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Article

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Design thinking as an effective method for problem-setting and needfinding for entrepreneurial teams addressing wicked problems

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Abstract

Organizations in a wide array of fields and disciplines are increasingly using design thinking as an innovative process to create products or services that address wicked problems in their industries. Design thinking, a method of creative and collaborative problem solving originating in the tactics of designers, is a product design and development process that is, more and more, being used as a tool to move innovation forward and structure creation processes in diverse disciplines, from product development to food creation to social science research. Increasingly design thinking has become popular beyond the confines of creative and design disciplines and into the realm of wicked problems in social and ecological systems. While design thinking has many forms and applications, this study uses a refined version built upon the key themes of inspiration, ideation, and implementation as defined by Tim Brown, CEO of IDEO (2009), and situates it within the social science discipline—namely, systems thinking, organizational learning, and action research. Through a distilled design structure this flexible methodology combines insights from organizational development, social psychology, systems theory, and design research. By embedding learning and reflective practices into the structure of design thinking, a hybrid model of design thinking emerges that is a more effective tool for framing, setting in context, and solving these types of problems within teams.

Keywords: Design thinking, Problem setting, Design process, Wicked problems, Systems thinking, Organizational learning, Needfinding

From large private companies to small NGOs, academic institutions, and government entities, all are striving to learn about and create innovative services, products, and experiences that address the problems the relevant stakeholders in their industries face. Design thinking, a methodology for problem solving that has its origins in designers' approaches, tactics, and needs to make this multi-disciplinary process explicit (Gregory, 1966), has increasingly emerged in recent decades as a powerful method to drive the innovation process in the pursuit of improvement. Design thinking, as described by the emerging management and innovation scholar Michael Luchs, is "...a

creative problem-solving approach—or, more completely, a systematic and collaborative approach for identifying and creatively solving problems” (2015, p. 1). Design thinking’s holistic approach to stakeholders and systems, coupled with its participatory nature, has made it an approachable technique to use beyond the fields of art, architecture, engineering, and technology that traditionally have design disciplines. The theories and practice of design thinking have grown in popularity and have been more heavily used in the academic discourses on management and in the business industry over the past several decades. Thus, this discipline has emerged as a problem solving tool beyond the traditional confines of design (Johansson-Sköldberg et al., 2013).

This leads to the following research question: to what extent does the application of design thinking, tasked with addressing wicked problems, represent an effective means for team problem setting and problem solving in organizations?

To fully grasp the concepts discussed in this proposal, it is helpful to clarify a few definitions before proceeding. *Wicked problems*: these are difficult and challenging problems, which appear in all fields and organizations; the most complex, multifaceted, and intractable problems with systemic impact are referred to as wicked problems (Churchman, 1967; Rittel & Webber, 1973; Roberts, 2000). *Organizations*: This term is defined as “social units (or human groupings) deliberately constructed and reconstructed to seek specific goals” (Etzioni, 1964, p. 3) and, in this study, they are defined as seeking to solve problems through the creation of a new product or service. *Design thinking*: The definition of design thinking in this study can be simply understood as the use of methods and research practices to solve problems that are traditionally not in the fields of design, architecture, or engineering.

A brief history of design thinking

Design thinking was evangelized and popularized by IDEO beginning in the early 1990s (Brown, 2009); however, it existed in the academic discourse much earlier in various forms. To understand the current and evolving use of design thinking, a historical review of this process is beneficial. Specifically, it is essential to examine the early work examining designers’ practice and research, occurring in the latter half of the twentieth century, by the parents of modern design thought: Lawson (1980), Rowe (1987), Archer (1979), and Cross (1991).

An initial push to make a more rigorous discipline out of design thinking sprang from what Michael Barry and Sarah Beckman—current researchers exploring learning in design thinking—refer to as “...a need to make design thinking explicit and a need to embrace the many disciplines that are engaged in some way with design” (Beckman & Barry, 2007, p. 26). The movement towards an explicit design method began in the 1960s, which would later be referred to as the first generation, and the subsequent movement in the 1970s and 1980s, known as the second generation (Rittel, 1984). This second generation of design thought began to emphasize the social aspects of design, by including active participants in the process (Beckman & Barry, 2007).

As described by Archer, “there exists a designerly way of thinking and communication that is both different from scientific and scholarly methods of enquiry when applied to its own kinds of problems” (Archer, 1979, p. 18). This assertion from Archer accents not only the thinking aspect but the unique way of communicating used by designers

applying the design thinking method towards problem solving. Similar to this, Cross explains that the design thought process is a research practice and a way of processing information, described as “designerly ways of knowing” (2001), that is an independent methodology with rich theory and should not be dependent on social science theory (2007). These two scholars lay the groundwork for design thinking to emerge as a distinct discipline for tackling problems in a myriad of disciplines.

In addition, Rowe outlined a systematic design process to problem solving that emphasized the role of the designer to address the needs of the client (1987). He described this user-centered process as design thinking, which was one of the earliest uses of the term. In Rowe’s design thinking process, a designer intervenes in a client organization; interprets the evidence gathered through quantitative and qualitative investigation; and makes an effort to address the challenges presented in the form of a product or service. In Lawson’s work, the process of design thinking, though not explicitly called that, is explored as a process that utilizes experimentation and information gathering tactics to tailor products (1980). Lawson’s definition predates Rowe’s use of the term of design thinking but similarly focuses on the designer’s expert role in assessing the needs of a client and testing possible solutions. This process is a tool that designers can masterfully use, informed by their expertise and designerly ways of knowing (Cross, 2001), to ultimately solve challenges that often fall into the definition of wicked problems. Rowe and Lawson focus on the intrinsically unique features of design thinking, with an emphasis on how the use of data gathering and testing make it an ideal tool for finding appropriate and optimal solutions.

These foundations of design thinking led us to Tim Brown’s definition of three overlapping, sometimes non-sequential elements—inspiration, ideation, and implementation—as outlined in *Change by Design* (2009) and popularized by IDEO. This simple structure serves as the foundation in which to organize the foundational theories for the proposed method in this article. This definition of design thinking is informed by the work of Lawson (1980), Rowe (1987), Archer (1979), and Cross (1991, 2001). This foundational design method is broadly defined as the three key elements can be repeated, can overlap, and can be non-sequential (Brown & Wyatt, 2010).

Design thinking adapted towards addressing wicked problems

For this exploration of design thinking’s effect and innovative potential in addressing wicked problems, it is essential to understand the corresponding academic discourse and how it has evolved with design thinking. The theory was first described in an editorial by management theorist Churchman (1967) as a reaction to the term, first coined by Horst Rittel. The article was an exploration of these difficult, virtually unsolvable problems in the management science discourse and responsibility of society and academia to accept their intractability and find innovation solutions to live with them (Churchman, 1967). This first formal definition of the concept was further expanded with more defined parameters with the article of Rittel and Melvin Webber in 1973 as uniquely complex problems. Rittel and Webber’s (1973) work framed wicked problems within the context of social policy planning, where problems are often not clear, and contrasted that with problems in mathematics and chess, where there are clear cut solutions. As stated by modern theorists Brian Head and Wei-Ning Xiang, “...the ubiquity of wicked

problems is the norm, and present in almost every pressing issue area that matters to human society today..." (2016, p. 1). This description describes the growing relevance and prevalence of wicked problems on human systems and how it has grown in importance from its inception.

Herbert Simon, a pioneer in design research and artificial intelligence, wanted to use a design approach, in the vein of the one described above, as a unique discipline, to tackle "ill-structured problems," which he described as problems with undefined characteristics (1969). Simon described his approach to design as a means of "...devising artifacts to attain goals..." (Simon, 1969, p. 114), which continued a trend of describing design as a solution making and transformative process. This interpretation of design thinking continued to gain momentum amongst theorists and practitioners throughout the twentieth century, which resulted in design thinking as a methodology becoming synonymous with problem solving, especially as a multidisciplinary practice for framing wicked problems (Buchanan, 1992). Design thinking as a method to solve problems outside the creative domain began with Herbert Simon, who applied design methodologies to science and his field of artificial intelligence (1969). This movement of applying the design thinking discipline to fields not traditionally associated with design continued with the product development process used by IDEO, known as Human Centered Design or HCD (Brown, 2008; IDEO, 2011). The degree of client participation and at which stages of the process vary between methods, but they agree on a key area of design thinking—that the client or product user is the primary focus.

As design thinking moves beyond the traditional creative sphere and enters the realm of addressing wicked problems across a wide spectrum of topics, the discipline is enriched by the rigorous research practices that the social sciences have to offer. The stand-alone discipline of design thinking explored in this article integrates some of the social science methodologies to effectively adapt to the new terrain of designing for social systems. Specifically, this discipline is informed by systems theory (Bertalanffy, 1969; Dentoni et al., 2023; Meadows, 2008; Senge, 1996), organizational learning (Argyris & Schön, 1978; Kolb, 1984; Senge, 1990) and action research (Lewin, 1946).

Design and systems

Systems are an essential element to implementing a design thinking process that addresses wicked problems, because they allow the designer to see a more expansive view of the problem. To understand how to design a specific product or service, the designer often analyzes the various systems that are involved, such as social, technological, ecological, or political systems. By understanding the inner workings of these systems and collaborating with relevant stakeholders, a designer can co-create a product or service that acts as a targeted intervention to improve the system. This perspective has its origins in general systems theory, formulated by biologist Ludwig Von Bertalanffy (1969), which expands the understanding of systems beyond science and analyzes all systems in an intricate, open, and holistic manner. The majority of design thinking approaches are human-centric perspectives on general systems theory in that they focus not only on the systems involved with a specific intervention but also on how the different systems interact with each other. Though most design thinking processes are human-centered, they are not exclusively focused on social systems, because the

ecological and built environment are also considered. Expanding on this viewpoint is organismic theory (Goldstein, 1995), which emphasizes human interconnectedness—that humans are intrinsically and inextricably intertwined with the natural environment and the ecological systems therein. In addition, Barry Commoner, in his work *The Closing Circle*, further stated that everything in living systems is connected to each other and what has an effect on one affects all (Commoner, 1971). These ideas inform systems thinking (Dentoni et al., 2023; Senge, 1996), which is an application of systems theory to interpret the intertwined and dynamic interactions among multiple interdependent elements to inform possible interventions. This approach to interconnected systems informs the design thinking approach through the very foundation of the process—placing the human at the center of the research and looking at all the ways this individual connects with the product, service, or system.

Design thinking to stimulate learning

The principles of design thinking are human-centered, that is, the results are specifically tailored to the end-user, and are created using a process of collaboration, active engagement, and reflection (IDEO, 2011). This process can be further explained using the double loop learning theory (Argyris & Schön, 1978), which informs how reflective practice foundationally builds on learning. Double loop learning involves single loop learning—repeated attempts to address the same issue with the same method—while additionally engaging in reflective practice to learn from past performance and emphasize repeat attempts to refine approaches (Argyris & Schön, 1978).

David Kolb, a scholar in learning science, similarly, outlines an experiential learning model (1984) rooted in social psychology, which focuses on concrete action, learning from experience, reflection, and experimentation. This theory involves an axis of learning with the y -axis containing two opposing methods of processing experience and an x -axis of opposing methods of transforming experience. This axis of learning can be seen in Fig. 1, and display experience processing in learning from a spectrum of concrete examples as one extreme and abstract conceptualization of ideas as the opposition. The processing of information is similarly balanced that with two opposing methods of

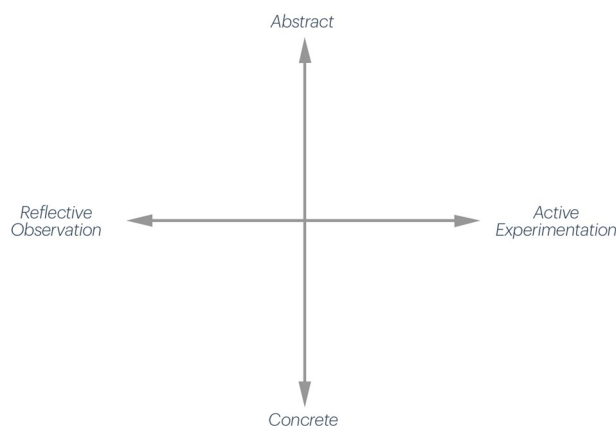


Fig. 1 Kolb Learning model as adapted from Beckman and Barry (2007), Kolb (1984) and Kolb and Kolb (2005)

transforming experience (Beckman & Barry, 2007; Kolb, 1984). The two diametrically opposed information transformation processes include reflective observation on one end and active experimentation on the other (Beckman & Barry, 2007). In simple terms, the process as seen in Fig. 1 shows two forces of learning that of processing reality and transforming it within each there is a tangible and intangible component. The work of Kolb, Argyris, and Schön increase the potential to learn from the design thinking process with rapid prototyping practice—reacting and changing the product, system, or service based on reflective practices and adapting based on those reflections. Rapid prototyping is influenced by social learning models, which emphasize interaction in learning and the importance of experimentation with both thought and action.

Charles Owen, a design academic from the Illinois Institute of Technology who has advocated for design as an engine for innovation (2006a), builds on the prototyping practice from Kolb, Argyris, and Schön. Owen theorized that the design process has discernable phases that, while often not in order, generally begin with the analytic research stage and end with the synthetic experimentation and creation stage (Owen, 1993). This innovation model begins with creating ideas and concepts from research and then applying them to experiments for testing. When used through the lens of learning, this proposed process, as illustrated in Fig. 2, begins to take shape as a non-sequential, innovative method to interpret and address complex problems. This process is illustrated in the work of Beckman and Barry (2007) who combined the elements of Owen (2006b) in a simple vestige of two axes and four quadrants. In this prescribed and infinitely repeatable process, concrete analysis brings about observable research that can then be applied to abstract analysis, that is, frameworks and theories. Finally, this leads to abstract synthesis, which is the creation of ideas that can be clearly synthesized to become concrete solutions.

Using design thinking in concert with action research

Design thinking, as described by Owen, seeks to form knowledge through action (1997), which is similar in style and approach to Action Research (Lewin, 1946) in the social

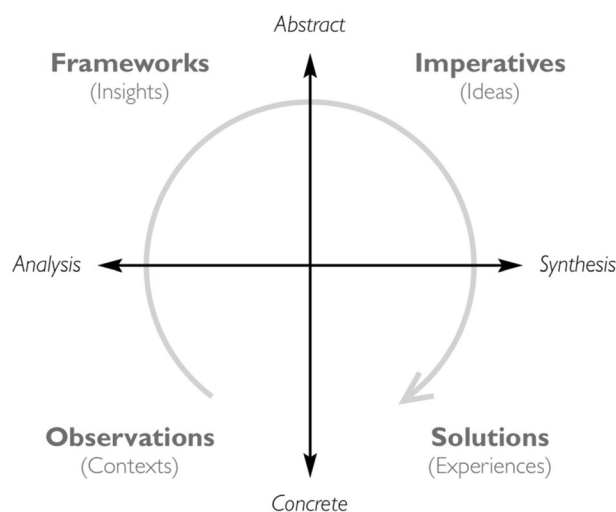


Fig. 2 Innovation process as adapted from Beckman and Barry (2007)

sciences. Action research was first created for researchers to take a participatory and active role in their studies to mold and guide their experience (Lewin, 1946), which echoes the role of the designer in a design thinking process. The designer or researcher needs to take account of their subjects and make observations, which is a traditional research paradigm while also understanding their impact as a participant in the process. In addition, reflective practice (Argyris & Schön, 1978) is a means to review and learn from past experience, and with this tool, a designer or researcher is able to build on observations of the research subject or client and create the best solutions for them. A similar approach to the use of knowledge aggregated from observations and reflective practice, is the needfinding model, which is an exploration of addressing the needs of a particular subject and working to create a solution tailored to solve this problem for them (Faste, 1987). Needfinding in design thinking does not occur as a sequential step after reflection and observation, but rather as a method to guide both of those processes to address the needs of the intended client or product user. Similarly, in action research, needfinding is necessary for the researcher to undertake to gain context of motivations of organizations and individuals involved. In action research, the subject and researchers are all participants and collaborators in the change process and its essential to understand their needs in this context, which parallels the collaborative and solution creating work of a designer.

Schön described design, in its traditional form, as a tacit process with designers' knowledge that is difficult to transfer or explain (1983). This situates designers as having specific expertise that is difficult for those without the professional know-how to comprehend or utilize. Design thinking seeks to clarify the discipline of design into a process more akin to implicit knowledge (Nonaka & Takechi, 1995), allowing design expertise to be disseminated to a larger audience, including both the designer and the client or product user. This implies that the interaction between the designer and the client is a reciprocal transaction or a communication between interacting components and systems (Germain, 1991; Luhmann, 1995). This interactive method represents the action research process, where both parties contribute to the creation process, with the designer leading the exercise. The change desired in the design thinking process, rather than research study, is an output in the form of a product or service made in collaboration with the client.

This approach to learning is common within design in that it is meant to create the ideal solution through experimentation, iteration, and continually learning from both. Using participatory action research, that is focusing on rapid learning, repetition of the practice-driven design thinking framework, and reflection, is essential for innovating and solving wicked problems (Argyris & Schön, 1991; Lewin, 1946).

Innovating through design thinking

Innovation, described as the "core renewal process" in an organization purposed with creating new products and services (Bessant et al., 2005), is the mechanism for addressing wicked problems. To innovate effectively to remain competitive, organizations have increasingly turned to the application of design thinking as a process for product development in recent decades (Johansson-Sköldberg et al., 2013; Lockwood, 2010). Design thinking-driven problem solving is a powerful and disruptive method that creates

innovative products and services that seek to address these types of problems across diverse fields.

This article uses a foundational approach to design thinking-driven problem solving, which is, in essence, a flexible framework that does not adhere to a strict structure. Rather, it is able to ebb and flow within the design challenge and cater to the relevant stakeholders. As stated by Sydney Gregory in the seminal work *The Design Method*, “[the] design method is a pattern of behavior employed in inventing things...which do not yet exist. Science is analytic; design is constructive” (1966, p. 6). Design, in this context, is used as an engine of product, system, and service creation that addresses individuals’ needs and challenges.

The design thinking process explained above can be considered an innovation process (Brown & Wyatt, 2010) and has a social learning component (Beckman & Barry, 2007). More specifically, this process can be defined as a problem setting method (Schön, 1983). Problem setting, as explained by design cognition scholar Willemien Visser is “...the process by which we define the decision to be made, the ends to be achieved, and the means that may be chose[n]” (2010, p. 4). Problem setting is the first step towards innovation and tackling a wicked problem. By defining the problem and understanding all of the pieces that interact with it, one can begin to address, but not necessarily solve a wicked problem. To understand how to use design thinking as a method within this innovative problem setting process, one must understand the context of the current design thinking discourse.

Towards a refined design thinking model

Organizations are consistently looking for innovative ways to advance their products, profits, and goals, and design thinking, though not clearly defined, has emerged as a driving force to meet these challenges. Despite the varying definitions (Brown, 2008; Dorst, 2006, 2010; Kimbell, 2015), there are enough similarities that describe the key elements of design thinking that bring it in line with other design and social science research methodologies. By combining a few of the fundamental elements into a hybrid model of design thinking, it can be used as a powerful tool to address wicked problems that organizations face. This method, as illustrated in Fig. 3, brings together the elements of Charles Owen’s map of innovation (1998, 2006a, 2006b), Kolb’s experiential learning (1984), and Tim Brown’s three signature elements of the design thinking process (2009).

The components of inspiration, ideation, and implementation (Brown, 2009) serve as the foundation of this hybrid model. Using Brown’s simplified construction could be interpreted as embracing the recent, popular versions of design thinking as a third or independent discipline. However, its approachable three-pronged structure provides a categorical separation between steps and meshes well with Owen’s concepts of innovation—the interplay of analysis and synthesis with abstract and concrete (1998, 2006a, 2006b). This powerful combination creates a streamlined and flexible framework, where innovation can occur in a non-sequential order, dictated by the needs of the problem. Interestingly, Archer foresaw this hybrid approach when he stated, “time is rapidly approaching when design decision making and management decision making techniques will have so much in common that the one will become no more than the extension of the other” (1967, p. 51). Archer’s foresight in the above hybrid

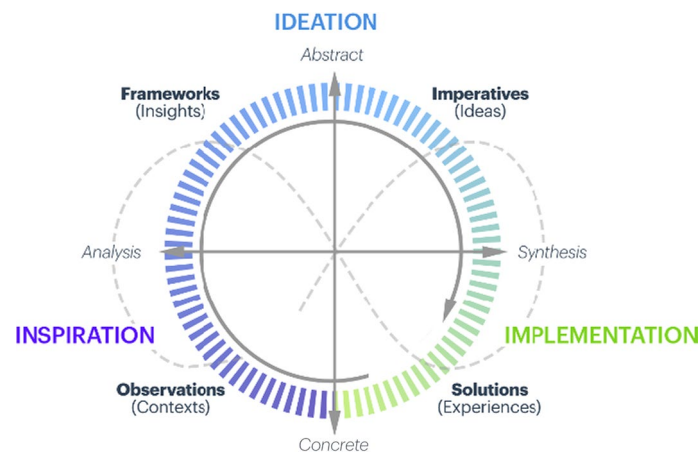


Fig. 3 Hybrid model of design thinking, which is a design process workaround with design thinking and innovation adapted from the work of Beckman and Barry (2007), Brown (2008, 2009), Brown and Wyatt (2010), Brown and Katz (2011)

design approach is in line with his third-way (1979) thought process but differs in that this design discipline works in concert with social science instead of wholly separate from it. Using this innovative hybrid design thinking model, wicked problems can be quickly identified and addressed, with an outlook towards finding specific solutions to fit users' needs.

Research design

Building on the theoretical model, based on the literature review above, a case study was undertaken to better understand the model in practice. The case study used a participatory design thinking exercise with a cohort of students enrolled in an applied entrepreneurial Masters-level course at Wageningen University. This course was targeted at students interested in entrepreneurship and circular economy, and worked with eight student teams that were developing business ideas using renewable materials in garment production. Disruptive innovation—a product, service, or approach that fundamentally upends the status quo of an industry or field (Christensen, 1997)—serves as a lens in this case study to analyze the effect of design thinking on problem solving and concept development of the student teams' entrepreneurial ventures. The course was focused on circular economic systems, which seeks to reuse resources in a closed, infinitely repeatable loop, which is in contrast to traditional linear economic models that use finite resources and create waste (Geissdoerfer et al., 2017). The Ellen MacArthur Foundation, a leader in applying the circular transition, define the concept as the following:

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the “end-of-life” concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models. (Ellen MacArthur Foundation, 2012, p. 7)

Circular economy seeks to reduce humanity's impact on the environment and climate by decreasing waste and using resources more efficiently, thus attempting to solve the wicked problem of negative human impact on the environment.

Creating a baseline

Participants in the study came from two types of academic backgrounds: a science-based one, and one rooted in the social sciences. There was an observable difference between each group in their ability to learn and apply design thinking. Students from a science-based background, such as environmental science or biochemistry, were able to learn and use design thinking concepts with greater ease than those with a social science, humanities, or management studies background. This noticeable difference may be attributable to the science-based students' ability to mix and match frameworks as needed to find solutions to complex problems. For example, in physics, students have been taught to use one formula for one situation with its own set of variables, and another formula for another situation with a second set of variables. In other words, the situation dictates what tools are used. Similarly, in the hybrid model of design thinking, which the students were exposed to, specific elements are only applied in certain circumstances and situations. Thus, as design thinking contains elements of the scientific method, this may have resonated more with the science-based students' usual ways of learning and applying methods.

The overall purpose of creating a baseline was to see what portion of the design thinking concepts had permeated in participants' minds and how they described those concepts. As such, I used what participants shared as their interpretation or impression of design thinking in their own words. In many cases their descriptions were of a concept without the use of the concept name (e.g., prototype, ideation), and I compared these explanations with the concepts used in the hybrid model of design thinking in an effort to make connections where possible. The students displayed their knowledge of design thinking during the interviews and through the course by describing important elements of the process, namely, creating prototypes, building on failed attempts, and repeated reflection on the implementation of their ideas. To establish a baseline, it was not necessary for participants to use the exact names or descriptions of the design thinking concepts, as the real test of whether they understood these concepts and could apply them would be uncovered during the design thinking in action (DTiA) section of data collection.

This qualitative methods study, informed by design thinking, was conducted in three phases: Phase 1 consisted of an ethnographic observational study and Phase 2 consisted of a series of six interviews (see Table 1) with past participants to assess their knowledge of and ability to apply design thinking to a real world problem.

The purpose of these two phases was to collectively gather data to understand the relationship between design thinking and problem solving in a team. Specifically, the data from the two phases seeks to answer to what extent design thinking represents an effective method for team problem setting and problem solving of wicked problems in organizations. Once collected, the data was codified (see Table 2) into four major themes: (1) the interviewee's personal motivation in life and vocational goals; (2) their professed knowledge in the aspects, uses, and approaches of design thinking; (3) the interviewee's

Table 1 List of interviewees with area of study, gender, and group identified

Interviewee	Age	Gender	Area of study	Group
A	25	Male	Urban Environmental Management	Epsilon
B	25	Female	Environmental Technology	Eta
C	25	Male	Environmental Science	Epsilon
D	21	Male	Urban Environmental Management	Eta
E	23	Female	Urban Environmental Management	Epsilon
F	24	Male	Urban Environmental Management	Epsilon

Table 2 Interview codification with four major themes and seven categories that correspond to lines of questioning in the interview protocol ([Appendix A](#))

	Major themes	Categories in the form of questions presented to interviewees	# of occurrences
i	Personal motivation in life and vocational goals 1	What is your major area of study and what do you want to do with that in your career?	7
ii	Knowledge of aspects, uses, and approaches to design thinking 2	What is most memorable to you about design thinking?	7
iii		Can you describe the value of using design thinking?	7
iv	Application of design thinking knowledge 3	What are different methods of approaching design thinking?	7
v		Apply design thinking in a scenario, where interviewee is working for Apple and tasked with innovating the iPhone to be more circular and sustainable to grow market share. What would you do? Describe in detail	7
vi		Are you confident in your knowledge of design thinking to apply it?	7
vii	Design thinking's perceived effectiveness 4	Is design thinking the best tool for problem solving?	7

application of design thinking in a scenario; and (4) their assessment of the effectiveness of design thinking.

Results

The research findings examine the research question, "To what extent does the application of design thinking, tasked with addressing wicked problems, represent an effective means for team problem setting and problem solving in organizations?" To answer this question, I used the four themes outlined above to conduct the data analysis, and the interpretation of the data will continue to follow these themes. For the interpretation, I split the four overarching themes into two categories. The first category incorporates the first two themes (personal motivation and knowledge of design thinking) and acts as a baseline to gauge, where the individual is academically and what design thinking concepts they have retained. This is useful information, because it paints a clearer picture of the participants' individual characteristics, which I then paired with the second category of themes to understand whether these characteristics play a role in the participants' application of design thinking to solve a wicked problem. The richest set of data comes from the second category. The latter two themes (application of design

thinking and perceived effectiveness) are included in this second category as a way to analyze DTiA through role-playing scenarios, which gives insight into the participants' practical knowledge and application of the hybrid design thinking model used for this experiment.

This DTiA exercise revealed three key features of the hybrid model, which combines behavioral science and traditional design methods to create a flexible and foundational model for addressing wicked problems. Three key aspects within the hybrid model that were particularly apparent in this second category were “problem setting,” “needfinding,” and “double-loop learning.” First, interviewees successfully applied problem setting by outlining all the necessary information that would be required to solve an assignment—in this case, the hypothetical scenario of working with Apple to improve the iPhone's falling market share. Interviewees correctly prioritized the following: (1) setting up a component team to tackle the issue; (2) collecting data on competitors to compare best practices; (3) understanding the needs of potential and past customers; and (4) creating a process to experiment and iterate on failures. These priorities exemplify the hybrid model's three central elements and how organizational learning, needfinding, and problem setting are key to the success of the model in addressing wicked problems. What's more, the interviewees were able to link ecological systems, such as environmental value chains and social systems while looking at both consumers and stakeholders to put the question into context. Second, participants used needfinding to distinguish what aspects of the real world problem were most important to take into consideration when evaluating possible solutions. These aspects focused mostly on the needs of human and ecological systems that were involved with the problem. Third, participants used double-loop learning to test possible solutions to the problems they faced and made iterative changes based on the positive or negative results. Specifically, the interviewees showed how they questioned all of the parameters of the prompt and laid a plan for testing, retesting, and iteration of ideas.

Discussion

This study's findings suggest that the hybrid model of design thinking is an effective framework for addressing wicked problems. Namely, participants were able to recall various terms, such as “prototyping” and “ideation” when defining this hybrid model. Furthermore, they displayed implicit knowledge by successfully using aspects of the model, including “double-loop learning,” “iteration,” and “reflective practices,” to find solutions during the DTiA exercise. For example, Interviewee C specifically defined “prototyping” as “a method to create quick test solutions that can then be iterated upon and improved with future versions towards a suitable solution.” Being an explicit definition of this design thinking concept, it is clear that Interviewee C understood and retained the information learned during the course. By contrast, Interviewee A did not identify “prototyping” by name but displayed use of the concept during the role-playing exercise.

The course participants used design thinking in the formulation of their entrepreneurial ventures, which were created to address the wicked problem of environmental sustainability. Two groups of participants in particular, Epsilon and Zeta, used design thinking to address very specific problems they identified within environmental sustainability, which are outlined below.

Epsilon team's use of the hybrid design thinking method

Epsilon's innovative solution was developed in response to the lack of incubation spaces for sustainable entrepreneurs in Wageningen, Netherlands—that is, workspaces and offices, where like-minded entrepreneurs can work and have access to investors and experts to grow their businesses. The team focused on Wageningen specifically, because they had the most experience in this city, as students at the local university and as entrepreneurs who had attempted a previous venture here already. Note that this was the team's second venture attempt for this study. They first explored how to grow a mushroom skin, related to the "living skin" research project, so that they could experiment with different types of coating to make the material waterproof. They planned to sell the waterproof coating to companies to make durable clothing, bags, or car interiors. Through experimentation and the prototyping process, the team tried to grow mushrooms but faced challenges with a lack of expertise and a space to grow the fungi. The team expressed frustration about these obstacles and through reflection realized that getting expert assistance and finding a space to experiment were essential to their success as a venture; however, perhaps, these were problems they could address. As such, the team shifted their focus to a new venture, which was to find an innovative solution to the lack of incubation spaces in Wageningen.

The team researched and tested their new venture concept of creating an organic, sustainably, and locally sourced café that is an office space for ventures in the city, has a network of experts to help entrepreneurs, and offers a location for entrepreneurs to sell and test their products and services. With this shift, the team then went to collect data and surveyed people around the city and the results showed that there was, in fact, demand from residents and sustainable entrepreneurs for this type of space and that Wageningen did not currently have any locations that met these entrepreneurs' needs. Specifically, they found that a co-working space and having access to experts are actually crucial for entrepreneurs in the early stages of their ventures, because it allows them to test their ideas and learn from others as they iterate on better solutions. Similarly, the team itself was able to learn from the failure and challenges of their first venture attempt, which inspired them to address that problem directly with a different venture. Epsilon's venture evolved to become a café, store, and incubation space for entrepreneurs in Wageningen that sought to create products or services that are environmentally sustainable and have closed-loop, circular waste streams. Their final venture concept included a plan for further development, testing, and iteration to continue learning as they grow and improve their products.

This team's journey from one venture to another provides an exemplary use of the hybrid design thinking model. This shift embodies Argyris and Schön's definition of double-loop learning, the students not only explored their original question related to their venture but also if it was the right question in itself. Argyris and Schön (1978) described the concept with the following metaphor:

Single loop learning can be compared with a thermostat that learns when it is too hot or too cold and then turns the heat on or off. The thermostat is able to perform this task, because it can receive information (the temperature of the room) and, therefore, take corrective action. If the thermostat could question itself about whether it should be set at 68 degrees, it would be capable not only of detecting error

but of questioning the underlying policies and goals as well as its own program. That is a second and more comprehensive inquiry; hence it might be called double loop learning. (pp. 2–3)

I shared the metaphor above with the students during the beginning of the course, and this group exemplified double-loop learning in the selection and refinement of their venture. Team Epsilon showed their understanding of the context of a venture and how that can change the very nature of a proposed solution as it was for them, when they shifted the problem they focused on. Furthermore, their reaction to changing circumstance can be interpreted as the team displaying Schön's (1983) concept of "reflection-in-action" (p. 79). The team struggled with their concept and made changes that ebbed and flowed with the challenges they faced, which in Schön's definition would be part of the designer's reflective "conversation with the situation." Their use of double-loop learning in regard to building on lessons learned and changing approaches based on feedback led them to their new venture and guided how they continued to iterate and improve that new venture. Furthermore, they expertly displayed problem setting and understanding the context of a venture and how that can change the very nature of a proposed solution as it was for them, when they shifted their problem. The final project from this team was well thought out, fit to context and was an exemplary use of the hybrid model.

Zeta team's use of the hybrid design thinking method

The Zeta team faced very different challenges in creating their venture. The team members, who came from diverse backgrounds and had varying interests and skillsets, came up with a plethora of ideas and had a difficult time choosing one idea to move forward with. The ideation and brainstorming process was not decisive or iterative, and the students expressed their frustration as the process rolled on without a clear venture in sight. The team worried that they had fallen behind and would not have enough time to complete all aspects of the project. With design thinking coaching by the researcher, the team was encouraged to refocus their efforts to think about any problem, not necessarily related to environmental sustainability, and see how they could collectively address it. Once they had decided on a problem, they could then begin introducing aspects related to reducing waste streams and circular economy in an organic way that would connect the problem they chose to the bigger, wicked problem of environmental sustainability.

The team used needfinding to find the requirements of the problem and then utilized framing and reframing to make their venture work in that context. This venture's process exemplifies frame innovation, coined by Dorst (2015), which he describes as a "key entrepreneurial activity" (p. 149). The team shifted frames, from seeing their venture as a means to solve an aspect of environmental sustainability, to solving a real-world problem that can be connected to environmental sustainability. The Zeta team went through further consultation and began discussing one team member's proposed problem based on her experience working with the United Nations (UN) on disaster recovery in Latin America. She described the problem of people needing quick housing when a disaster strikes; the logistic challenges of getting temporary, single use housing into the disaster area; and the waste the homes leave once they are no longer used. This discussion led the group to connect this issue to the "living skin" fungi material to create temporary housing that could be lighter weight, biodegradable, and reusable. This idea connects

the problem posed within the problem of environmental sustainability, which was their task. Furthermore, this shift exemplifies an understanding of systems thinking and interconnectedness of social and ecological systems. Once the initial concept was developed, they began to refine the idea using team members' expertise working in international development and aid as well as environmental sustainability. They then turned to the questions of how to make this into a venture and who would be their target audience. This process led them to brainstorm how they could balance the needs of potential clients (disaster response organizations), potential users (disaster victims), and the natural environment (ecological footprint). The team conducted surveys and found that potential clients would be interested in cost and scale of the potential solution, while potential users would be most interested in comfort and durability. Those considerations were then balanced with creating the minimalist ecological footprint and having a viable business model so the venture would thrive. They made two crucial decisions at this juncture: first, they decided not to manufacture the material but to source it from a third party, and second, they decided to structure their venture as a non-profit focused on the UN and disaster recovery agencies.

Using the design thinking concepts of rapid prototyping and reflection they were able to quickly figure out which ideas were working and abandon those that were not, which ultimately led to a venture they described as "living houses." This iterative process they embodied shows the power of using design thinking for concept refinement. The team's final venture concept was a not-for-profit organization that sourced biodegradable and reusable materials to create light-weight, temporary housing to be sold to NGOs, governments, and public international institutions for disaster victims around the globe. Their plan included next steps for further testing and iteration to improve the product and business model. In both cases, the Epsilon and Zeta teams used the hybrid design thinking model to problem set and problem solve as they set up and executed their ventures. This clearly helps address the central research question of the study by showing the utility of design thinking as tool for addressing wicked problems both in the internal venture creation process and the problem the venture sought to address, environmental sustainability.

Connecting team's use of design thinking hybrid method to interview data

While these team examples provide evidence to support the positive impact of design thinking on problem setting and solving for wicked problems, the most interesting results came from the Phase 3 interviews that took place 1 year after completion of the course. During these interviews the participants were tasked with using the hybrid design thinking model in a theoretical applied scenario. Through these participant interviews, I was able to explore which features of design thinking they had internalized and how they might apply those to a real world problem. As explained in the following discussion, the participants' ability to use design thinking concepts implicitly and explicitly over a year later shows that the concepts were adopted as a *modus operandi*, at least in part. As shown in the matrix in Fig. 4, the participants all showed a high ability to apply the competencies regardless of their ability to define them as. In addition, the participants who did not recall the definitions were able apply the competencies to a higher level of specificity and knowledge than two out of the three interviewees that could.

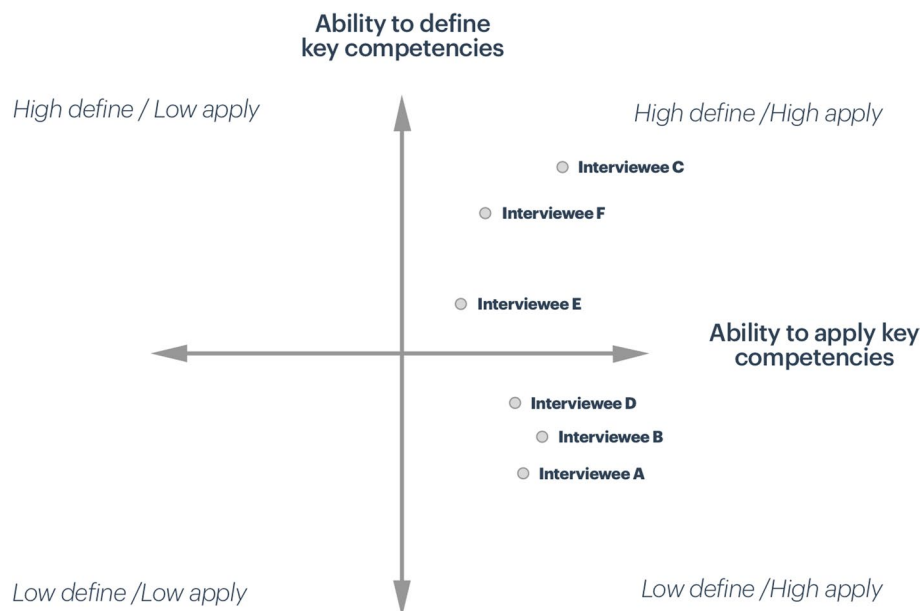


Fig. 4 Matrix showing interviewees' ability to define (x-axis) and apply (y-axis) on key design thinking competencies

In the scenario with the interview, participants were tasked with describing the steps they would take to tackle the problem of declining market share of the iPhone. Without being specifically prompted, all interviewees included some form of waste reduction and environmental sustainability into their action plan in the scenario. Some causation for the inclusion of these environmental themes could be the students' backgrounds, their association with the course's focus on this particular wicked problem, and/or a general growing awareness of the global climate crisis. That said, their ability to connect a problem to a deeper, wicked problem demonstrates their use of the competencies of system thinking and problem setting from the hybrid design thinking model. They were able to place a practical task within a wider context and connect it with wicked problems involved, such as climate change and electronic waste.

Much like in the case of the Zeta team described above, any seemingly unrelated problem can be used as a gateway to begin discerning the mechanics needed to address a specific, wicked problem, which will lead to creating experimental solutions that can be further tested. Furthermore, the participants were able to identify, in name or description, the three core elements of the hybrid design thinking model—inspiration, ideation, and implementation—and delineate corresponding activities for each while also explicitly and implicitly describing design thinking's approach to solving wicked problems. The participants' perception of and demonstrated application of design thinking elements in their problem solving procedure in the interview sheds light on the effectiveness of design thinking as a problem setting and solving tool. This suggests that the participants embraced design thinking, specifically the three-pronged hybrid model that melds design methodologies and behavioral science, as a useful process for problem solving. More important than the interviewees identification of the steps of the model, was their application of problem setting and problem solving strategies that follow the three main elements of design thinking. Participants were able to show the use of brainstorming

(inspiration), prototyping (ideation), and iteration (implementation) in various ways and interchangeably. This nimble and engrained use of the concept shows its effectiveness as a problem setting and problem solving tool as well as its impact on users.

Connecting findings to the existing literature

This study was informed by a literature review which examined the history, theories, and application of design thinking in addressing wicked problems. In this study, design thinking is considered a “third discipline” or independent area of study that applies behavioral science and design methodologies to a proposed hybrid model. This hybrid design thinking model strengthens typical design methodologies by including (1) systems thinking, taking into account interconnectedness of ecological and social systems; (2) organizational learning, using double-loop learning, reflective practice, and iterative prototyping; and (3) elements of action research, such as collaborative and cyclical feedback with designer and client. This integrated process is particularly pertinent when working on problems beyond traditional design, for it lends a structural framework to behavioral science research using the three phases of ideation, prototyping, and implementation. In the hybrid design thinking model, behavioral and organizational considerations are not merely optional, but rather an essential element that works in congress with design methodologies.

As outlined above, the findings of this study are in line with the literature and research that indicate that design thinking is a potent tool for addressing wicked problems. By their nature, wicked problems are intractable and complex, so when testing ways to solve them effectively the method must be able to adapt with that nature. Specifically, this research suggests that design thinking represents an innovative process uniquely equipped to address wicked problems through its use of “problem setting.” That is, the effective use of needfinding—looking for solutions for relevant stakeholders—and double-loop learning—applying iterative knowledge and testing assumptions while doing. Although the participants in this study represent a very small treatment group in a specific educational setting focused on tackling environmental wicked problems, there is potential to test this experiment more broadly in educational settings focused on a variety of wicked problems.

Implications for future research

There are four overarching implications that result from this study that academic researchers and practitioners should take into consideration when exploring how to use design thinking as an effective method to address wicked problems. First, future research should conduct experiments using design thinking to address wicked problems that occur within other thematic areas, such as gender inequality, wealth distribution, employment with new technologies, and religious tensions, among others. Second, future research should test a variety of team compositions and study settings beyond that of a university. For example, team members could be part of a research institution, corporation, government, or NGO, and studies could be conducted within those organizations or across disciplines. Third, future research should explore what other aspects of design thinking are effective and learn why they are or are not successful in tackling wicked problems. Fourth, future research should test the hybrid design thinking model's

effectiveness using other forms of design thinking as a control. Finally, beyond academia there are implications of this study for professional practice. Gleanings from this study and use of the hybrid model in the field can occur immediately if used as an adaptable and editable tool for problem solving. This can be used in NGO's, governments, universities and companies working on wicked problems in their work.

Limitations

This was a qualitative methods study that included a participatory design exercise focused on students enrolled in an entrepreneurship and circular economy course, where they were tasked to use design thinking as a method for creating innovative solutions to the wicked problem of environmental sustainability. While designed to examine how effective design thinking is for setting and solving wicked problems for teams, there is a clear limitation of its application on settings outside education, such as in business and practices outside of academia. Although the course was hands-on, involved the creation of a nonprofit or for-profit business, and was team-based, it still took place in an educational setting rather than in the open marketplace. In addition, this study unfolded in a European context and specifically within the Netherlands, which limits its scope further. As stated earlier, there are wider implications for this data beyond being held in an academic setting that influence the results and potential uses of design thinking. As stated above, future studies should be conducted with teams outside of academia who are tackling different wicked problems other than environmental sustainability. Different results could occur in different settings and problems and future research can explore those possibilities.

Beyond the components of the research, this study had limitations with time, as it had to be carried out during a specific semester and was dependent on student availability. In addition, due to university considerations, including the time needed for proposal review and IRB approvals, there were delays in conducting the interviews which were originally set for May 2018, but were carried out in December 2018 and January 2019. However, this allowed for a shift in focus of looking at how the knowledge and practice of design thinking remained implicitly and explicitly in the interviewees' problem solving practices. A final limitation is that this study was a doctoral dissertation, which means it had a limited budget and a specific time period in which it was required to be completed.

Final thoughts

Analysis of designers' thinking and doing has been explored for over a half century, and design thinking, in particular, has evolved over the last three decades from a process only used by designers to more expansive use. Along with the expanded use of design thinking is the rightful criticism, skepticism, and curiosity with the approach, which can offer an opportunity for further refinement and transdisciplinary use. This evolution has expanded design thinking from traditionally creative fields to help create products to practical, ergonomic and aesthetic standards to being used by governments, social policy researchers, non-governmental organizations, and many more to solve societal problems and the most difficult among them, wicked problems. The hybrid design thinking model strengthens design methodologies with systems thinking, organizational learning, and action research, which can help deepen and inform the design methods when

working on problems beyond traditional design. IDEO's popularized design thinking process with the three elements of inspiration, ideation, and implementation provides a structure that can be used as a basis to add insights and tactics from social sciences—namely, systems thinking, organizational learning, and action research—and designer's methods more broadly. Systems thinking offers an opportunity for teams to zoom out and have a macro view of the dynamic, interconnected elements of the wicked problem they seek to address through iterative solutions and reflection. Organizational learning offers a posture of learning which can strengthen the iteration, testing, and reflection processes in design thinking. Finally, action research informed practice with design thinking enables teams to be active participants, researchers, and designers in finding possible solutions to wicked problems. Design thinking when applied to solving problems in an entrepreneurial education setting will add to the effectiveness and innovative nature of the solutions created. Through creative brainstorming, experimentation and reflection being integrated into the creation of entrepreneurial solutions to wicked problems there is great potential ramifications beyond educational settings, such as industry, government, and civil society.

Appendices

Appendix A: Interview Protocol—November 2018

[To open the conversation a bit of small talk and catching up with the former student, what they have been up to and what do they have planned next and this lines up to the informal questions below (in no particular order).]

*Welcome and thank you for this time and to explore some of these concepts with you and get your perspective. Now that you have completed the Design Thinking course, I would like to explore with you whether, in your future career, you would consider design thinking as a way for teams to tackle difficult problems, and any ideas you may have on the subject. This is **not** designed in any way to test your knowledge about design thinking, or to reflect on how you did in class. I would simply like to understand whether, with what you've learned, you feel that design thinking is a good way to tackle tough problems, and how you would go about doing that.*

Questions to warm up and understand context—5 ~ min

- What is your major/main subject of study?
- How do you want to use your education and what do you want to do as your vocation?

Design thinking and problem solving—40 min

[The purpose of the first question is to begin to brush on problem setting and begging the design thinking process, the parameters and elements. The goal is to solicit data from participants through storytelling and their thoughts on the topic.]

- Can you tell me a story about your experience with design thinking in the class that you thought was memorable?
- Are there other examples of things that struck you about design thinking?
- What is it about the design thinking approach that you like the most?
- Is there anything that you don't like, or would do differently?
- Let's do some role playing. Let's say, tomorrow you get hired by Apple to be the head of their new development team. They have a serious problem: the iPhone has reached a saturation point. You are tasked to come up with an entirely new set of functions that will totally reinvent the iPhone. How would you go about doing that, if you were using the design thinking approach? If you can, break it down using the three-phase hybrid model we discussed: Ideation-Prototyping-Implementation.
- Is there anything about design thinking you feel you need to know more about, before you could confidently begin to use it?

Wrap up—10–15 min

- So in sum, do you think design thinking a good method to produce disruptive innovation, or would you use other methods?
- Does design thinking need to be adapted to the fast pace of disruptive change today?

Appendix B: Ethical Approval for Research—April 2018

FGU Institutional Review Board | (805) 898-4034 | IRB@Fielding.edu



April 20, 2018

Rahmin Bender
Cc: Fred Steier

RE: IRB No. 17-1107 (Pilot/Dissertation) "APPLYING DESIGN THINKING TO ENTREPRENEURIAL LEARNING SPACES PURPOSED WITH ADDRESSING WICKED PROBLEMS" by Rahmin Bender.

Dear Rahmin,

On behalf of the Fielding Institutional Review Board, this letter is to confirm that the formal Revision Request received on 4/18/2018 has been **APPROVED** for the study listed below.

STUDY ID: 17-1107 BENDER Rahmin (SLS-HOD Nov 2017)
REVISION TYPE: General (submitted 4/18/2018)
DETERMINATION: APPROVED (4/20/2018)
STUDY EXPIRATION: 12/14/2018

This study is subject to continuing review by 12/14/2018 unless closed before this date.

Any additional changes or modifications to your approved study must be submitted to the IRB for review and approval. Some changes may be approved by expedited review; others may require full board review. **Revision Request Instructions** can be downloaded from the IRB website.

Please contact irb@fielding.edu if you have any questions or require further information.

Best wishes,

Annabelle Nelson, PhD
Institutional Review Board Chair
Fielding Graduate University

1) IRB Approval Information

Name: Rahmin Bender.

IRB#: 17–1107

Title: Applying Design Thinking and Practice to team projects seeking to create regenerative and sustainable products to address the wicked problem of sustainable garments

Faculty: Fredrick Steier.

Type: Title Change and General Revisions.

2) Study Summary

The dissertation project seeks to explore through participatory action research, how the application of design methods to address wicked problems represents a disruptive innovation in the process of solution creation and if so or not, to what extent. The disruptive innovation is framed within the context of the Netherlands, the public University education system and the field of sustainable fashion and garment production. The specific context of this study will be at Wageningen University and Research in the Netherlands working with student teams creating business ideas, using design thinking and aligned methods, with the renewable materials in garment production. The forty Masters students in a circular economy course will be split into eight teams that will work with designers using these materials to create business and product concepts using design thinking processes facilitated by me.

3) Revision Checklist

I. Change title to: Applying design thinking to entrepreneurial learning spaces purposed with addressing wicked problems.

- Title changed to emphasize more on the application of design thinking on the learn space and how it addresses the wicked problem, rather than focusing more and more on the

II. Change question 2 element (c) from “(c) how design process impacts team dynamics of product creation team” to (c) how design process impacts the co-creation of the entrepreneurial learning space.

- Question changed to focus additionally on how using the design process not only impacts the outputs of the course but the course itself.

III. Change question 3’s following elements.

- Change this bullet: “World Café held after the course to accumulate data and feedback from participants and put into context with the notes.”
 - New Text: Changed to Design Charrette held after the course to accumulate data, feedback and put notes into context through a participatory designing of future iterations of the course.
- Change this bullet: “Depending on IRB is performed data collection will be focused on the World Café portion that will be held in January post course and the course and work will be looked at historically.”
 - New text: IRB includes data from the course that ended in the end of 2017 as well as data from the participatory design workshop titled a design charrette occurring in 25 April 2017.
- Add the following bullet

- Design-based Research informed by action research and design thinking will serve as the research method for analyzing the historic data from the course and data collected in the design charrette to address the research questions posed.

The above changes are made to reflect a change from a World Café method to a more intimate design charrette. This change was made because of difficulty getting a large enough participation for a World Café to work, ideally 20 or more people. The design charrette will use the same research element but be in a smaller setting, which will allow for more interaction. Finally, the addition of design-based research to emphasize the element of the entrepreneurial learning space and how that was actively formed and influenced by the use of design methods.

Abbreviations

DTiA	Design thinking in action
IRB	Institutional Review Board

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Author contributions

The author read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

The data and materials used in the research are available through the ProQuest dissertation database as part of graduation requirements for the PhD at Fielding Graduate University.

Declarations

Competing interests

The author declares no competing interests.

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