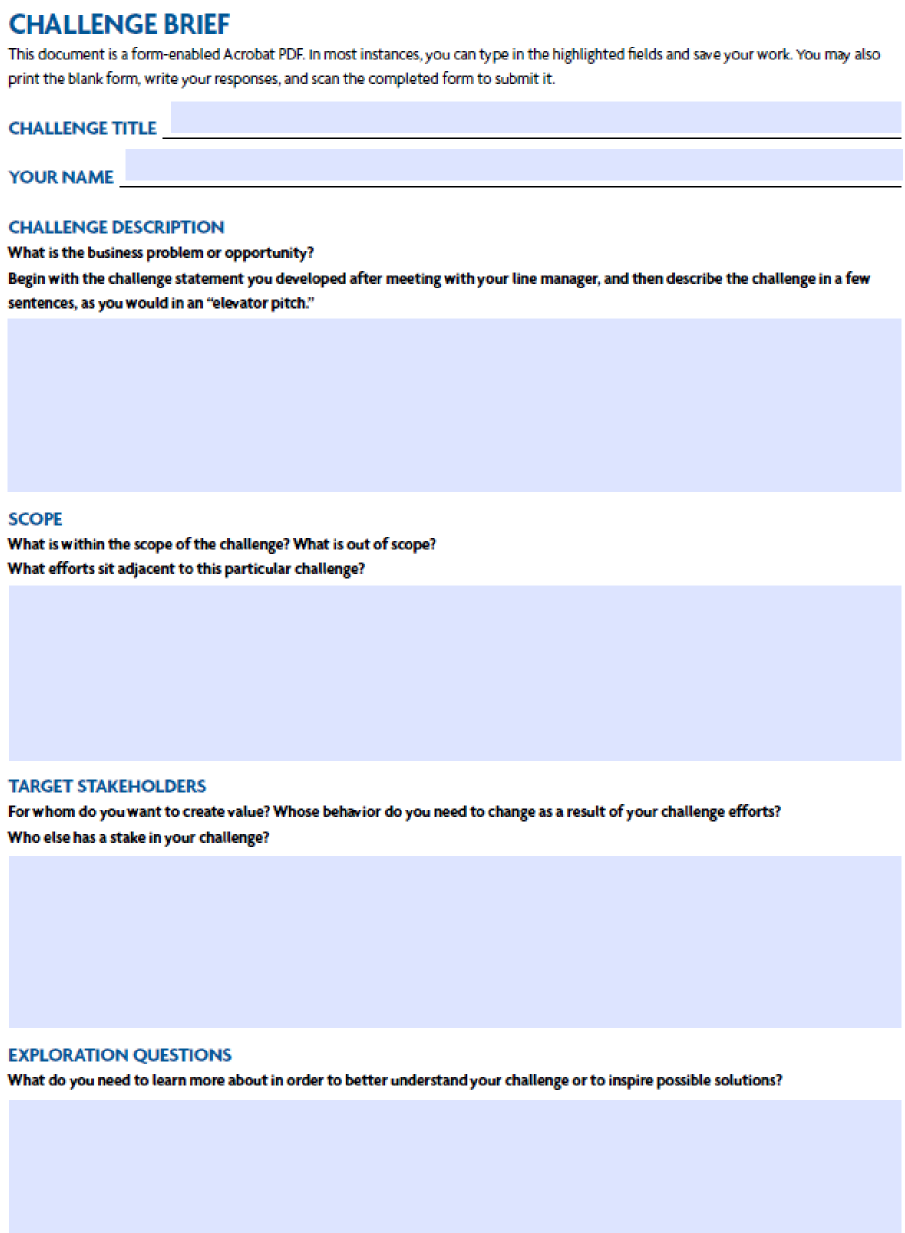
Co-creation encourages stimulating users with some sort of artifact that they engage with physically or mentally. These artifacts include storyboards, which are representations of the problem/solution environment in the form of a newspaper comic strip with different points in the process represented by successive panels.

Learning Launch Experiment is the phase where design thinkers implement the solutions in the targeted environment. The purpose of these experiments is to test the viability of proposed solutions more rigorously than in the prototyping phase, where stakeholders typically interact with a prototype in a setting separate from an actual business operation. Learning Launch Experiments are intended to put the solution into business operations, and generate operational performance data that can confirm or disconfirm hypotheses about the solutions' effectiveness.

6.2 Challenge Briefs Project problem statements

Every participant in the Program filled out the following Challenge Brief during the initial phase. The following images are a blank version that participants received at the outset of the training program.

Figure 6.1 Challenge Brief side 1



CHALLENGE BRIEF

This document is a form-enabled Acrobat PDF. In most instances, you can type in the highlighted fields and save your work. You may also print the blank form, write your responses, and scan the completed form to submit it.

CHALLENGE TITLE

YOUR NAME

CHALLENGE DESCRIPTION

What is the business problem or opportunity?

Begin with the challenge statement you developed after meeting with your line manager, and then describe the challenge in a few sentences, as you would in an "elevator pitch."

SCOPE

What is within the scope of the challenge? What is out of scope?

What efforts sit adjacent to this particular challenge?

TARGET STAKEHOLDERS

For whom do you want to create value? Whose behavior do you need to change as a result of your challenge efforts?

Who else has a stake in your challenge?

EXPLORATION QUESTIONS

What do you need to learn more about in order to better understand your challenge or to inspire possible solutions?

Figure 6.2 Challenge Brief side 2

PRELIMINARY RESEARCH PLAN

Who could you interview to learn more about your target stakeholders and/or address your exploration questions? List actual human names, not organizations or office names as proxies.

Name	Relationship to Challenge	Topics to Explore

How might you identify additional people to interview?
What other data do you have or need to inform your work on your challenge?
When and how will you assemble that information?

EXPECTED OUTCOMES AND SUCCESS METRICS

When your challenge is successfully addressed, what outcomes would you like to see?
How will you measure success?

CHALLENGE PLANNING

Who might you consider inviting to help you address this challenge?

Name	Relationship to You / Your Challenge

What other resources do you need to be successful in addressing your challenge?

6.2.1 Examples of challenge statements with low specificity

Challenges structured with lowly specific opportunities were characterized by more open questions and lack of direction toward potential solutions. (e.g. What would make the customer pay more attention to our products?)

How would we excite and engage (Key Customer) in a way that enables embedding collaborative planning principles in the most mutual manner.
We want to build strong relationship with the customer that enables us to become his category advisors.
We want to support the customer grow Chocolate and Petcare category at least as fast as the market growth.

How can we have a clear understanding of what is under-pinning our growth so we can allocate our resources accordingly?
I would like to go from a place where we think we know what strategies are working to a place where we understand which ones are working and more importantly why they are working so we can focus our resource on value creation.

How might we design and implement an ICTC in Asia that maximize value creation to business segments and align to T&B vision for now and future?
ICTC is a center of expertise that centralizes tax and treasury activities across all segments in a country to provide local insights and single point of contact. ICTC is a pioneer project that provides ample opportunities to realize our T&B organization vision. We want to be bold in our thinking to design an ICTC that is fit for current purpose and yet be agile for future.

6.2.2 Examples of challenge statements with high specificity

Predictive codes were characterized by statements that highlighted probable solutions. (e.g. We need to cut costs in this product category to get better sales results.)

C&T has been proven to be an impulse business with up to 70% of purchases been unplanned (Dog). As a Petcare business we are used to driving a Destination Category where ~80% of our sales are completed on the shelf. We know that if you are not planned (Impulse) we need to interrupt the shopper via secondary siting to capture their attention to remind them to purchase. There is therefore a potential disconnect within Petcare between how we think / are set up to deal with our category and the different needs for C&T.

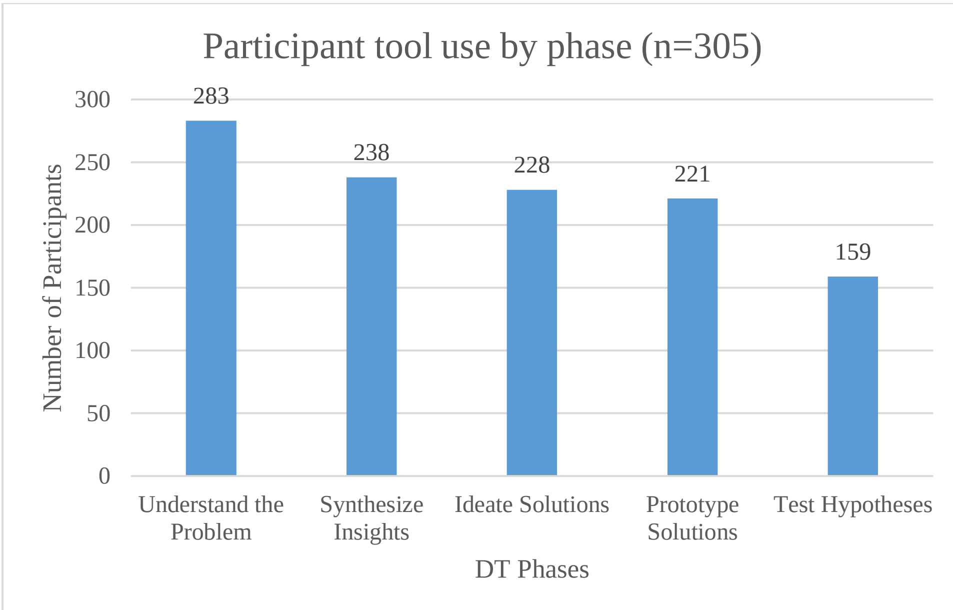
Business situation:
German single bar business declined for 8 consecutive years as of 2006 which led to significant pressure on profit and overheads. The single bars business has a 20% share of the NSV but appr. 33% share of the profit.
The challenge is to long-term grow the single bars business to secure the national profit. In the previous year the single business could grow with 5,1% NSV - first the first time since 2006. After this turnaround we need to find a long-term growth model for all relevant channels in grocery and impulse! We need to overcome the challenges in the market due to i.) price war of multi packs/ low price per kilo for Mars chocolate; ii.) declining penetration in traditional impulse channels; iii.) strong growth of foodservice offers and iv.) the price-value equation for single bars. We need to benefit from the impulsivity of our chocolate bars and the growing convenience trend of the German consumers.

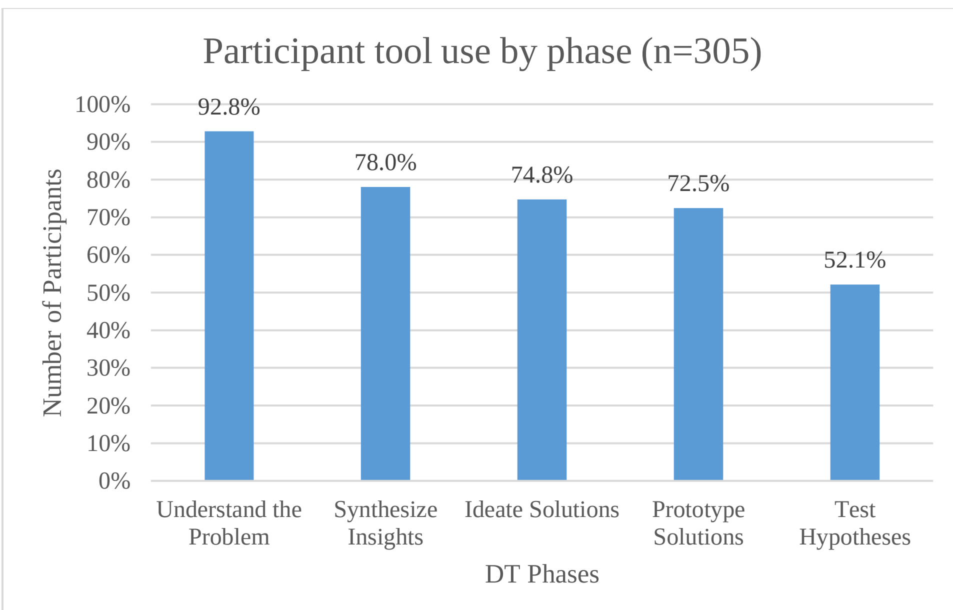
How can we develop e-portfolio basing on on-line market landscape and shopper, in particular to release candy category potential?
Our current portfolios are mainly focus on Gum and singer serve item, all of them are produced domestically. However on-line shopper will look for price/ convenience /value items and bigger packs. Furthermore, on-line shopper will look for more imported items. We're working with brand team/R&D/CMI/customer to build E-portfolio strategies till 2020 to drive digital commerce growth.

X-Candy is our Biggest Chocolate Brand worldwide. In order to drive the future growth of the brand we want to continue to develop Equity Based Activations (EBAs) to drive Brand Equity, Be in More Households (penetration) and generate Sales. As a lead market we want to locally develop and implement the Good Marketing EBA as a Swiss market where X-Candy is TOP 9, strongly supported (36 weeks in 2014), has been growing strongly over the last 2 years. We would work as lead market with the Global X-Candy's Brand Board to develop and implement the EBA for Switzerland and alongside to prepare the EBA for Global Roll out (EBA Pantry for Global Brand Board X-Candy).

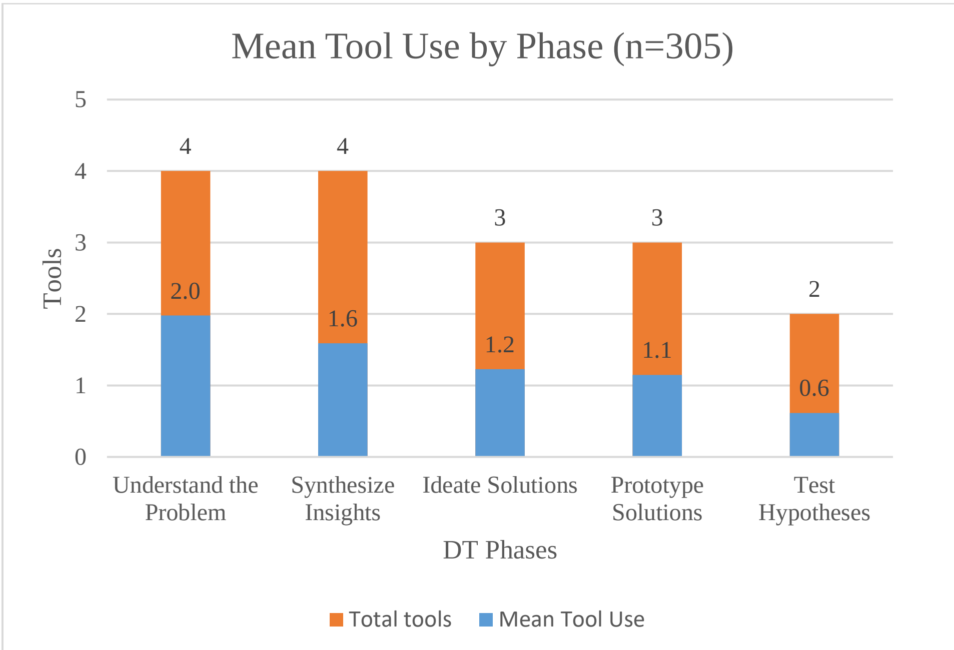
6.3 Descriptive statistics

Number of associates who used at least one tool from the associated tool category.

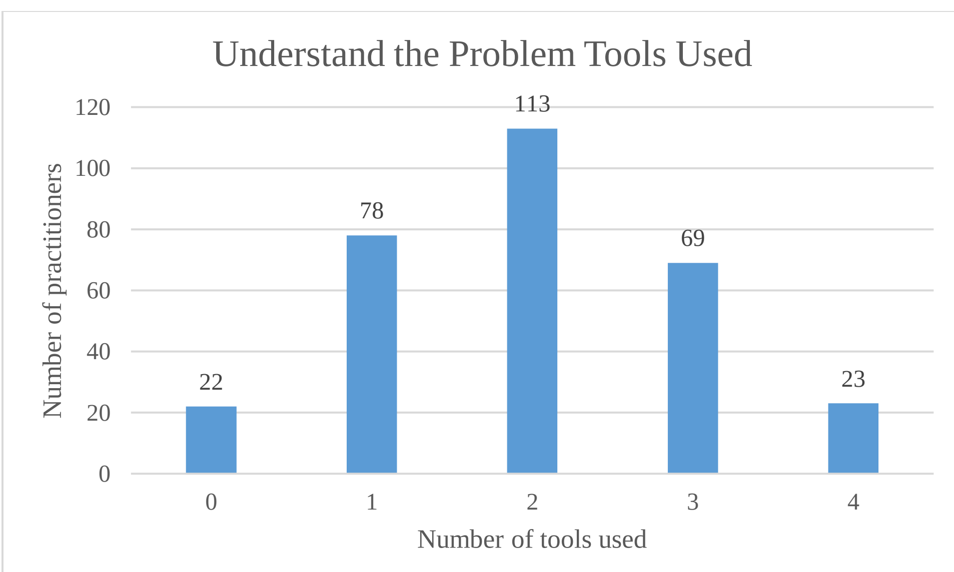




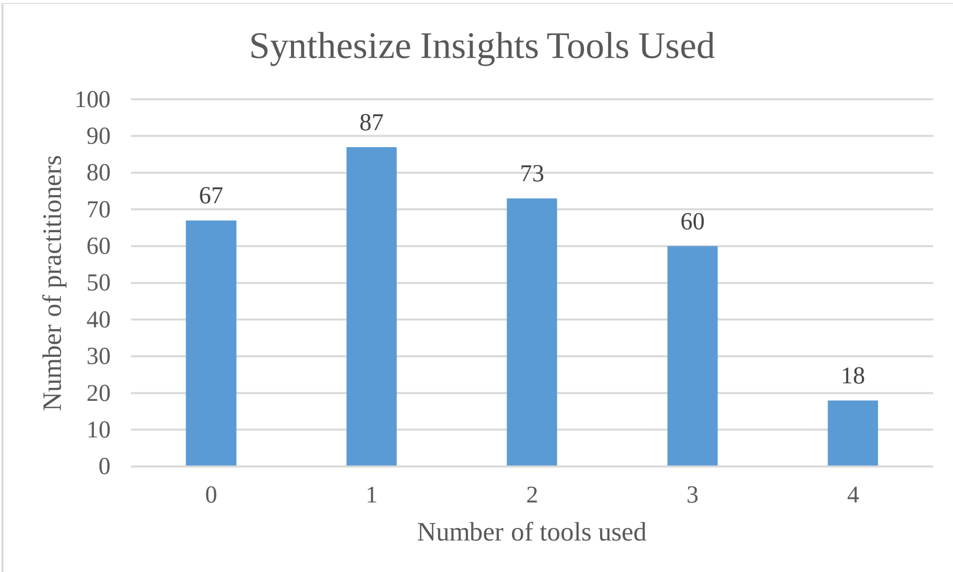
6.3.1 Mean Tool Usage by Phase



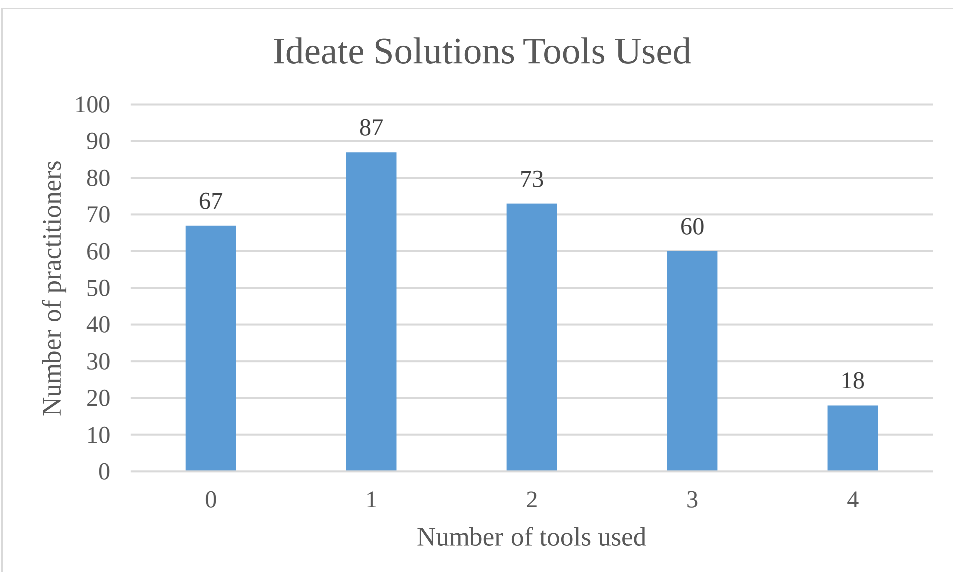
Number of participants who used the corresponding number of tools for each category



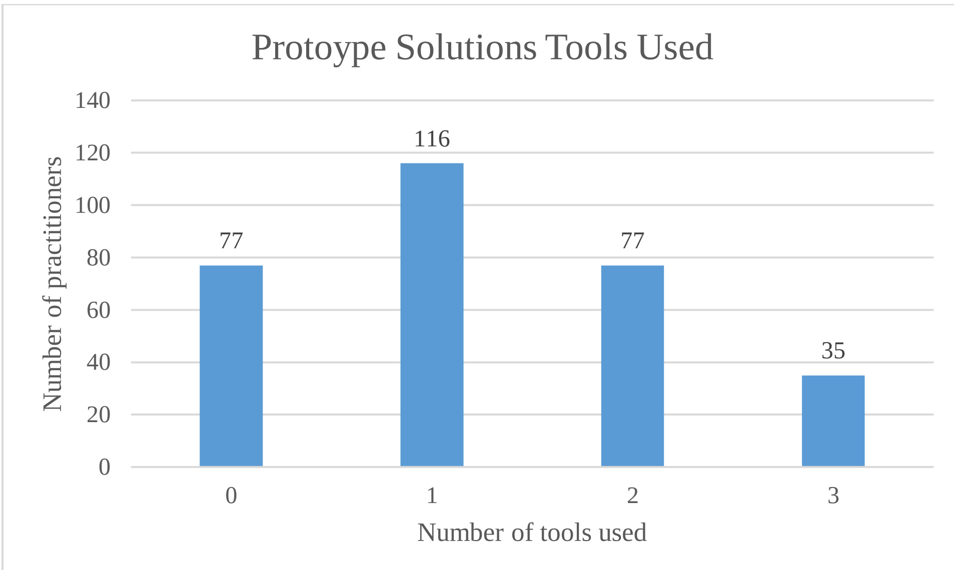
Number of participants who used the corresponding number of tools for each category



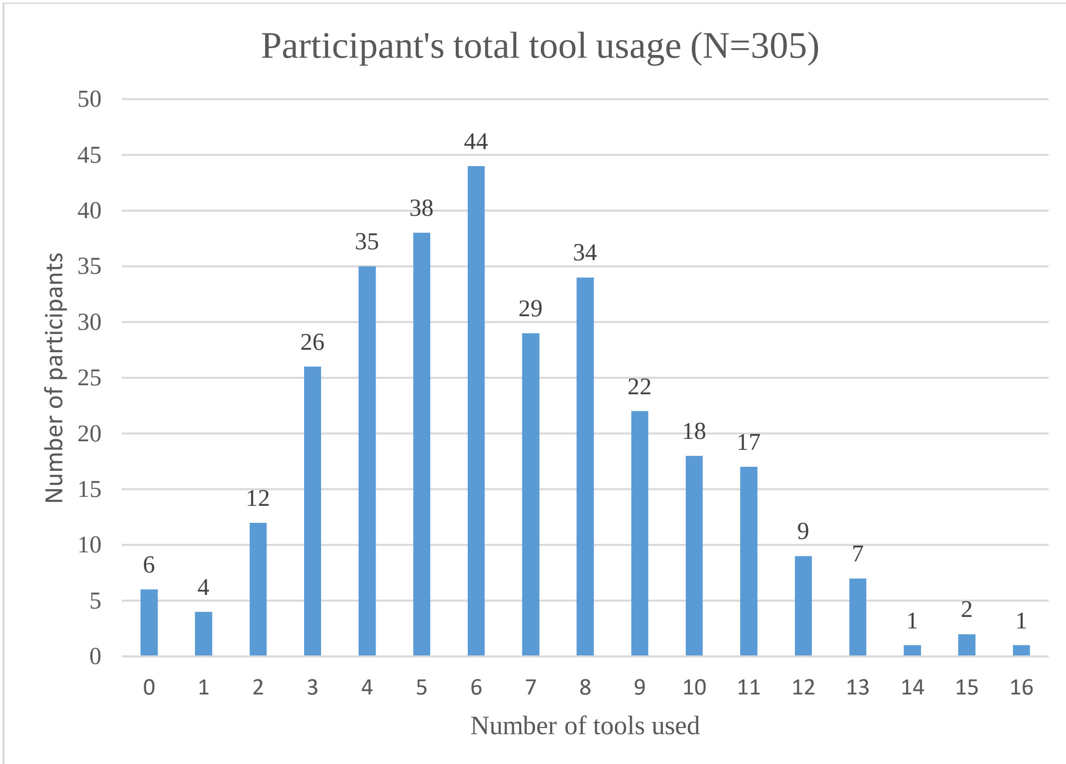
Number of participants who used the corresponding number of tools for each category

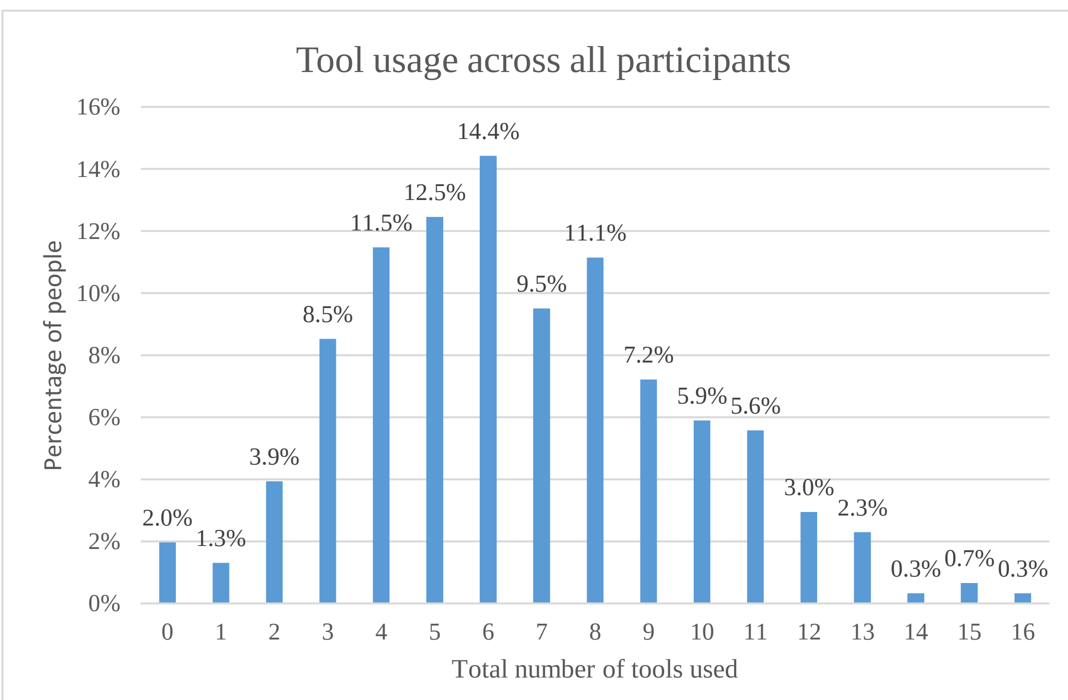


Number of participants who used the corresponding number of tools for each category

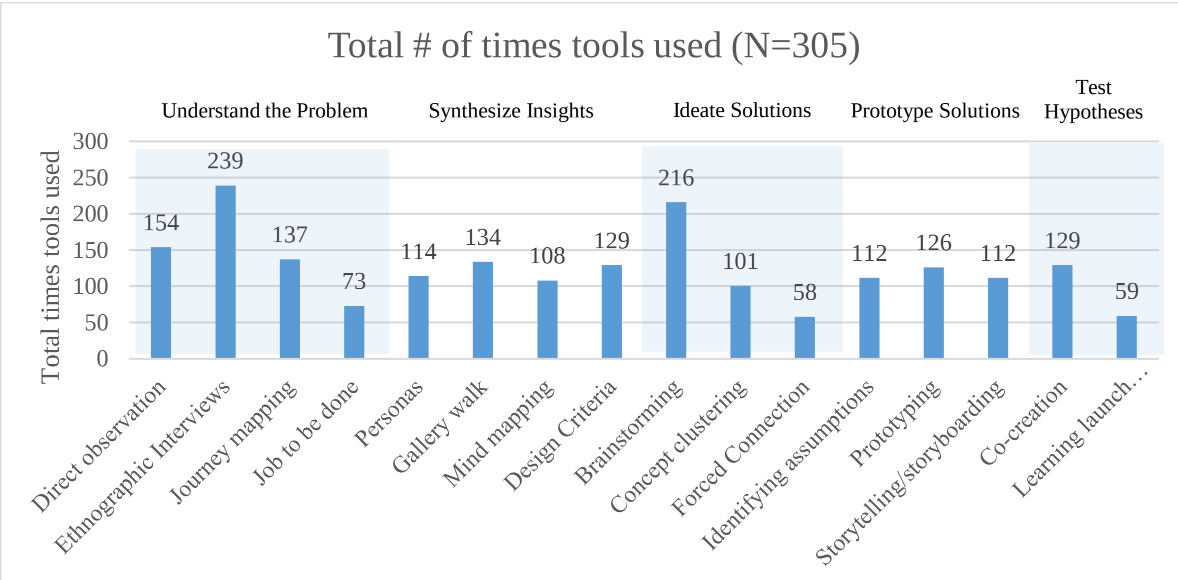


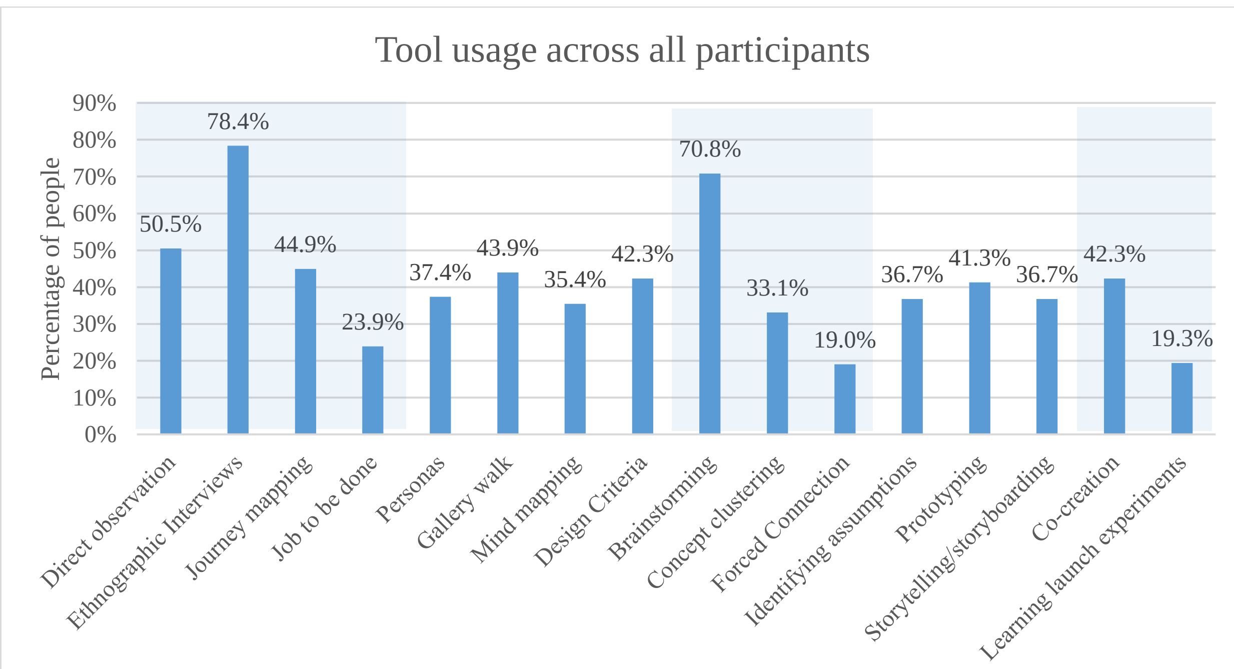
6.3.2 Total tool usage:





6.3.3 Specific tool usage:





6.4 Training program completion survey

Participants were asked to fill out the following training completion survey.

Read each item and mark the response that best captures your experience with the … program OVERALL.	
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	This course helped me develop as a leader at Tharsis.
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	I can apply what I learned in this program to my day-to-day job.
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	I will recommend this course to another Mars associate.
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	My calls with the L3 coach helped me apply insights from the course to my development plan.
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	My calls with the L3 coach helped me apply insights from the course to my L3 challenge.
Strongly agree, agree, somewhat agree, somewhat disagree, disagree, strongly disagree	My challenge provided me with an opportunity to practice some of the tools and concepts introduced in the course.
What was the most useful element of the course for you?	Open-Ended Response
What changes would you suggest to improve the course for future participants?	Open-Ended Response
Which tools from the course did you utilize in your work on your challenge? (Please mark all that apply.)	What is? Direct observation
Yes, No	What is? Ethnographic Interviews
Yes, No	What is? Journey mapping
Yes, No	What is? Value chain analysis
Yes, No	What is? Job to be done
Yes, No	What is? Personas
Yes, No	What is? Gallery walk
Yes, No	What is? Mind mapping
Yes, No	What is? Design criteria
Yes, No	What if? Brainstorming
Yes, No	What if? Concept clustering
Yes, No	What if? Concept development - forced connection
Yes, No	What if? Napkin pitch
Yes, No	What wows? Identifying assumptions
Yes, No	What wows? Prototyping
Yes, No	What wows? Storytelling/storyboarding
Yes, No	What works? Co-creation
Yes, No	What works? Learning launch experiments

Yes, No	Other (please specify)
What do you consider one of your greatest successes in your work on your challenge?	Open-Ended Response
Have you completed a learning launch presentation for your challenge?	Response
Have you submitted your learning launch (or other summary of your challenge progress) to the program office?	Yes
	No. I will submit it by (insert date in MM/DD/YYYY format)

6.4.1 Perceived Team Collaboration

Examples of answers to the question, "What do you consider one of your greatest successes in your work on your challenge?" that participants provided after working on their projects and included perceived team cooperation successes:

> The participation and strong involvement of my colleagues to achieve the proposed challenge, and how they were feeling as their own challenge
>
> The brainstorming and have working sessions with people related to the project. Have different analysis, points of view... in order to develop the concept and define where we are able to play and have more benefit.
>
> I think my challenge will have a real impact on the team - and has the potential to impact adjacent teams (Global CMI team). My challenge addressed an issue that's existed for quite some time and now I think we'll make real progress on it!
>
> Learning to consider the "what if" and "what wows." It is a real mindset change for me. It has helped me be more comfortable in delegation as well as I realize now that everyone has a different and possibly unique perspective on things.
>
> the best part was the conversations and the journey mapping, the team were very excited and felt that they are part of the change coming
>
> Successful work end engagement of the project team and good feedback of management.
>
> team collaboration- setting up one cross functional team to manage the business