DISSERTATION

THE CREATIVE SYNTHESIS INVENTORY: CONSTRUCTING QUANTITATIVE MEASURES CAPTURING ATTRIBUTES OF DESIGN THINKING

Submitted by

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In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Summer 2017

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ABSTRACT

THE CREATIVE SYNTHESIS INVENTORY: CONSTRUCTING QUANTITATIVE MEASURES CAPTURING ATTRIBUTES OF DESIGN THINKING

Stimulated by Lockwood's discussion of design thinking, creativity, and innovation and their impact on new business growth (2009), this research project sought to develop quantitative measurement of factors and attributes contributing to increased innovation in organizations; specifically within the context of creative synthesis encompassing the design thinking environment. Creative synthesis is the process or leap of faith and intuition leading to the achievement of an effective and creative problem solution.

The development process resulting in the Creative Synthesis Inventory (CSI) considered the six step framework developed by Schmiedel, vom Brock, and Recker's (2014). The development process incorporated three phases and used responses from professional and industry experts and over six hundred student participants. Checkpoints were used at the conclusion of each step and the research design used mixed methods resulting in validation of a 19-item instrument. The CSI is intended to enable organizations and consultants to locate strengths and weaknesses for specific factors and attributes related to the constructs within the creative synthesis process.

ACKNOWLEDGEMENTS

This dissertation would not have been possible if not for the support and encouragement of many throughout different divisions of my life. First and foremost, I must thank my Doctoral Committee: Gene Gloeckner, you have taught me so much more about research methods than I ever thought possible. You inspired me in our conversations, and you've always believed in me. Katharine Leigh, you are a curator of my thoughts and one of my best friends. Over the many years of working with you, you have never given up on me. You help to push my limits and pull the words from my mind when I couldn't think of them myself. Thank you for all that you have done for me so selflessly. Carole Makela, I writing this knowing I am only one of hundreds that wouldn't be sitting here today if it wasn't for you. You are a true believer in all of your students, who help us to see what we often struggle to see for ourselves. Thank you for your persistence and patience as I worked through this research project.

I would also like to extend my sincere appreciation to my outside committee members. Laura Malinin, you have always been encouraging and insightful. It has been a great joy to work with you throughout this journey. Thank you for all that you have given to me over the years. Anna Perry, thank you for your thoughts and insight. The short time that I have spent with you has been a pleasure.

I am indebted to the dozens of professors who helped to bring my ideas to fruition. I hold your names in confidentiality, but you know who you are. To the hundreds of students who provided feedback pivotal to the success of this study - if not for your willingness to help me, I truly would not be sitting here today. With all my heart to each and every one of you, thank you for your assistance.

I would be remiss if I did not take this opportunity to thank my graduate support group. Michele Marquitz, I met you on the first day of my graduate studies, and knew then how lucky I was. You have been a wonderful friend and support system through the years and I am grateful to all that you have done. Jerry Zellers, you encourage me daily to never give up. I am so happy to have met you, and I am thankful for all that we have shared. You are truly remarkable. Sara Colorosa, I have benefited tremendously from the insightful, challenging conversations we have had over the years. All of your support of my success helped to manifest my ideas and clarify my thoughts as I developed the research for this dissertation.

Dan West, you are a deeply sincere, intelligent, hilarious, and talented man. You are my adventure buddy, my partner in crime, my most favorite person. Your undying support has had a profound impact on my life in the past year. Thank you for your patience, late night walks, and idea-sparking questions. You have helped to nurture my thoughts when I needed it most, and for this I am deeply indebted to you.

Katelynn Martinez, what a joy it has been to get to know you. I can only hope this achievement inspires you to continue your education. You are a talented woman who has so much to offer in this world. If I can teach you one thing, I hope it is to continue to push yourself in your pursuit for what sparks your imagination and emboldens you to search for more.

Tina Little, you have showered me with nothing less than love and support since the day I met you, and words cannot express what this has meant to me. Thank you for loving me the way I am.

To all my Friends and Family, too many to mention here, you have been on this ride with me since the beginning. Thank you for remaining in my life, excusing me from weekends, family vacations, and holidays when my research had to take precedence. Thank you for your love, support, and patience while I chased my dreams and worked through this immense endeavor.

DEDICATION

This work is dedication in memorandum to my mentor, Theodore Chamberlain, a man who has shown me the invaluable lessons that come with the pursuit of education. Your words gave me the strength and encouragement I needed to be sitting here writing this today.

Your stories forever live in my mind, and your vivacity for life inspires my dreams and reminds me to never hold back in the chase for fulfillment- whether that is in the rice fields of Asia or in the depths of the Pacific Northwest. I hope to look at those who surround me and know I've inspired them in the same ways you once inspired those who surrounded you.

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TERMS AND DEFINITIONS

Abductive Reasoning: "The logic of design: you are asked to design a telephone for mature people; you know that mature people like clarity and elegant forms of [colors]; you propose a design with a smoothly contoured, soft-white case and clear, black buttons…" (Cross, 2011, p. 28).

Attribute: A sub-factor or component of a factor (e.g., market potential is an attribute under the factor of organizational quality).

Construct: A major concept that cannot be measured by a single measure; instead several factors and attributes are necessary sometimes resulting in the creation of an index measuring construct (e.g., visualization is a construct that can be measured assessing several factors).

Creativity: The process of engagement in creative acts, regardless of whether the resultant outcomes are novel, useful, or creative (Drazin, Glynn, & Kazanjian, 1999). Creativity is a component of the thinking process generateingideas – where ideas are understood as something causing progress within an organization (Eskildsen, Dahlgaard, & Norgaard, 1999).

Creative Design: An emergent bridge which addresses a unique problem-solution pairing….[it is] a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two 'spaces' – problem space and solution space" (Dorst & Cross, 2001, p.14).

Creative Synthesis Process: The process or leap of faith and intuition heading toward an appropriate problem solution. The process consists of creative thinking using imagination and visualization of a problem, combined with prototyping and evaluation comprising an innovative processes giving utility to a strategic solution.

Deductive Reasoning: "The reasoning of formal logic: if *a* is the as *b*, and *b* is the same as *c*, then *a* is the same as *c*." (Cross, 2011, p. 27).

Design Thinking Environment: Encompassed within the climate of an organization, as a human-centered innovation process emphasizing observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis, which influences innovation and business strategy. Ultimately, the objective is to involve consumers, designers, and business people in an integrative process, which can be applied to product, service, or even business design (Lockwood, 2009b). Design thinking "inherently optimistic, constructive, and experiential addresses the needs of the people who will consume a product or service and the infrastructure that enables it…design thinking relies on [the] ability to be intuitive to recognize patterns, to construct ideas that have emotional meaning as well as being functional, and to express ourselves in media other than words or symbols" (Brown & Wyatt, 2010).

Discovery: Developing a deep understanding of a product or user through engagement, observing, creative thinking, and feedback; listening to hear, understand and then explain points of views and perspective of problems and needs (Curedale, 2016).

Evaluation: A process providing the individual or design team with an iterative process to test prototypes and refine the problem solutions before the idea is considered finished (Martin & Christensen, 2013).

Factor: One of several components measuring a construct (e.g., abstract framing of reality as a factor of imagination).

Imagination: The capacity of consciousness to envision things not present in the physical world [surrounding] us…it is the capacity…to negate the given and material essentially enabling abstract thinking and ability to categorize (Folkmann, 2010).

Inductive Reasoning: "The logic of science: you observe all the swans in a given region; you note that each and every swan is white; you form the rule that all swans are white…" (Cross, 2011, p. 27).

Innovation: The intentional introduction and application within a role, group, or organization of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit role performance, the group, the organization or the wider society. The element need not be entirely novel or unfamiliar to members of the group, but it must involve some discernable change or challenge to the status quo (Runco, 2007).

Prototyping: At the core of the implementation process during design thinking is prototyping. Ideas are turned into actual products and services that are then tested, iterated, and refined; "through prototyping, the design thinking process seeks to uncover unforeseen implementation challenges and unintended consequences in order to have more reliable long-term success" (Brown & Wyatt, 2010, p. 31).

Trans-disciplinary: When an approach to a problem crosses many disciplinary boundaries to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem.

Visualization: The mental synthesizing of images that can be manipulated, and the skill with which an individual can sense properties of new combinations of things. Processing information with our brains, through our eyes to communication the relationships of complex information (Curedale, 2016; Walkup, 1965).

Wicked Problems: A "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decisions makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (Rittel, 1973, p. 160).

CHAPTER I

INTRODUCTION

Organizational success is “no longer about creating dominance in scale-intensive industries, it is about producing elegant, refined products and services in imagination-intensive industries. As a result, business people don’t need to understand designers better – they need to *become* designers” (Martin & Christensen, 2013, p. 9). Design thinking and creativity are driving innovation and innovation is driving new business creating new growth (Lockwood, 2009a). Design thinking, as a trans-disciplinary approach, fosters creativity and innovation in a process of overlapping spaces (Brown & Wyatt, 2010). Within these spaces, a collective mind-set builds a track record of tackling and finding solutions for complex and even ‘wicked problems’, creating customized solutions (Buchanan, 1992; Martin, 2013). These solutions derived from the application of innovative ideation respond to the need to predict and evaluate potential improvements (Ambrose & Harris, 2010; Coughlan & Prokopoff, 2013; Martin, 2009; Owen, 2007). The power of creative thinking and doing, for designers, fosters and generates new ideas (Dorst & Cross, 2001; Martin, 2013); in other organizational types, design thinking invites elements of the design process valued in the design professions - discovery and visualization.

Design-led organizations outperformed other organizations by 93% in return on new and innovative investments, validating the importance of design thinking’s role in addressing strategic priorities, communicating organization values, and enhancing the organizational environment (Design Management Institute, 2015; Lockwood, 2009b). Organizations utilize design thinking to innovate and succeed (Brown, 2008; Cooper, Junginger, & Lockwood, 2009;

Lockwood, 2009b; Martin & Christensen; 2013). This approach to problem solving reveals how knowledge advances toward refinement from:

> a) mysterious (something we cannot explain); to b) heuristic (a rule of thumb guiding us toward solution); to c) an algorithmic approach (implementing a predictable formula resulting in an answer) to d) code (when the formula becomes so predictable it can be fully automated). As knowledge acquisition advances through these four stages, productivity grows and costs drop, creating massive value and internalization of creative innovation strategies within individuals and teams (Martin, 2009, pp. 38-39).

The design thinking and creativity literature suggest using integrative performance measurements to evaluate the success of creative innovation. Qualitative explorations can be identified locating the presence of design thinking factors. However, personal communications with experts in the field clearly indicated quantitative assessment focused on measuring the design thinking environment and creative synthesis process are absent, yet desired by companies, in existing process evaluations and implementations (R. Martin, personal communication, August 29, 2013; D. Kelley, personal communication, September 17, 2013). This gap invited the exploration and development of quantitative measurement to provide quantitative values that could be compared over time for organizations and teams operating seeking clarity to track change leading to increased innovation.

An important consideration in this research study was the differentiation between the process for seeking creative innovation and the environment promoting the process. This distinction clarified the existence of the ’leap of faith and intuition’ needed in creative problem solving – in this context, the process of creative synthesis. Design thinking as the environment, invites the creative synthesis process to materialize and take part in the problem seeking and solving of challenges presented to organizations. Conceptualizing an understanding of the creative synthesis process, constructs, key factors and attributes is depicted in Figure 1 with four dominant constructs of the creative synthesis process as *Imagination*, *Visualization*, *Prototyping*, and *Evaluation*. When these four constructs are interactively in play, the outcome is creative synthesis.

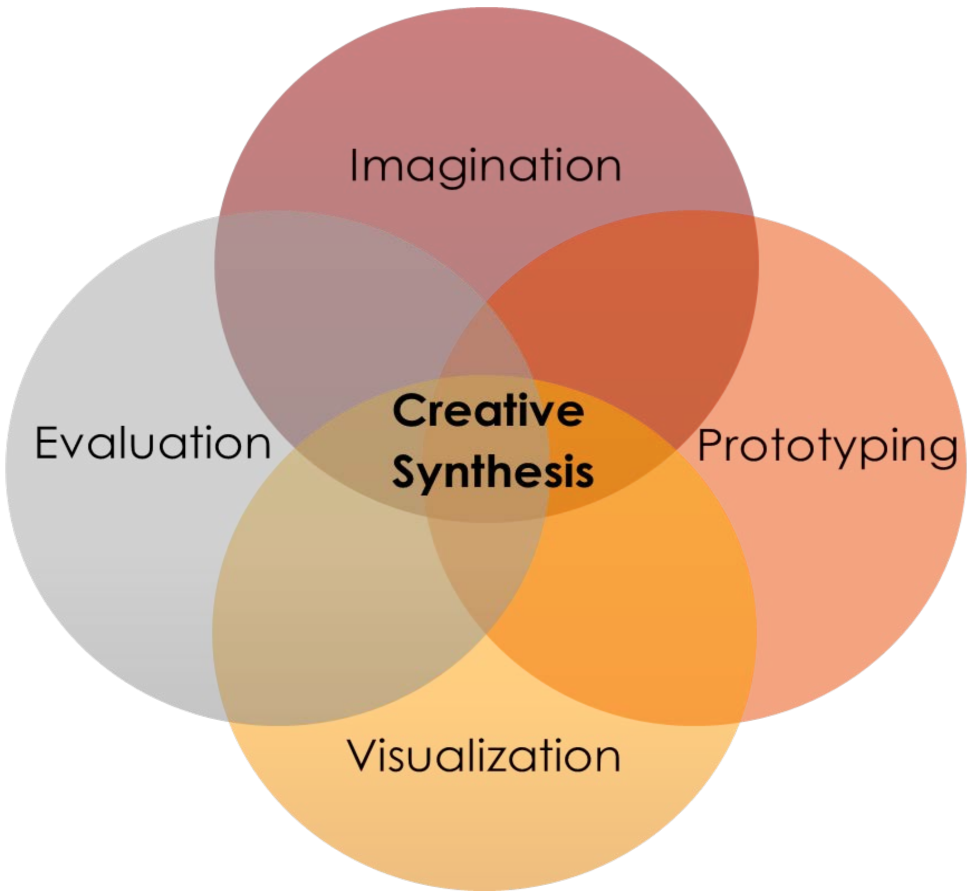

Figure 1. Constructs comprising the creative synthesis process in the design thinking environment.

Purpose of Study

Initially the research intent was to utilize a quantitative instrument with an organization to capture data explaining the four constructs in situ; however, finding the lack of such an instrument, the research goal shifted to construct a quantitative instrument with measures attributable to the creative synthesis process. The creativity and design thinking literature confirmed the absence of a quantitative assessment instrument and therefore, the purpose of this study was to examine and identify the factors and attributes of each construct to subsequently develop and validate a quantitative instrument.

Research Questions

Two research questions framed the research study:

RQ1: Can a quantitative instrument measure the creative synthesis process within the design thinking environment?

RQ2: Is there a difference among groups representing different disciplinary backgrounds?

A quantitative measurement would enable organizations to potentially locate, and better understand the presence or absence of design thinking in their organization. The importance of design thinking enables pinpointing areas of strengths or needs for improvements and would invite new ways of envisioning, addressing, creating, and measuring a culture of creative and critical inquiry into an organization's quest to achieve a more defined and innovative outcome and process.

Assumptions

Four assumptions were made at the beginning of the project. First, faculty interest in engage in the process of identify factors contributing to the four design thinking constructs. Second, given faculty support to engage the researcher with their course participants, it was anticipated that factors and attributes of the creative synthesis process would encompass their students. Third, all faculty and upper division students would be familiar with diverse inputs and resources to produce a final product with some measure of creativity. Finally, student participants were assumed to have participated in individual and team-based projects, priming the students' creative thinking prior to participating in this study.

Perspective of the Researcher

I entered my doctoral program with a sequence of design and human resource management experiences affecting my perspective of this current study. Earning my Masters of Science in Design and Merchandising at Colorado State University, my thesis research focused on organizational learning as a means to improve performance with the purpose to assess the use of knowledge types identified in Cohen and Levinthal's Theory of Absorptive Capacity (1989; 1990). My focus was to enhance existing research regarding organizational absorptive capacity by examining evidence of new knowledge through the lens of micro and/or macro sustainable change. In 2009, I received my BS in Apparel and Merchandising from Colorado State University in Fort Collins, CO.

Professionally, I have designed men's active wear with a Denver-based private design studio, working to enforce quality standards for more than 100 garment designs with apparel manufacturers' worldwide. During the completion of my PhD, I served as Assistant Human Resource Manager for a university department. Through various opportunities during this time, I partnered with internal and external cooperators and stakeholders, conducting agency-wide analyses to increase employee performance and success. My ability to conceptualize the big picture while simultaneously focusing on details allowed me to achieve high quality results in short time frames. Other professional experiences included four years instructing two undergraduate courses at Colorado State University in which I expanded views of the design and creative process to students, faculty, and staff inside and outside of the academic setting and the presentation of several research-based papers focused on the design thinking process and its relationship to human resource development. These experiences framed my doctoral inquiry into the factors of design thinking and the construction of the creative synthesis process.

Measuring the creative synthesis process, where thinking transforms to doing, became the natural focus of my doctoral research. Combining existing models, instruments, and studies conducted by design thinking leaders (Brown, 2009; Cross, 2011; Martin 2009), I have attempted to make a professional contribution to the body of knowledge surrounding the application and implementation of design thinking, creating quantitative metrics to fill a void in the creative synthesis process.

Delimitations

In the study participants/respondents were limited to a) faculty and graduate students engaged in research collaborations focused on creativity, innovation, and design thinking discussions, and b) third- and fourth- year students engaged in specific courses with either a lab or lecture delivery format space taught by the faculty described above (i.e., Anthropology, Art and Art History, Design and Merchandising, Electrical and Computer Engineering, Horticulture and Landscape Architecture, Journalism and Media Communications, Marketing, Mechanical Engineering, Education, and Theatre and Dance). The study took place at a large, land grant, western region university over the course of four sequential academic semesters.

CHAPTER II

LITERATURE REVIEW

Design thinking, as a construct, continues to evolve as a strategy to engage and solve complex problems and has been adapted by design and non-design entities as an approach to enhancing creativity and innovation in organizations (Brown, 2008; Martin, 2009; Wrigley & Straker, 2015). Curedale (2013b) reflects on a developmental history of design thinking with various disciplines drawing upon their own knowledge base, for example, interior design programming and post-occupancy development and evidence-based design in healthcare planning (K. Leigh, personal communication, June 1, 2017). An approach to problem solving in organizations emerged initially with Wallas' Four Stage Model of Creativity (1926), visualizing four primary stages as preparation, incubation, illumination, and verification. This model can be considered as another source in creating a foundation for design thinking. Mattingly Huber (2011), in her examination of design process models drawing from diverse disciplines also illustrates the similarity to later conceptualizations of the components of the design thinking environment. Archer, in the 1950's, initially conceptualized critical components of the design thinking and described design as "the repository of knowledge…not only the material culture and the contents … but also the executive skills of the doer and the maker (1979; p. 20). Rowe popularized design thinking in the literature, emphasizing the idea of problem solving and the "complex texture of decision making" (1987; p. 2). Rowe's ideas surrounding design thinking acknowledged the design process, stressing 'problem-seeking' (Pena & Parshall, 2012) as not restricted by an idealized step-by-step process by which designers approach creative problem solving.

This literature review is organized to examine: a) design thinking and creativity models utilized predominately within organizations seeking change to compete in the global marketplace; b) the focuses of design thinking within groups and organizations; and c) published models addressing constructs within the creative synthesis process establishing a foundation for the development of quantitative measurement. The literature is bereft of quantitative measures to assess the design thinking environment. From the review of literature, a conceptual model was developed illustrating the constructs embodied in creative synthesis.

Design Thinking

Design thinking, as a merger of the design process used by disciplines engaged with the physical environment (e.g., architects, industrial designers, graphic designers, interior designers, engineers) and business processes (Cooper, Junginger, & Lockwood, 2009); Brown, 2008; Sermon, 2014), sought to provide organizations with strategies for visualization enhancing the potential for creativity. The phases of the design process- pre-design, user needs identification (programming), schematic design, design development, project documentation (construction documentation), project administration, and post-project evaluation - played a major part in supporting the problem seeking and problem solving phases. During the 70s and 80s concepts related to design thinking began to appear in the research literature characterized as *visual thinking, mind mapping,* and *human-centered design along* with implementation in organizations such as IDEO (Brown, 2009) followed by tools for use by groups (Curedale, 2013a, 2013b).

Since the 90s, the term, *design thinking*, has been attributable to a multiplicity of meanings, confusing its interpretation by groups and organizations (Badding, Leigh, & Williams, 2014). From 2006 to 2013 (Table 1), more than a dozen commonly used definitions emerged across literature related to design thinking, describing the concept as a thought process; systematic problem-solving approach; method; and/or mind set.

Researchers (Curedale , 2013a, 2013b; Martin & Christensen, 2013) perceived design thinking as a systematic problem solving process with stages including problem seeking and discovery, with subsequent problem solving and visualization. Their ideas encompassed an approach to problem resolution connecting design thinking to design and business processes.

Table 1 presents the different interpretations of design thinking by different researchers. Again, terminology is varied creating the potential for subtle interpretations in meaning. Dunne and Martin (2006) further distinguished design from design thinking suggesting design thinking as the cognitive process used by designers versus the designed objects they produced with Wrigley and Straker (2015) characterizing design thinking as the ability to combine empathy, creativity, and rationality to analyse and fit solutions to particular contexts.

Table 1
Design Thinking Definitions (2006-2013)

Researcher(s)	Design Thinking Definition
Dunne & Martin, 2006	"Approaching management problems as designers approach design problems…" (p. 512).
Owens, 2007	"…is in many ways the obverse of scientific thinking. Where the scientist sifts facts to discover patterns and insights, the designer invents new patterns and concepts to address facts and possibilities" (p. 17).
Brown, 2008	"A methodology that imbues the full spectrum of innovation activities with a human-centered design ethos" (p. 1).
Lockwood, 2009a	"… is essentially a human-centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis, which ultimately influences innovation and business strategy. The objective is to involve consumers, designers, and business people in an integrative process, which can be applied to product, service, or even business design" (p. xi)

Table 1. *cont.*

Martin, 2009	"Design thinking [is] the wider application of a design perspective beyond just product aesthetics, as a potential source of sustainable competitive advantage…to be a 'design thinking' organization…requires gaining the ability to strike a better balance between exploration and exploitation of the innovation process than is typical of most organizations today" (p. 37).
Rylander, 2009	"…is composed of two ambiguous words that defy straightforward definition…[existing definitions] call attention to the two components that are addressed in…literature – that design problems are somehow different and that the way they are addressed by designers is somehow different" (p. 10).
Acklin, 2010	"Design thinking acts as a bridge between the reactive and the proactive notions of design management by establishing a sustainable culture for design in a company" (p. 55).
Ambrose & Harris, 2010	"Design thinking is a subject that includes many terms relating to technical or creative concepts" (p. 177).
Brown & Wyatt, 2010	"…incorporates constituent or consumer insights in depth and rapid prototyping, all aimed at getting beyond the assumptions that block effective solutions. Design thinking – inherently optimistic, constructive, and experiential – addresses the needs of the people who will consume a product or service and the infrastructure that enables it…design thinking relies on our ability to be intuitive, to recognize patterns, to construct ideas that have emotional meaning as well as being functional, and to express ourselves in media other than words or symbols (pp. 29-30).
Cross, 2011	"Something inherent within human cognition; it is a key part of what makes us human" (p. 3).
Curedale, 2013a, 2013b	"A people centered way of solving difficult problems. It follows a collaborative team based [trans]-disciplinary process. It uses a toolkit of methods and can be applied by anyone from the most seasoned corporate designers and executives to school children. Design Thinking is an approach that seeks practical and innovative solutions to problems. It can be used to develop products, services, experiences and strategy…Design Thinking combines empathy for people and their context with tools to discover insights. It drives business values" (from 2013a, p. 13).
Liedtka, King & Bennett, 2013	"…it is an approach to problem solving that is distinguished by…discovery in advance of solution generation using market research approaches…expands boundaries of both our problem definitions and our solutions…is enthusiastic…[and] committed to conducting real-world experiments…it is capable of reliably producing new and better ways of creatively solving a host of organizational problems" (p. 2).

Design Thinking Implemented in Organizations

The design thinking literature suggests visualization of concepts and delivery of novel services (Cooper, Junginger, & Lockwood, 2009) are strategic, leading to new forms of value (Brown, 2008) and discovery of unmet needs. The Design Management Institute, a promoter of design thinking, consults with corporate/design organizations (53%), consulting organizations (22%), members from academia (17%), public service constituencies, and others (8%), reinforcing the importance of design thinking to organizations on a global level.

Design thinking has been utilized as the driving force in an organization's ability to increase competitive advantage (Martin, 2010) and return on investment (ROI), creating the need to understand its value in the work place (Sermon, 2014). The implementation of design thinking to solve complex organizational problems can result in solutions as small as changes made to the packing of a product to increase sales (Sermon, 2014), or as large as influencing strategic decisions (Brown, 2008; Lockwood, 2009b). Examining organizational applications of design thinking clarifies the diverse ways in which design thinking has been used. Organizations internalized design thinking (e.g., IDEO, Apple, Google, and Tesla Motors):

- IDEO: An award-winning, global design firm helps organizations in the public and private sector innovate and grow through a design based, human-centered approach envisions new companies, also designing the products, services, and experiences brining new companies to the marketplace (IDEO, 2015). IDEO consultants think like designers in their approaches to developing products, services, and organization strategy bringing together what is organizationally desirable with what is technologically feasible and economically viable. Methods include "business model prototyping, data visualization, innovative strategy, organizations design, [and] qualitative and quantitative research (IDEO, 2015). IDEO teaches those who are not trained as designers to use creative tools to find an array of problem solutions, helping organizations envision and achieve a competitive advantage in the global marketplace.

- Apple: Apple has made its name as one of the world's most innovative companies (Fast Company, 2015) through a business strategy "leverag[ing] its unique ability, through the design and development of its own operating system…to brings to its customers new products and solutions with superior ease-of-use, seamless integration, and innovation industrial design" (Reference for Business, 2015).
- Google: the Company's programs have innovated ways businesses find customers, entrepreneurs become creative, and publishers make money from their content (Google, 2015b). To reflect the consumers they serve, Google hires smart and determined employees who share common goals and visions for the future, "hailing from all walks of life" and speaking dozens of languages. Founders and executives are made available to everyone, and all employees are made to feel comfortable sharing ideas and being creative. Numerous venues (email, weekly meetings, and the café) are provided to the employees to encourage and facilitate the transfer of knowledge and ideas. Overall, Google offices and cafes are designed to encourage interactions between employees within and across teams and to spark conversation about work and play (Google, 2015a).
- Tesla Motors: Since the company began, Tesla Motors has created two model vehicles, the Model S and the Model X. Guided by the mission to accelerate the world's transition to sustainable transport, Tesla cars marry technology and design to the focus of energy innovation (Tesla Motors, 2015).

While IDEO and others have implemented strategies to capture the essence of design thinking within their organizations, design thinking has been intangible for many other organizations. The lack of universal definitions and common language becomes problematic for organizations desiring to implement the design thinking concept and develop comparison with consistent organizational performance indicators.

As organizations have embraced design thinking, the demands for individuals trained in this this approach to problem resolution has increased with design thinking appearing in major U.S. and international universities, centers, and labs.

Examining Models of Design Thinking

Researchers have explored a variety of models depicting design thinking. Numerous design thinking models and ideas were considered with nine models selected for further examination based upon their purpose, outcome, and components related to and impacting design thinking at the organizational and group levels.

Design Ladder, Danish Design Center (2003)

The Design Ladder has been used as a framework to better understand ways design enhances creativity, innovation, and competiveness among organizations. Created in 2003, the Design Ladder measures the level of the design activity in business (Design Wales, 2011; Figure 2). As a first-step in developing a method to assess economic benefit of design and considering ‘cost’, the Design Ladder identifies four stages of design maturity in an organization:

- *Stage One: No Design* - The utility and needs of the end-user are not a consideration to the organization. Design has little to no role in product service development, and often is carried out by non-design professionals.
- *Stage Two: Design as Styling* - Design is relevant only in terms of product aesthetics or ergonomics. Style and appearance decisions are often purchased from non-design professionals.
- *Stage Three: Design as a Process* - Design is considered as a process or method in product service delivery and output but only during the initial stages of development. Design solutions that are sought are procured externally and later adapted to the requirements of the end-user through a multidisciplinary approach.

- *Stage Four, Design as Strategy* - The design process is infused to the core of the organization and plays a major role in the organization's key objectives and product development. Design encourages continual renewal of business concepts and provides a means to encourage innovation.

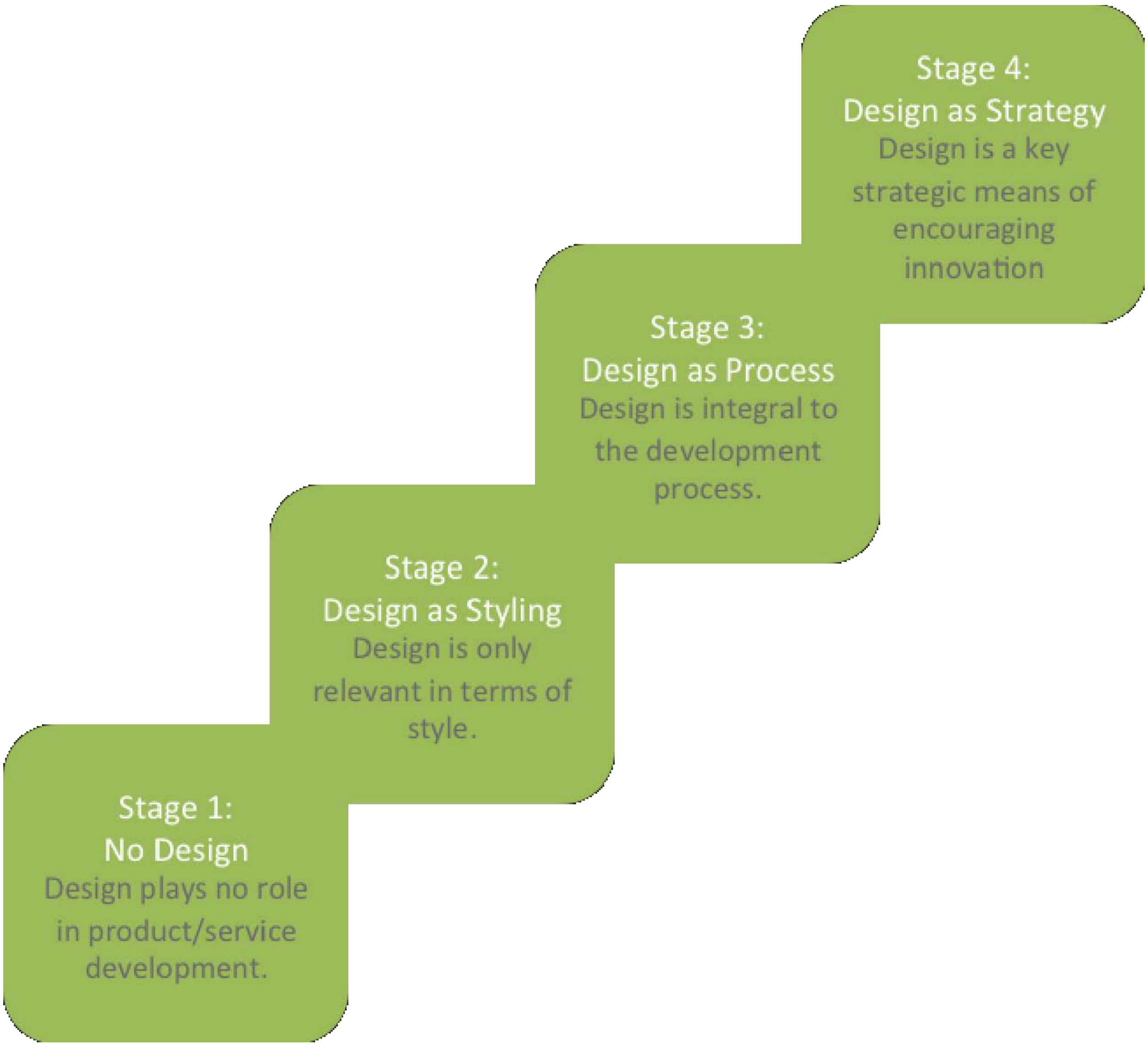

Figure 2. Design Ladder created to evaluate economic benefits and design maturity (Danish Design Center (2003).

Balanced Score Card (2005)

Borja de Mozota's model and instrumentation measure the impact of design value in organizations and has been commonly used in business management as the Balanced Score Card; the scorecard is utilized to implement organizational design strategies (Figure 3).

Four ways of implementing design are located on the Balanced Score Card -- the four powers of design (Borja de Mozota, 2005; 2006):

- *Design as differentiator* - providing competitive advantage through avenues including consumers, market, and price.
- *Design as integrator* - improving product development (encompassing teams using visualization as a tool).
- *Design as transformer* - development of new business opportunities aiding organizations in adjusting to change.
- *Design as good business* - supporting sustainable business affecting the bottom line, value, market share, and an organization's return on investment (ROI) (Borja de Mozota, 2006, p. 45).

When the score card is implemented within organizations, outcomes impact organizational vision and strategy (Borja de Mozota, 2005). The score card has been tested in organizations worldwide (e.g., Steelcase, Decathlon) and used as an indicator of organizational performance and value placed on performance (Borja de Mozota, 2006). The scorecard links design strategies to value and offers an approach to quantitatively measure an organizations' use of or improvement with the four factors identified by the model.

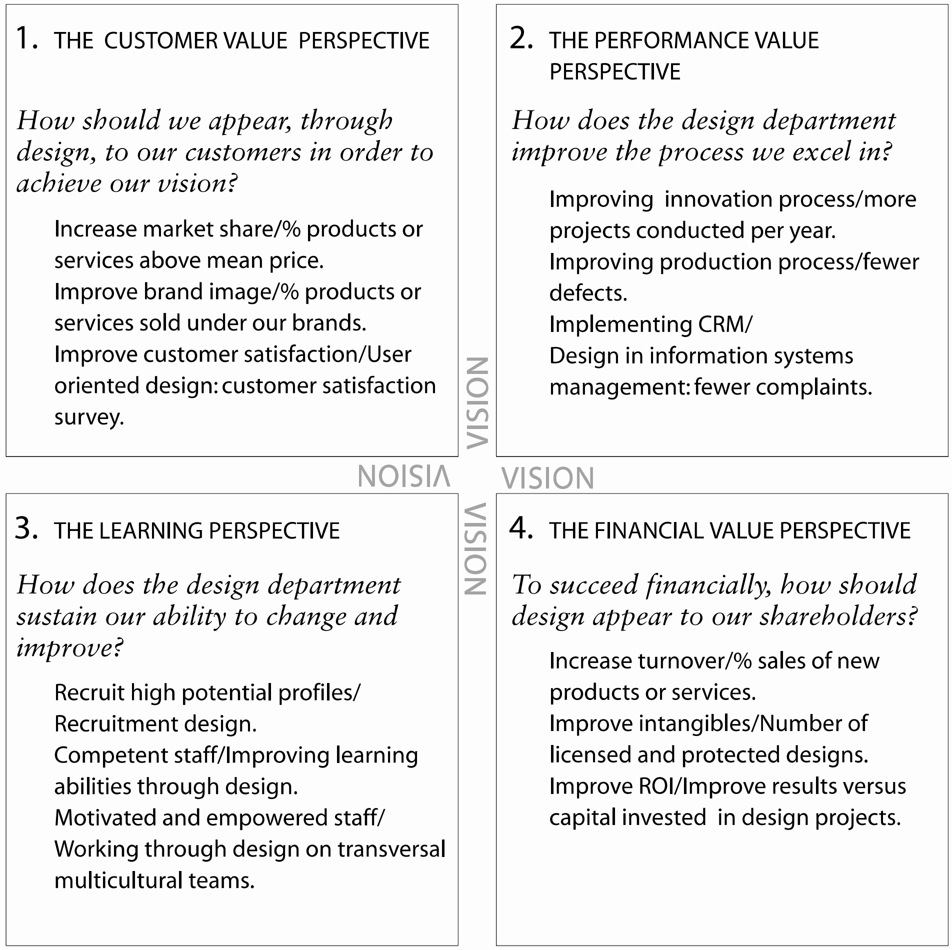

Figure 3. Balanced Score Card created by Borja de Mozota (2006).

The Three Gears of Business Design (2009)

The implementation of design thinking strategies was used as a path to understand stakeholders’ priorities, as a tool to visualize new concepts, and as a process to translate new ideas into strategy. Fraser (2009) created The Three Gears of Business Design (Figure 4) suggesting “the greatest payout of design thinking is in the design of business itself…” (Lockwood, 2009a, p. 40).

Figure 4. The three gears of business design (Fraser, 2009).

The gears represent a framework meshing together user needs, concept visualization, and strategic business design for enterprise success (Fraser, 2009):

- *Gear 1: Empathy and Deep Human Understanding* - Aims to achieve deep user understanding and establish a context for creative thinking encouraging innovation and value creation. Through the exploration of new opportunities, the organization is able to gain context regarding the user -- what they do and how they feel.
- *Gear 2: Concept Visualization* - focuses on concept visualization as a goal. Gear two stresses the use of various tools during the strategic planning process to explore a broad set of problem solutions. Creative tools like prototyping and ideation enrich the organization and allow for the discovery of novel solutions.
- *Gear 3: Strategic Business Design* - analyzes design thinking strategies, which will drive success, prioritizes activities, which deliver those strategies, and defines how the design thinking strategies fit together operationally and economically (Fraser, 2009). Through this, "broad concepts [align] with future realities through strategy formulation and design of the business model itself" (Lockwood, 2009a).

The meshing of the three gears is suggestive of the ways key attributes of creative thinking are integrated and are also significant to knowledge acquisition within an organization. Finding and assimilation of new concepts into the organization's operating system creates feedback loops reinforcing innovative ideation, optimizing problem-solving performance techniques, and increasing the organizations' ability to visualize strategies driving success and organizational competitive advantage. The momentum of acquired knowledge reflected through creative thinking impacts preparedness for change and is measured through the creation of a strategic business design, thus optimizing performance and creating competitive advantage within the organization. Ideally, the three gears mesh together to solve business problems faster, resulting in new strategic models.

Emerging from the three gears of business design are a number of key factors and attributes: creative thinking incorporating the discovery, innovation, problem solution, and visualization of knowledge; deepened understanding and value creation, strategic business design and optimized performance suggestive of an organization's preparedness for change.

Design Organization Continuum (Bubble Model, 2009)

Junginger's model depicting the four roles of design raises awareness of design for leadership, as few organizations know at any given point in time "when, where, and how they are making use of [design]" (p. 4). To answer these questions (Figure 5) *bubbles* are used to visualize four "archetypical" places where design thinking and design methods are found and shape organizational qualities to describe the design thinking organization.

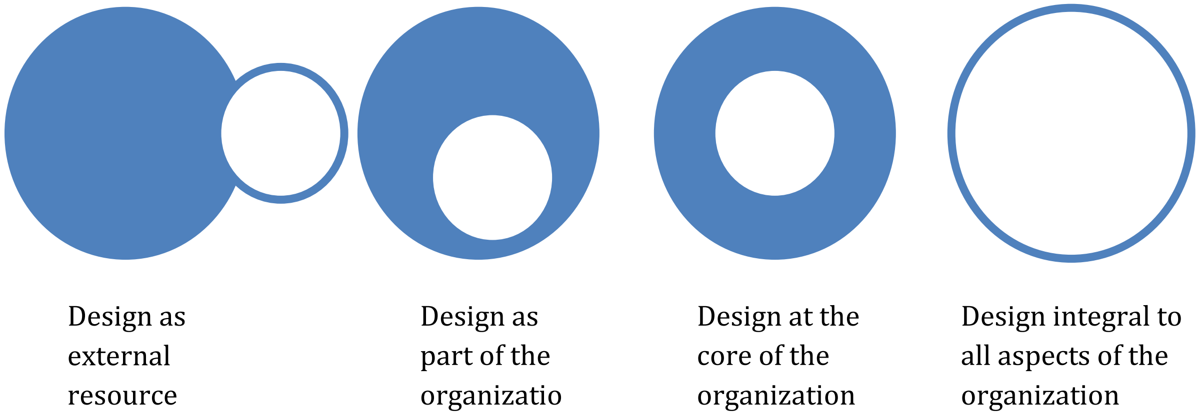

Figure 5. The four roles of design thinking in an organization (Junginger, 2009).

The bubble model was intended for use to discuss, assess, speculate, describe, analyze, plan, and communicate the role of design in the organizational context (Junginger, 2009). Design can be:

- *Add-on*: design on the organization periphery with no defined role, seen as an external resource without a continuous presence, and often limited to classic design problems of product communication and function.
- *Design as part of the organization*: design as a component of selected teams in specific locations, with gaps existing among the teams and the remainder of the organization. Design remains limited to existing products and services.
- *Design at the core of the organization*: design is exceedingly visible with access to organizational leadership. Design is linked directly to strategy with significant impact in the organization and on its identity.
- *Design integral to all aspects of the organization*: design is being questioned, formed, and shaped by ongoing design-oriented inquiries. Design as a process of creative problem identification and problem solving involves a wide variety of complex situations, uncovering and changing organizational beliefs, values, and norms.

The bubbles generate conversations about how and where design could be used in an organization. The ability to recognize the location of design activity enables an organization to link creative problem solving approaches and strategic business principles (Junginger, 2009).

The bubbles, rather than representing standards of good or bad, provide a commonly understood language when communicating why design thinking may or may not be used at the macro or micro levels of an organization (Junginger, 2009). Factors to be considered from this model include design thinking in proximity to the organization's core.

Design Management Staircase (2009)

The hierarchical staircase was developed through research collaborations at INHOLLAND University (Haarlem, Netherlands) beginning in 2007. The Design Management Staircase was developed as an assessment and benchmark tool to suggest the greater the design management behavior, the greater the strategic importance of design to the organization. The Design Management Staircase illustrates the relationship among five design factors and four levels of design management capability and maturity (Figure 6).

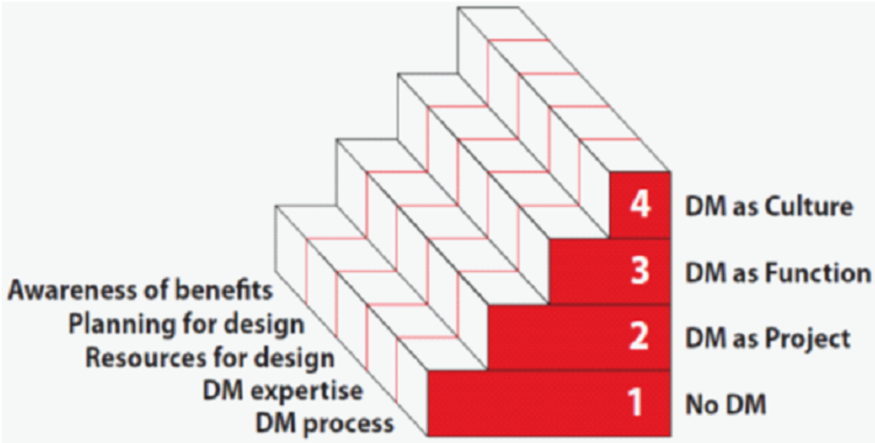

Figure 6. Design Management Staircase created by Design Management Europe (Kootstra, 2009).

The four level of maturity are:

- *Level one: No design management* - Design activities are often inconsistent in quality and results, consequentially due to a lack of poorly defined procedures. If design policies exist, they are *ad hoc* or recently implemented. Design has little to no role in an organizations competitive advantage.

- *Level two: Design management at a project level* - design activities remain at the operational level of the organization with little to no collaboration among departments. Design is used only to meet direct business needs (i.e., redesign of product packaging) and is not recognized as a tool for new product development or innovation.
- *Level three: Design management at a functional level* - design activities are entrusted to one employee or department acting as the gatekeeper for the organization with formal responsibility for managing the design process. Design becomes a tool for shortening product cycles and is a permanent feature of product development.
- *Level four: Design management at a cultural level* - design activity begins to espouse design into organizational culture. Design innovation strategies develop as a tool for innovative communication, presentation, marketing, and retail concepts and are incorporated into whole departments, becoming the organization's main business processes in place of older less integrated strategies.

The five design factors bear upon the success or failure of the sequential levels of design management. The design factors are:

- *Factor 1: Awareness of benefits* - Senior management lacks awareness concerning the benefits of design and are not likely to value design as a competitive asset.
- *Factor 2: Planning for design* - Design becomes connected to the organization's other areas of business (i.e., product development) and wider policy making processes. Linking areas of business not previously linked will most likely deconstruct current organizational structure and facilitate more effective collaboration.
- *Factor 3: Resources for design* - Design-aware organizations develop a strategy for design, which becomes widely communicated. A clearer strategy allows design activities to a line within business or market targets.
- *Factor 4: Design management expertise* - The quality of design is greatly dependent on the availability of design staff (i.e., professional designs, design managers, design teams) and the maturity of tools and methods developed.
- *Factor 5: Design management process* - The design management team's responsibility is to ensure the best use of design possible, ensuring appropriate investments in design projects, design staff, and the creative working environment.

Fundamentally, scores of the factors are calculated based on three to four questions per factor. Scores are determined by the average of the three to four questions per factor.

Integrated Design Management Process (2009)

Recognizing the best design processes are integrative, collaborative, and iterative, Lockwood (2009a) created the Integrated Design Management Process, a spiral model with intersections allowing team members to enter and exit the design process as needed (Figure 7). As the spiral moves closer toward the final design decision, the design team is able to discover, shape, and form the design process.

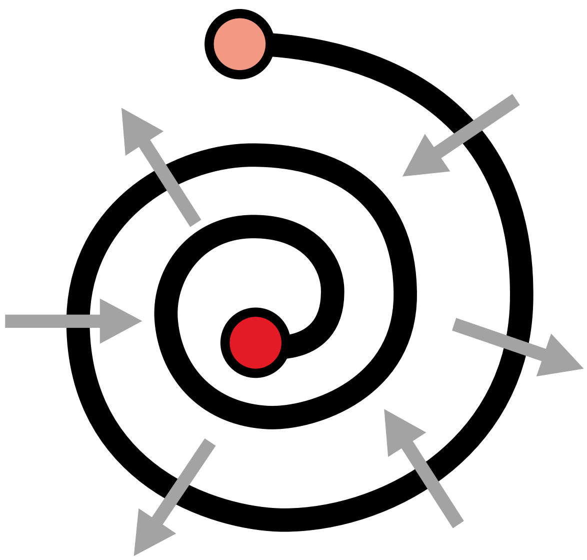

Figure 7. Integrated Design Management Process, created by Lockwood (2009a).

The Integrated Design Management Process begins by defining the problem. By doing so, the design team is able to develop deeper insights into customers' behaviors and motivations. Next, the design team seeks patterns and connections to sort through findings and make connections to customers' needs and desires. Continually, the gray arrows indicate the arrival and departure of various team members in to and out of the design process. These interactions allow for design-reviews, check-ins, and feedback loops. In ideation, the design teams create quick concepts through rough sketches, prototypes, or stories to communicate findings and explore problem solutions. In this model, it is assumed the ideation phase gives way to the innovation where new products, services, processes, and partners emerge. Flexibility and creativity are stressed, as the goal is to solve the right problem.

A Design-Driven Innovation Management Model (2010)

Acklin's (2010) design-driven innovation management model proposed a circular linkage between internal and external drivers in strategy building, innovation management, and design management (Figure 8). Working in the model are six stages: impulse, research, development, strategy, implementation, and evolution.

- *Impulse* - the interaction between ecosystem and organizational impulses lead the organization to an analysis of what they already know or have learned about their product and markets. The goal of this stage is to assist the organization in recognizing the types of market and customer trends that have been emerging and to begin formulating a first hypothesis.
- *Research* - a diverse mix of research techniques internally (research and development, experimental research, etc.) and externally (open innovation, market and trend observations) are applied to assist the organization in understanding their proposed hypothesis.
- *Development* - concepts are informed by the criteria deducted from the material gathered during the research stage.

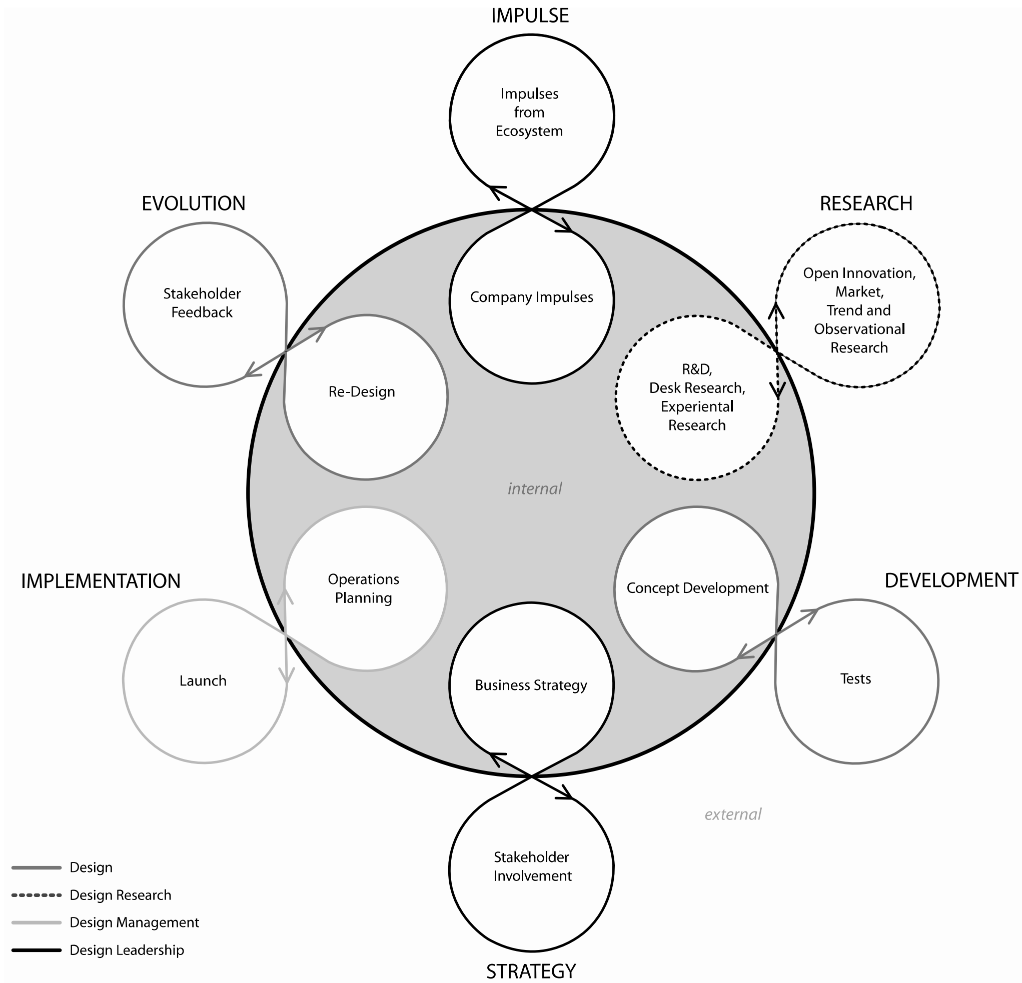

Figure 8. A design-driven innovation management model created by Acklin (2010).

- *Strategy* - should follow the impulse, research, and, development stages and should never be the starting point of the design-drive innovation model (Figure 3). This stage should analyze business strategy and stakeholders' involvement to continue offering new products in the forefront.
- *Implementation* - operations planning and the launch of the adapted brand and communication strategy take place during this stage. Appropriate adjustments of operations safeguard a well-coordinated customer experience.
- *Evolution* - the last stage emphasizing the importance of stakeholder feedback and re-design. During this stage feedback is used to improve the product or service.

Preliminary conversations with chief financial officers of small and medium sized enterprises demonstrated promise in the design-driven innovation model's ability to adapt existing organizational frameworks of design and design management into visual models that are easier to understand and use (Acklin, 2010).

Knowledge Funnel (2010)

The knowledge funnel depicts value creation in achieving balance suggesting an organization's competitive advantage (Martin, 2009, 2010) hinges on the balance between exploration (search, risk-taking, experimentation, and discovery) and exploitation (refinement, selection, efficiency, and implementation) during the innovation process (Leavy, 2010; Martin, 2010). The three levels of the knowledge funnel, referred to by Martin as points of view, aid in advancement of knowledge and capture of value by pinpointing market opportunity, devising a product offering to that selected market, and codifying business operations within the organization (Figure 9; Martin, 2009, 2010, p. 37).

The funnel visually represented an organization's advancement in knowledge acquisition, narrowing as the organization became increasingly more informed and aware as increased knowledge simplifies complexities, becomes more refined, and ultimately increases success in performance (Martin 2009, 2010). The knowledge funnel's points of view require reconciliation with concepts surrounding the organizations acquired knowledge. The first point of view stems from strategies constructed by the collection of rigorous quantitative data. Through the analytical thinking process, judgments, bias, and variations are reduced. The second point of view, in contrast with the first, suggests intuitive thinking is centred on the primacy of creativity and innovation. Martin (2010) posits the combinations of these points of view are the foundations to the knowledge funnel. Organizations mastering the combination of these two points of view gain long-term competitive advantage through a third point of view, the knowledge funnel – the methodology of design thinking. Design thinking builds an organization's knowledge base aiding in the movement from mystery to heuristic to algorithm and back again more easily and consistently (Leavy, 2010, p. 8). The knowledge funnel develops equilibrium between exploration and exploitation during the innovation process, enhancing knowledge value in organizations.

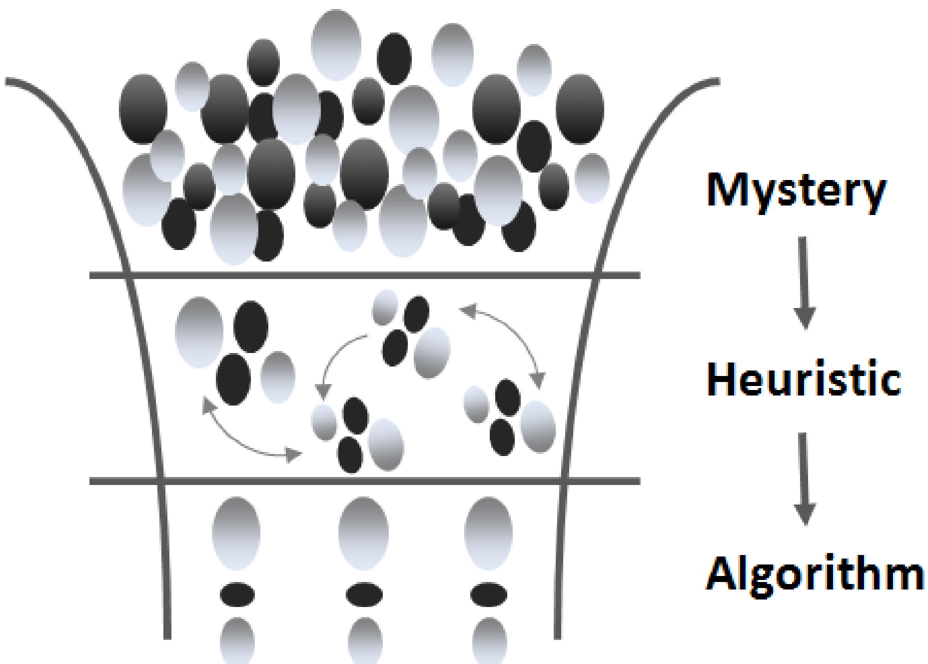

Figure 9. The Knowledge Funnel created by Martin (2010).

Design Value Scorecard, Design Management Institute (2013)

According to the Design Management Institute (DMI), design thinking organizations outperform other organizations, validating the critical nature and impact of design thinking on performance and productivity (2013). The scorecard (Figure 10) allows organizations to track accomplishments to locate their use and level of maturity relative to design thinking strategies. The scorecard permits an organization to identify location as a continuum illustrating the resources given to key growth drivers leading to the development and delivery of improved strategic performance (The Value of Design, 2016; Westcott et al., 2013).

The scorecard consists of three best-practice “zones” to reflect how organizations implement design to improve business value. Moving horizontally on a continuum in the design value scorecard, the zones are:

- *Zone 1: Development and Delivery* - tangible impacts through methods such as the redesign and/or other aesthetic and functional product attributes. Delivery, service, and customer communication appear here.
- *Zone 2: Organization* - a shift and re-thinking of the organization and stresses design value defined in metrics such as product conversion, customer value, loyalty, and market share.
- *Zone 3: Strategy* - reserved for organizations that have made design a core competency. The move to incorporate design into strategies can be studied through an organization’s structure, operations, profit margin, and stock performance.

Five levels of design maturity move vertically on the scorecard from *Optimized (maturity)* as the most established level of design maturity with the greatest productivity, through to *Initial/ad hoc* as the least established level of maturity characterized by low quality in product output and high levels of risk and waste (The Value of Design, 2016; Westcott et al., 2013). The level of design allows an organization to begin tracking and evaluating progress of design use, value, and return on investment. Over time the organization can realize progress through evaluation and feedback, encouraging increased support and resources for leaders to aid in growth and increased competitive advantage. Measuring design maturity functions as a fundamental organizational quality when incorporating characteristics of design thinking. In certain instances when design implementation is not ideal, the scorecard illustrates an organization’s digression.

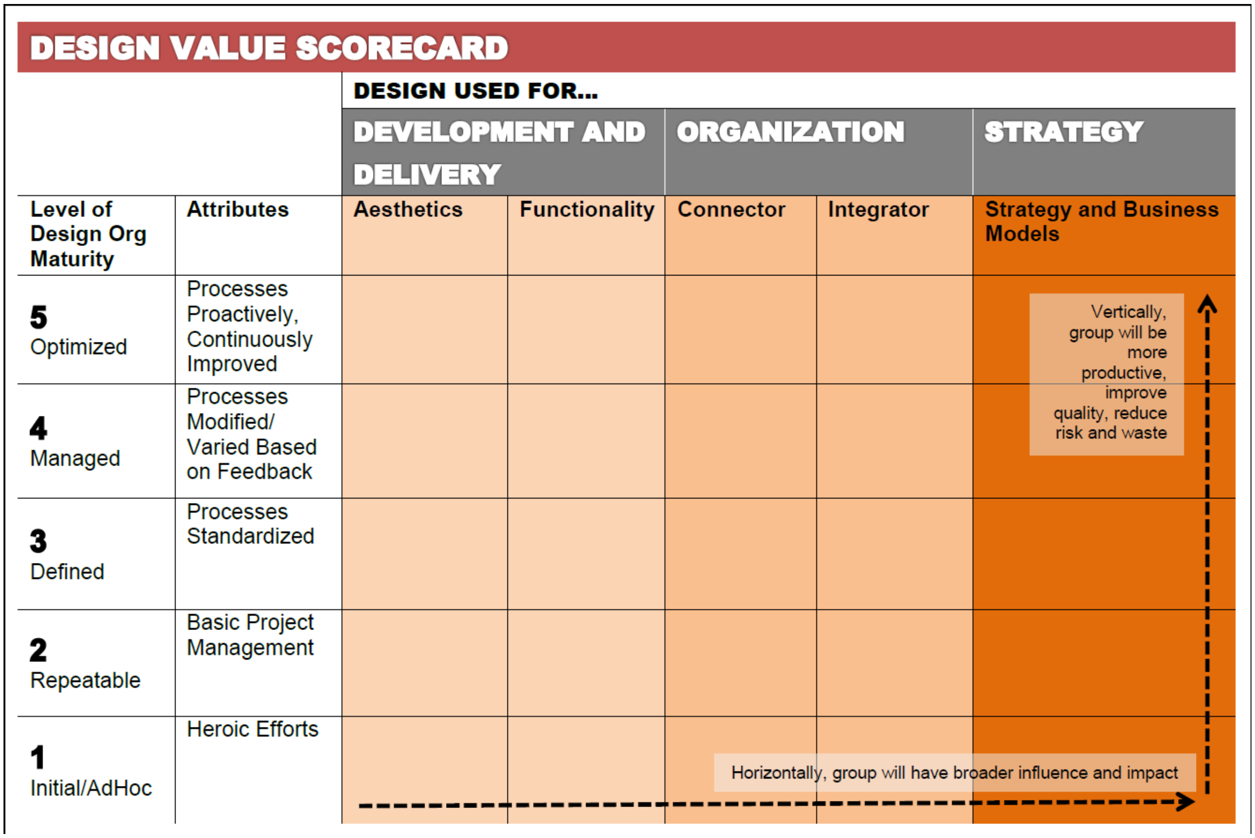

Figure 10. The design value scorecard used to locate an organization's performance in design maturity (Westcott et al., 2013).

Emerging from the design value scorecard are a number of key factors and attributes including levels and maturity of design application, important organizational qualities in the change management process; competitive advantage and evaluation, and feedback techniques indicative of an organizations' preparedness for change.

Summary of Design Thinking Models

The models selected for review each present a way of locating and documenting where creativity can be found and depicting a level of design maturity (Table 2). They integrate value with location to strategically identify potential weaknesses and/or strengths. In each model or approach, the specificity of location is generalized to the degree that identifying actual factors that can be measured and compared is lacking raising the question 'and then what'?

Table 2
Organizational Design Thinking Models

Researcher	Model	Purpose	Outcomes	Components	Level of measurement
Danish Design Center, 2003	Design Ladder	Evaluate the economic benefits of design and design maturity	Understand how design enhances creativity, innovation, and competiveness	1. No design, 2. Design as styling, 3. Design as process, 4. Design as strategy	Organization
Borja de Mozota, 2005	Balanced Scorecard	Implement and measure design strategies and value	Changes to vision and strategy, indicates value placed on performance	Design as a differentiator, integrator, transformer, good business	Organization
Fraser, 2009	The Three Gears of Business Design	Create a linkage between user needs, concept visualization, and strategic business design	Business problems are solved faster, new strategic business models are created	Empathy and deep human understanding, concept visualization, and strategic business design	Organization
Junginger, 2009	Design Organization Continuum	Raise awareness of design's location in organization	Foster discussions about where and how design can be used	4 bubbles depicting design as: external resource, part of the organization, the core, integral to all aspects	Organization
Kootstra, 2009	Design Management Staircase	Assess the relationship between design factors, capability, and maturity	Link design management behavior and strategic importance of design	Levels of maturity: 1. No DM, 2. DM as project, 3. DM as Function, 4, DM as culture; Design factors: 1. Awareness of benefits, 2. Planning for design, 3. Resources for design, 4. DM expertise, 5. DM process	Organization
Lockwood, 2009a	Integrated Design Management Process	Allow team members of the design group to enter and exit the design process as needed	Flexibility, creativity, finding and solving the right problem	6 different intersections: team members come and go, flexibility, continuous improvement, collaboration, design check-ins, design reviews	Group and Organization
Acklin, 2010	A Design-Driven Innovation Management Model	Create a circular linkage between internal and external drivers	Strategy building, innovation management, and design management	Impulse, research, development, strategy, implementation, evolution	Organization

Table 2. *cont.*

Martin, 2010	Knowledge Funnel	Depict value creation in achieving balance between exploration and exploitation during innovation	Advancement of knowledge and capture of value, finding market opportunity, product offering, and codifying business operations	3 points of view in advancement of knowledge: Mystery, Heuristic, Algorithm	Organization
Westcott et al., 2013	Design Value Scorecard	Clarify the linkage between the use and maturity of design	Track and evaluate the progress of design, looking to design maturity as fundamental	Zones: 1. Development and delivery, 2. Organization, 3. Strategy; Levels of maturity: a. Optimized, b. Managed, c. Defined, d. Repeatable, e. Initial/Ad Hoc	Group and Organization

Design Thinking Instrumentation in Practice

A search to locate qualitative instruments used to comparatively measure design thinking in organizations identified two instruments. The first, The Economic Effects of Design was developed in September 2003. A study using this instrument was conducted as a collaboration with the Danish Design Centre, Advice Analyse, I&A Research, Anders Holm and Bella Markmann, and the University of Copenhagen (National Agency for Enterprise and Housing, 2003). The intent of this instrument was to demonstrate design makes a difference among small private businesses. The measures were developed from telephone interviews with private Danish businesses with a minimum of 10 employees. In total 1,074 telephone interviews were conducted to collect data identifying:

- total investment in design;
- differences in gross revenue performance and development in employment and export share; and
- differences in gross revenue, employment and exports for organizations adopting a comprehensive approach to design versus those who do not (National Agency for Enterprise and Housing, 2003, p. 3).

The study findings of the Economic Effects of Design determined Danish organizations:

a) Invest 5 billion Danish Krone (DKK) externally and 2 billion DKK in internal design purchases annually; in USD dollars investment equate to 7.1 and 2.8 billion, respectively (in 2003).
b) Those who invested in design had gross revenues DKK 58 billion higher than those who did not invest, confirming findings from another study - design firms valuing creativity and innovation experienced higher revenues (Leigh, 2011);
c) Organizations experiencing increased design activity, achieve an additional 40% gross revenue; and
d) Organizations employing design professionals and purchasing design services externally, export 34% of their products worldwide, assuring their products receive global attention.

Moreover, the study found a positive correlation between design and employment, with job creation higher in organizations in which design was employed (National Agency for Enterprise and Housing, 2003, p. 4). Findings stemming from this instrument suggest Danish design firms placing design at the core of their organizations and obtaining design services both internally and externally experienced improved performance (National Agency for Enterprise and Housing, 2003). Although the findings were stated as significant, *p*-values, effect sizes, or integral ranges were not reported.

CAPTIW.v2 Instrument

The final version of the CAPTIW instrument, developed by researchers under the sponsorship of an American Society of Interior Designers Transform Grant in 2013, attempted to capture and link performance in the workplace environment to the innovation in an organization. At the center of CAPTIW is the CHPKW (Creative & High-Performing Knowledge Workplace) model, analyzing how the physical environment impacts organizational culture, process, and people to increase innovation performance (Lee, 2015b). The CAPTIW instrument was developed as a three-part instrument to be used with organizations.

- Part one collected organizational information and existing innovation strategies.
- Part two examined innovation performance of an organization.
- Part three evaluates Key Performance Indicators (KPIs) of the physical work environment.

KPIs analyzed in CAPTIW were organized around two Workplace Design Criteria frameworks: Creativity and Innovation; and Employee Performance, Health and Well-being. Through the use of a scorecard system, the seven KPIs were calculated and weighted by impact or significance in achieving creative and innovative performance. The seven KPIs and sub-KPIs analyzed in CAPTIW included:

a) *Space Type*: choice of work spaces, interaction (collaboration work spaces), recharge spaces;
b) *Space and Furniture Layout*: flexibility of primary work spaces, flow of connectivity;
c) *Space Size and Access to Equipment*: amount of spaces, access to equipment;
d) *Neural and Psychological Stimulation and Relaxation*: unique/fun atmosphere, stimulation of senses, relaxing environment;
e) *Furniture Ergonomics and Technology*: furniture scale and integration with technology;
f) *Ambient Conditions*: acoustics, visual comfort, thermal comfort, indoor air quality; and
g) *Healthfulness*: healthfulness (Lee, 2015b).

At the conclusion of the CAPTIW assessment, the scorecards would be given to the organization with a report detailing the KPIs current score, a benchmark (or ideal score) and if the KPI was a current strength for the organization or an opportunity for improvement. Further, CAPTIW identified *fully implemented*, *partly implemented*, and *not implemented* innovation strategies in the organization (Lee, 2015a). Demos of CAPTIW were published (Lee, 2015a), however findings from client organizations are not available due to proprietary contracts.

While the findings of both instruments support quantitatively measuring design thinking in actual organizations, proprietary conditions and language barriers combined to make these instruments inaccessible by other organizations or researchers. In addition, the latter instrument also presents a level of complexity challenging to analyze without the study software.

Design Thinking in the Literature

The empirical literature and models reviewed gleaned characteristics attributable to design thinking and began to define factors and attributes for consideration (Table 3).

Table 3
Characteristics Attributable to Design Thinking

Characteristics of Design Thinking					
I. Knowledge	II. Culture	III. Work Environment	IV. Strategy within Org.	V. Maturity of Org.	VI. Use of design within Org.
Key Factors	Key Factors	Key Factors	Key Factors	Key Factors	Key Factors
•Creative thinking o discovery o invention •Potential knowledge •Acquisition assimilation •Knowledge transformational o exploitation	•Clear goal integration •Encouragement of creativity	•Acceptance of failure •Adequate resources •Autotelic resources •Merging of action and awareness •Challenging work •Disappearance of self-consciousness •Distraction-free •Immediate feedback •Lose sense of time •Pressures •Organizational and supervisory encouragement o freedom	•Business design o finance perspective o process perspective •Codifying operations •Customer focus o empathy o deep understand-ing •Learning perspective •Market operations •Visualization	•Design maturity o ad hoc o repeatable o defined o managed o optimized •Stages of maturity o design plays no role o relevant in style o design part of development o design key to strategy	•Aesthetics •Existing on periphery •Influential •Integrated •Integral to organization •Within multiple departments •Within one department

Creative Synthesis Constructs

The creative synthesis process was defined as the leap of faith and intuition leading to problem solution. The process consisted of Imagination and Visualization of a problem, combined with Prototyping and Evaluation giving utility to a strategic solution.

Imagination

Imagination and its role in design has been a complex and elusive construct to comprehend. With numerous definitions available, contrasting views exist regarding the term "imagination" and, in particular, its role in design. To some, imagination is one's capacity to negate the materiality surrounding us and enable a new type of abstract thinking located in one's consciousness (Sartre, 1940, as cited in Folkmann, 2010). In contrast, the very thought of imagination is problematic -- we cannot begin to know or understand the inner space of consciousness with regard to imagination's connection to design (Liddament, 2000). Folkmann (2010) argued "it is necessary to be critical of any metaphysical assumptions in the concepts… [employed] when speaking about design, imagination, and creativity" (p. 1). In the discourse of imagination's role in design, literature has addressed features of the *modus operandi* of imagination in design through the creation of theoretical models (Folkmann, 2010; Hermann, 1991; Koestler, 1981) and clarification of reasoning (Cross, 2011).

A Prism of Schematization (Folkmann, 2010). Looking beyond concrete tools used by designers and examining the structural relationships between the activity of imagination and the creation of design solutions, Folkmann (2010) proposed a schema to capture the cognitive, imaginative framing of reality. In the Prism of Schematization, analysis was focused on the construction of meaning in the interaction of the internal mental setting and the outward physical manifestation of the imagination (Figure 11).

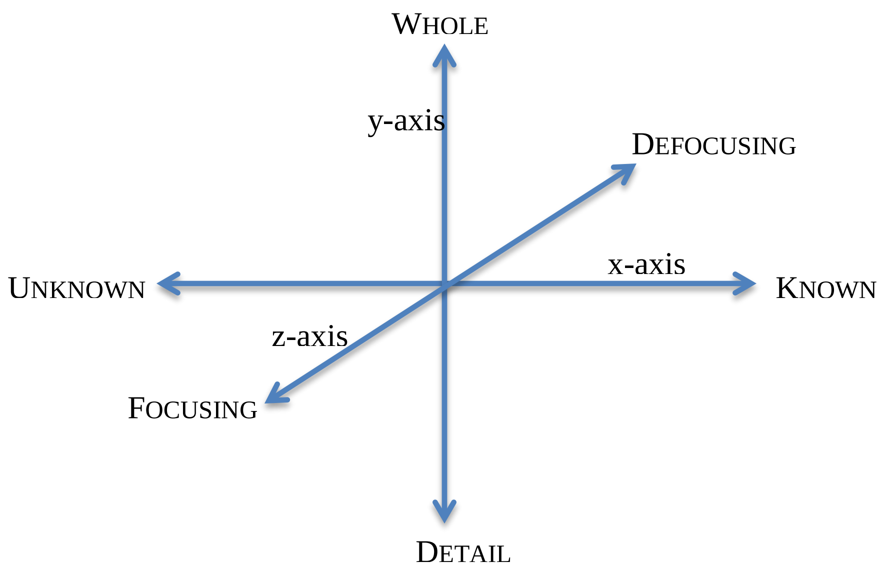

Figure 11. A model of the Prism of Schematization in Imagination (Folkmann, 2010).

Three general dichotomous meta-conceptual concepts (or settings) have been identified as effective in the designer's process "of turning inner imaginings into products" (p. 3). These are presupposed knowledge, imaginative starting point, and degree of focus.

- *Presupposed knowledge* - Known vs. Unknown. Design problems often function as an exploration of the unknown. Therefore, designers cannot know in advance what knowledge will be relevant for developing a design solution. In the Prism, the interface between the known and unknown filters the construction of experience and meaning. This dichotomy may explain why the design process cannot take a starting point solely as the acquisition of knowledge. Instead, the design process must involve the integration of the unknown to create layers of meaning.

- *Imaginative starting point* - Whole vs. Detail. With regard to the ongoing development of problem solutions in design, whole versus detail describes the extreme between top-down (whole) and bottom-up (detail) processes. For example, the starting point of the design process may be viewed as a conceptual whole where key concepts are clearly stated, or the design process may be viewed as an experimental exploration of details where only success criteria are clear and the designer must experiment and explore to find the best-fit solution. Whole versus detail are building blocks to one another and are linked. Often, distinction between whole versus detail in the design problem is which perspective the designer or design team mentally choose as their starting point.

- *Degree of focus* - Focusing vs. Defocusing. In the context of imagination, the relationship between problem and problem solution requires a designer to employ variations of focus before arriving at the appropriate solution. The activity of focusing is closely connected to idea generation and is associated with goal-orientated processes closely connected the design requirements stated by the client. Defocusing acts complimentary to focusing, allow the designer to think with a broader background relating previously unrelated ideas and concepts to the problem solution.

These three dichotomies were not utilized as a rigid set of rules, but rather as a flexible framework with multiple entry points capable of raising diverse types of questions for the process whether individual or teams of designer(s). When engaged in the design process, the Prism was used to 1) challenge designers on their own conception of imagination and creativity; 2) analyze actual design solutions; and 3) question designers about their mental models.

Combining presupposed knowledge, an imaginative starting point, and the degree of focus defined the structure of the Prism of Schematization in Imagination, proposed as a model for design creativity. The Prism "can be used to challenge designers on their own conception of imagination and creativity, and the overall framework of schematization can be employed in analyzing actual design solutions, and as a starting point for questioning designers about their mental setting in the design process" (Folkmann, 2010, p. 7).

Whole-Brain Creativity Model (Hermann, 1991). To express creativity as whole-brained, Hermann (1991) adapted the Whole-Brain Creativity Model from Wallas' Four Stages Model of the creative process relating each to the four quadrants of the brain (left cerebral hemisphere, left half of the limbic system, right half of the limbic system, and the right cerebral hemisphere). The Whole-Brain Creativity Model acted as a metaphor, depicting the ways in which an individual accesses the four quadrants during all phases of the creative process (Figure 12).

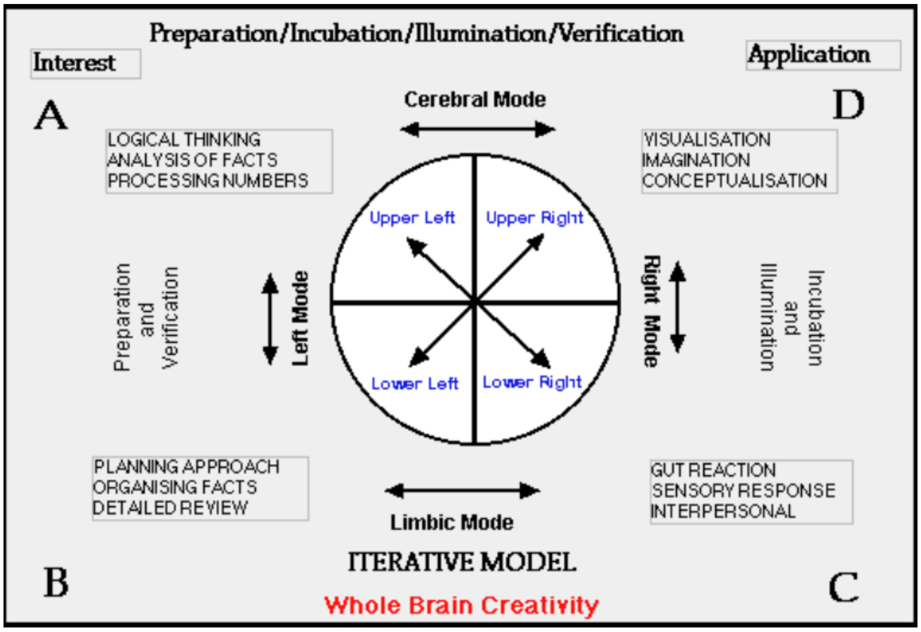

Figure 12. Hermann's Whole-Brain Creativity Model explain the creative functions of the brain (1991).

The model divided the learning process into two categories: structured (left) and unstructured (right). In A and B on the left side of the brain, hard processing deals with logical rational, critical, quantitative issues and activities. Procedural activities involved planning, organizing, and sequential elements of the learning process. In contrast, C and D were the unstructured, non-linear, and non-verbal modes of the right brain. Activities of the right brain were visual, conceptual, and simultaneous and soft processing involving emotion, expressive, and interpersonal activities. Together, the left and right brain comprised the full range of preferences for teaching and learning new activities.

Koestler's Concept of Bisociation (1981). In the 60s Koestler developed a model describing the combination of previously unrelated structures called the creative act (Berthold, 1998). The creative act did not create new ideas from unknown concepts, instead the creative act "combine[d], reshuffle[d], and relate[d] existing but…separate ideas" (Koestler, 1981, p. 2). The model of Bisociation (Figure 13) distinguished metaphoric thinking (comparisons made between qualities of objects usually considered in separate classifications) from associative thinking (associations between a given subject and all pertinent present factors without drawing on past experience) and "[d] the mixture of one human mind of concepts from two contexts or categories of objects…normally considered separate by the literal processes of the mind" (Berthold, 1998, p. 16).

According to Koestler, bisociation occurred when the creative mind becomes "double minded" and was able to think simultaneously on more than one plane or matrix of thought (Berthold, 1998). Figure 13 depicts two matrices (or domains or knowledge of thoughts). M_1 and M_2, representing two self-contained but opposing matrices of thought. An idea, represented as a thick line, π, is perceived simultaneously in both matrices, not through one associative context (M_1 *or* M_2), but is considered to be *bisociated* with two associative contexts (M_1 *and* M_2). In the diagram, six concepts perceived by the creative mind appear separately in M_1 (c_1 - c_5) and M_2 (c_1 - c_3, and c_6). The concepts c_1, c_2, and c_3 are associated with π because concepts c_1, c_2, and c_3 are perceived in both matrices simultaneously. In other words, π in Figure 13 depicts the creative act (Berthold, 1998; p. 16).

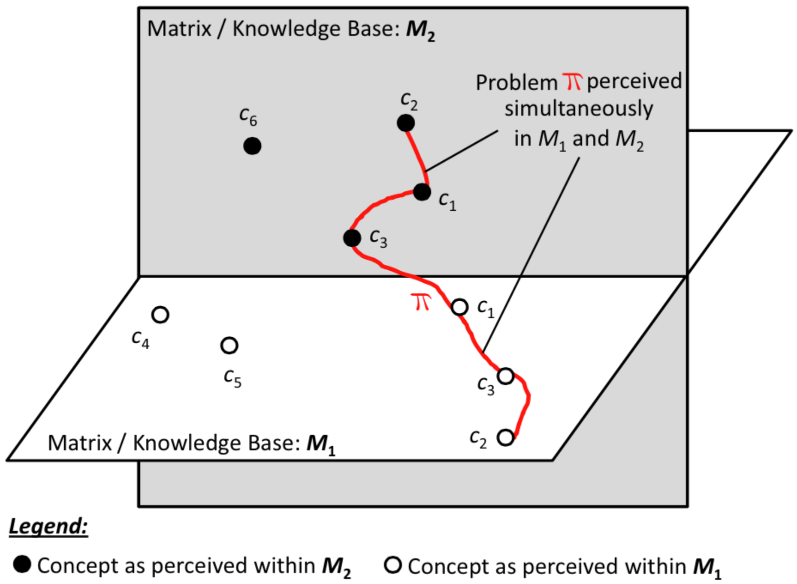

Figure 13. Koestler's Concept of Bisociation model depicting creative acts as "double-minded " or using two matrices of thought – metaphoric and associative (Berthold, 1998).

Rational Design Process. Attempts to understand typical ways in which designers work has led to efforts providing design methods with guidelines, encouraging designers to work more "rationally" (Rowe, 1987). These guidelines outlined a generalized process of first analyzing the problem and then breaking the problem into sub-problems. Next, the designer finds suitable sub-solutions (or alternatives), evaluating those solutions and then selecting and combining sub-solutions into a greater overall finalized solution (Cross, 2011; Rowe 1987). Simply, the rational design process becomes a structured process of analysis-synthesis-evaluation (Cross, 2011) distantly similar to Wallas' (1926) early design process model. However, March (1987) noted criticisms of "inappropriate" models imported from problem solving theories as too "rational" for designers' "intuitive" ways of thinking (March, as cited in Cross, 2011).

Types of Reasoning. March (1987) argued two conventionally understood forms of reasoning -- deductive and inductive -- only "apply logically to analytical and evaluative types of activity" (March, as cited in Cross, 2011, p. 27). To address this gap in understanding, March concluded the type of activity associated with designers is that of "synthesis," identifying the concept as abductive reasoning. Defining types of reasoning (Table 4), he preferred to call abductive reasoning productive reasoning or appositional reasoning recognizing designers make a "proposal for a solution that, when juxtaposed to the problem, seems to be an opposite response" (Cross, 2011, p. 28).

Table 4
Type and Definition of Reasoning

Type of Reasoning	Definition by example
Deductive	"The reasoning of formal logic: if *a* is the same as *b*, and *b* is the same as *c*, then *a* is the same as *c*."
Inductive	"The logic of science: you observe all the swans in a given region; you note that each and every swan is white; you form the rule that all swans are white…"
Abductive	"The logic of design: you are asked to design a telephone for mature people; you know that mature people like clarity and elegant forms of [colors]; you propose a design with a smoothly contoured, soft-white case and clear, black buttons…"

Source: Cross, 2011; pp. 27-28

Additional techniques were available to spark designers' imaginations with tools including "journey mapping, value chain analysis, mind mapping" (Liedtka & Ogilvie, 2013 p. 41) and sketching (Cross, 2011). Expanding imagination enables designers to match the problem, finding an appropriate solution through use of interactive activity. Visualization and imagination consider the thinking and cognitive aspects of the process.

Visualization

Visual thinking was often cited as a central attribute to the creative process (Brown, 2009; Fraser, 2013; Liedtka & Friedel, 2013; Liedtka & Ogilvie, 2013; Lockwood, 2009a; Walkup, 1965). The ability to visualize an end result of the process, or a product, is fundamental to the ways in which designers think and work (Liedtka & Ogilvie, 2013) and necessary to move from creative thought through to creative doing (Fraser, 3013). Visualization appears in every stage of the creative innovation process (Liedtka & Ogilvie, 2013), however, little is known about how a creative individual develops the ability to mentally visualize and subsequently manipulate thoughts into new combinations of ideas and prototypes successfully.

The visualizing of ideas takes many forms and is necessary to express ideas absent of words and numbers (Brown, 2009). This form of thinking requires the ability to 'see' the end result, the complete picture, and the ways the business will work to utilize and integrate the final product. Useful techniques utilized in expressing creative energy can include more than simple images. Mind maps, two-by-two matrixes, post-it notes (Brown, 2009), systems mapping (Fraser, 2013) or other visual frameworks aid in the exploration and description of creative ideas in valuable ways contributing to the divergent process of creating choices. Making choices is critical to a design team or individual to move beyond the visualization of ideas (Brown, 2009) onto a new prototype (Fraser, 2013). Visualization techniques bring ideas to life and lead to the envisioning of new possibilities. Techniques are "an approach for identifying, organizing, and communicating in ways that access 'right brain' thinking while decreasing our dependency on 'left brain' media such as numbers. It consciously inserts visual imagery into our processes and focuses on bringing an idea to life…" (Liedtka & Ogilvie, 2013, p. 258).

To better understand the nature of creativity and to develop more methods of assessing its presence and teaching it to others, research has suggested focusing on identifying: a) with greater exactness the nature and structure of the mental visualization process, and b) how well one's ability to visualize impacts productive creativity (Walkup, 1965). Following the more cerebral activities, next, the doing or physical aspects of the creative synthesis process are examined.

Prototyping

Prototyping invites the generation of low-resolution artifacts probing different aspects of the problem solution (Institute of Design at Stanford, 2015). Prototyping creates a context where ideas take physical shape, allowing the best ideas imagined and visualized to be tested, iterated, and refined before moving into the evaluation phase (Brown & Wyatt, 2010; Coughlan & Prokopoff, 2013; Institute of Design at Stanford, 2015). In the early stages of design, prototypes should be rough and rapid to allow those working with them to learn quickly and investigate potential future options (Brown & Wyatt, 2010; Institute of Design at Stanford, 2015; Raney & Jacoby, 2013). Traditionally, prototyping was used as a method to evaluate unintended consequences and potential future success of a design idea (Brown & Wyatt, 2010; Resnick, Myers, Nakakoji, Shneiderman, & Pausch, 2005). However benefits of prototyping have become far greater than testing for only functionality (Institute of Design at Stanford, 2015). Prototyping provides feedback prior to the problem reaching solution (Rodriguez & Jacoby, 2013), helping to deliver results faster (Brown, 2009), and serves as a low-risk method of quickly exploring multiple problem solutions before a commitment to produce is made (Coughlan & Prokopoff, 2013).

Documented uses of prototyping have proven useful when design teams seek to: a) gain empathy and deepen understanding of the design space and user; b) build multiple solution spaces; c) test and refine solutions with end users; and d) inspire other design team members through the display of a vision. Further, prototyping helps design team members:

- *Learn* - “if a picture is worth a thousand words, a prototype is worth a thousand pictures” (Institute of Design at Stanford, 2015)
- *Solve disagreements* - eliminate ambiguity, assist in ideation, and reduce communication;
- *Start a conversation* - initiate different kinds of conversations with different end users;

- *Fail quickly and cheaply* - create quick prototypes allows the evaluation of ideas with minimal investment of both time and money;
- *Manage the solution-building process* – breaking down the problem-solution space into smaller and more manageable areas for evaluation (Institute of Design at Stanford, 2015, p. 15).

Evaluation

The final construct of the creative synthesis process provides an iterative process to test prototypes and refine problem solutions before the idea is considered finished (Rodriguez & Jacoby, 2013). The evaluation phase of a design idea allows opportunities to build empathy through observation and engagement and can clarify if and when the prototype falls short. Discussions of evaluation techniques in design literature have been facilitated through utilizing various tools (Fraser, 2013; Løvlie, Downs, & Reason, 2008; Rodriguez & Jacoby, 2013) and models (Frey, Herder, Wijnia, Subrahmanian, Katsikopoulos, & Clausing, 2009). Evaluation ensures an organization has taken into account a myriad of considerations including market potential, opportunities for alignment to strategic goals, and potential competitive advantage. The evaluation phase of the creative synthesis process allows organizations to get feedback on potential solutions, ensuring they are playing to their own strengths, rather than those of their competitors (Canada, 2013). Several tools were identified in the literature review, used during evaluation.

Co-Creation. As a tool used in the feedback loop of a problem solution, co-creation welcomes input and feedback from those internal and external to the development team including end users, enterprise partners, and decision makers. Inviting others into the process of evaluating the solution yields more “robust and relevant solutions, fortify[ing] concepts and increas[ing] changes of breakthrough success” (Fraser, 2013, p. 254).

Service Usability Index. The Service Usability Index (SUI) provides a method to measure the quality of experiences with a prototype, enabling the organization to take action to improve their design. The SUI allows organization to see why an end user likes the prototype and what could be interpreted as wrong, why, and how it affects the overall value of the prototype in the eyes of the users. The index is constructed to rate the quality of service with a number between two of the four parameters, between one and 10. The overall rating is based on four parameters:

a) *Proposition*: does the end user understand the value intention of the service?
b) *Experience:* does the end user feel good about the service?
c) *Usability*: can people easily use the service?
d) *Accessibility*: is the service universally usable for all similar end users?

The final number is arrived at through in-depth interviews and by shadowing end users as they use the product, looking for the value, enjoyment, and needs for improvement (Løvlie, Downs, & Reason, 2008).

Story Telling. Story telling allows the value proposition of a particular problem solution to be told in a simple, emotional, and concrete manner to the end user by the designer or design team (Rodriguez & Jacoby, 2013). Stories emerging from those of the end user can prove to be immensely valuable, as the stories they tell often reveal a web of unmet needs emerging from the use of the prototype (Fraser, 2013).

Pugh Controlled Convergence. The Pugh Controlled Convergence (PuCC) (Frey et al., 2009) advocated for an iterative process of narrowing down and evaluating ideas created from a product development team and adding to the set of design concepts under consideration. The goals of narrowing down ideas are: (1) a *controlled convergence* to a strong design concept product development team believes can take market-lead; and (2) development of a shared understanding for the reason of choice. Ultimately the team should narrow down ideas to the selection of a design concept that is well understood and known to be generally strong.

Information from the product development team was presented and discussed in the form of a matrix (Table 5), where the columns of the matrix are labeled with a description or drawing of the design concept. The rows of the matrix are labeled with short, concise criteria statements by which the design concepts should be judged. Symbols (+, −, or **S**) are placed within the rows of matrix, indicating which design concepts related to that design column are better (+), worse (−), or roughly equal (**S**) to the current market lead.

Evaluations for each concept are developed and entered into the matrix through facilitated discussion among team members. It is important to note that the product development team does not vote. Instead, the team members discuss each design concept, using the symbols to denote the teams' overall thoughts and opinions about the idea. While Table 5 presents a neatly drawn depiction of a PuCC matrix, in practice the matrix is often a messy collage of drawings and notes through early design stages.

Table 5
Example of a Pugh Controlled Convergence Matrix (adapted from Frey et al., 2009)

Concepts Criteria	Base: Ear muffs with heat control	GPS hat	Exercise hat	Massage hat	Clippable doggy-eared hat
Novelty	**S**	+	+	+	**S**
Feasibility	**S**	_	**S**	_	**S**
Marketability	**S**	**S**	+	**S**	_
Clear Need/Market	**S**	**S**	+	**S**	+
Personal Interest	**S**	_	**S**	+	+
Total	0	-1	+3	+1	+1

The feedback generated from the use of evaluation tools and models allows organizations and design team to begin feedback processes. When the design team shares an understanding of the design idea's strengths and shortcomings, such understanding facilitates the production of an increasingly optimal problem solution (Ambrose & Harris, 2010).

Conceptual Framework

The analysis of design thinking and creative synthesis models led to the development of the framework for a conceptual model of the creative synthesis process. Table 6 identifies constructs, factors, and attributes within the creative synthesis process (for comparison, see Table 3 for the components of the design thinking process) and serves as the foundation for the conceptual model and its components. The model in Figure 14 illuminates the need to explore the constructs of the creative synthesis process within design thinking.

In the conceptual model, four constructs form a set of tasks used in the design thinking environment of organizations, shaping the creative synthesis process. Cognitive constructs (Imagination, Visualization) requiring abstract thinking while the more concrete constructs of Evaluation and Prototyping require actions to produce ideas, products, or services; this bi-modal differentiation also distinguishes among idea and object and thinking from doing.

Table 6

Constructs of the Creative Synthesis Process

Creative Synthesis			
I. Imagination	II. Visualization	III. Prototyping	IV. Evaluation
Key Factors	Key Factors	Key Factors	Key Factors
• Combines and relates existing but discrete ideas • Distinction between metaphoric and associative thinking • Ignore the contextual environment • Abstract framing of reality • Interaction of mental setting and outward manifestation • Unknown relevance of knowledge necessary for solution • Interstices between known and unknown • Blurry layers of meaning after knowledge acquisition • Inter-play between whole and detail • Consideration of diverse concepts in unique relationships • Exploration of details and best-fit solutions • Perspective identifies starting point • Un-focusing before arrival at appropriate solution • Discovery	• Ability to see relationships • Ability to mentally manipulate thoughts into new combinations • Expression of ideas absent of words and numbers • "See" ways to utilize and integrate the ideas • Use of tools: o two-by-two matrixes o post-it notes o systems mapping • A system of divergent and convergent thinking leading to the creation of ideas • Sharing with others ideas, thoughts, and processes • Consideration of organizational objectives	• Ideas brought to physical realm • Objects are tested, iterated, and refined • Rough and rapid objects used to acquire feedback and learn quickly • Increased empathy through observation and engagement • Evaluate unintended consequences and future success of a design idea • Test functionality • Increase empathy, deepen understanding of end user • Resolve disagreement among teams • Support ideation, visualization • Spark discourse • Contextual solution-building process • Break down problem-solution space • Create mock-ups • Use of scaling • Narrowing of ideas • Feedback	• Measurement of success • Judging of design concept • Intent to inform team decision making • Assessing organizational qualities and envisioning changes: o Market potential o Alignment to strategic goals o Competitive advantage • Feedback from internal users and external stakeholders: o End users o Enterprise partners o Decision makers • Measure quality of experience from end user perspective, seeking to understand: o Value intention o Perception o Ease of use o Universal application • In-depth interviews and shadowing of end users • Utility • Innovation • Stories communicating a problem solution and unmet need • Use of tools to narrow down best practice/best fit idea, creating a shared understanding • Input to future decisions

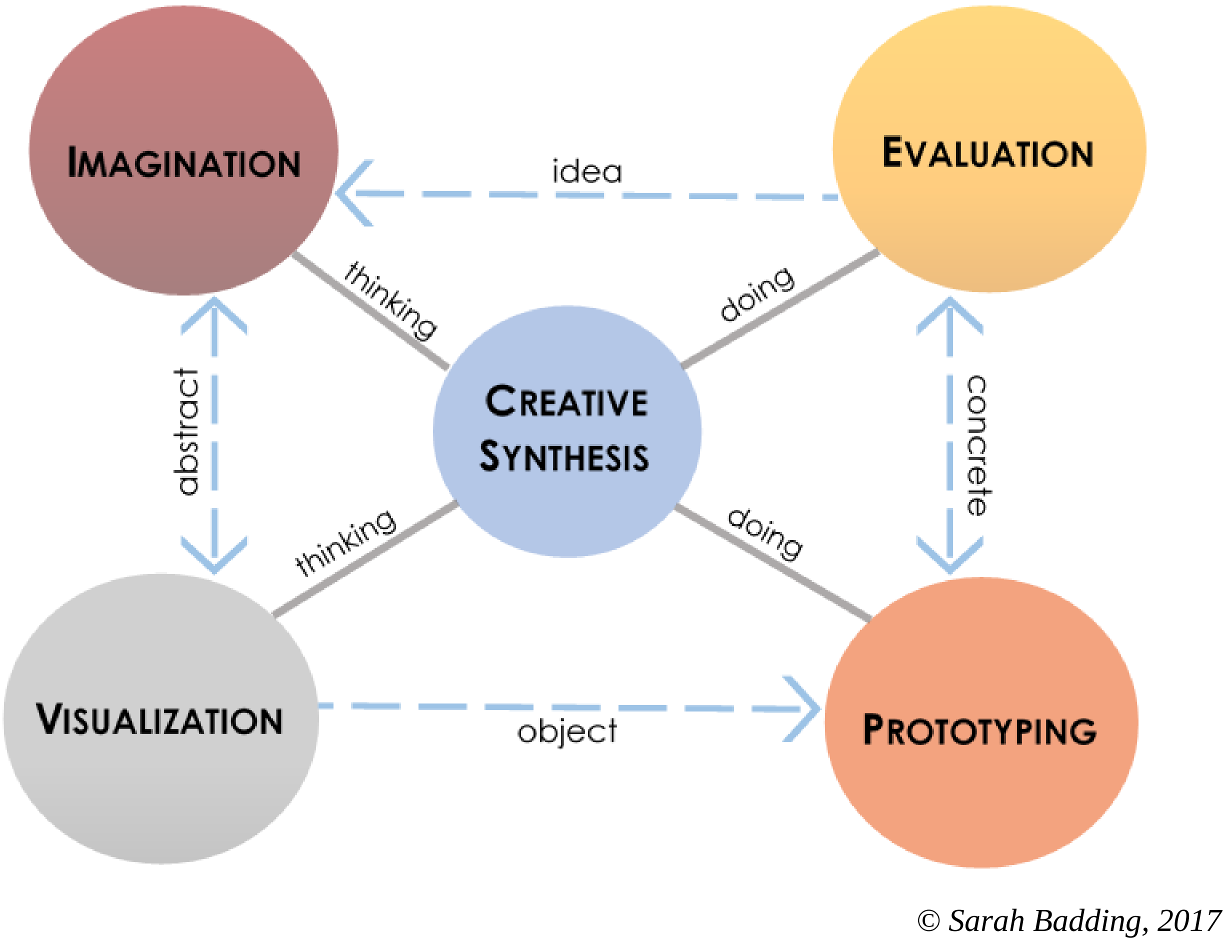

Figure 14. Conceptual model of the creative synthesis process within the design thinking environment.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

Metrics to measure design thinking and creative synthesis components are absent in the research literature (Cooper, Junginger, & Lockwood, 2009b; R. Martin, personal communication, August 29, 2013; D. Kelley, personal communication, September 17, 2013) An analysis of the literature revealed no instrumentation for measuring either design thinking or components encompassing creative synthesis process. The purpose of this research is to develop metrics enabling researchers to effectively explore and measure the design thinking environment.

This chapter provides details of the instrument development, testing, and sample selection, and identifies statistics employed to examine measurement reliability and validity. Survey administration and approach to data analysis are also discussed. The research design follows the six step process (Figure 15) adapted from Schmiedel, vom Brock, and Recker (2014) in two phases; the first phase develops and identifies items with the second phase, to confirm results.

Empirical Approaches to Instrument Development

A comprehensive search was conducted aimed at locating quantitative instruments, measures, or items measuring design thinking in organizations; terms searched encompassed design *thinking, quantitative measurement, instrument*, and *organization*, which failed to yield results. When the search was broadened to include creativity, innovation, and climate, four quantitative instruments were found (Table 7)

Table 7

Comparison of Instrumentation, Participants, Variables, and Statistical Analysis in Creativity Studies

Author	Instrument	# Participants	Variables	Analysis
Amabile et al., 1996	KEYS: Assessing the Climate for Creativity	3,708 employees from 27 organizations	Organizational encouragement, supervisory encouragement, work group supports, sufficient resources, challenging work, freedom, organizational impediments, workload pressures, creativity, productivity	Factor Analysis, Multiple Regression
Amabile & Gryskiewicz (1989)	Work Environment Inventory (WEI)	645 participants from 5 organizations	Freedom, challenge, resources, supervisor support, co-worker support, recognition, unity, and cooperation, creativity supports, time pressure, evaluation, status quo, political problems, creativity, productivity	Factor analysis, MANOVA, factorial ANOVA, Multiple Regression
Ekvall, 1996; Isaksen, Lauer, Ekvall, & Britz 2001	Creative Climate Questionnaire (CCQ)	192 researchers 234 engineers	Challenge/Involvement, Freedom, Trust, Idea-Time, Playfulness, Conflict, Idea-Support, Debate, Risk-Taking	Factor Analysis
Leigh, 2011	Organizational Creativity	90 participants from 4 architectural firms	Value discipline, organizational encouragement, intellectual stimulation, leader support and feedback, positive interpersonal exchange, sufficient resources, freedom, challenging work, workload demands, organizational roadblocks, creativity, productivity, job interdependence, workplace values, customer intimacy value discipline index, operational excellence value discipline index, product leadership value discipline index, organizational encouragement index, intellectual stimulation index, leader support and feedback index, positive interpersonal exchange index, sufficient resources index, freedom index, challenging work index, workload demands index, organizational roadblocks index, creativity index, productivity index, job interdependence index, workplace values index, creative work environment.	Descriptive Statistics, Factor Analysis. Bivariate Correlation, Multiple Regression

Instruments developed for the purpose of studying creativity and innovation in organizational settings employed a variety of analytical and statistical approaches including: principal axis factor analysis, principal component factor analysis, linear regression, multiple and hierarchical regression, bivariate correlation, and measures of association, a majority with effect sizes. Many variables in these same studies encompassed concepts focused on support, resources, evaluation, trust, and encouragement. Table 7 compares the approach to analysis employed and variables studied in these creativity studies.

Specific statistical analyses (i.e., factor analysis, multiple regression, bivariate analysis, and measures of association) are used to develop and validate instrumentation capable of measuring the design thinking environment in organizations.

Challenges to Future Findings

Statistical analyses dispute findings in the KEYS instruments for creativity and innovation used by organizations. Rosenberg (2007) found contradictory findings in Amabile's et al. (1996) KEYS: Assessing the Climate for Creativity instrument: Political problems did not relate to productivity; Challenge and freedom were stronger predictors of creativity than productivity, and measurement concurrence was found across managerial levels. Rosenberg (2007) also recommended creativity and challenging work be combined.

Rosenberg's (2007) research hypothesized employees' perceptions of the creative work environment was significantly influenced by managerial status. Rosenberg re-measured the KEYS scales across three managerial levels (supervisors (n = 2,100), middle managers (n = 15,829), and executives (n = 2,690) confirming no support for freedom in the creative working environment.

Approach to Instrument Development

Literature from diverse disciplines and researchers studying creativity formed the foundation for the multi-stage approach to develop and test measurement scales examining the parameters of the creative synthesis process:

- education (Elliott, 2013; Perkins, 2014);
- health care (Lynn, 1986);
- business process management (Schmiedel, vom Brocke, & Recker, 2014);
- information systems and technology (Moore & Benbasat, 1991; Recker & Rosemann, 2010);
- organizational development (Horvath & Greenberg, 1989; Van Saane, Sluiter, Verbeek, & Frings-Dresen, 2003); and
- work environments (Amabile, Burnside, & Gryskiewicz, 1995; Amabile, Conti, Coon, Lazenby, & Herron, 1996; Amabile & Gryskiewicz, 1989; Leigh, 2011; Ng & Feldman, 2012; Witemeyer, 2013).

These researchers identified a) points at which reliability and validity should be confirmed, b) types of statistics used with plausible levels of confirmability, and c) the sensibility of a sequence of actions leading to a final instrument. In addition, valid sources used in instrument development. Table 8 identifies the steps and phase development (c), the statistical analysis proposed (b) and validity and reliability (a) used during instrument development.

Table 8

Steps, Phases, Analysis, and Validity, Reliability, and Statistics used in Instrument Development

Phase	Steps	Source	Validity and Reliability	Statistics
I. Attribute Identification	1.	Literature Review	Content Validity (establishing accurate representation of the attribute measured)	—
I. Item Development	2.	Expert Review; Instrument Creation	Predictive Validity (the degree to which variables accurately measure constructs)	—
II. Pre-Test	3.	Student Participants, Instrument Revision	Construct Validity (the degree to which variables accurately measure constructs) Content and Face Validity	Exploratory Data Analysis, inter-item consistency testing, Split-Half Reliability
II. Instrument Revision	4.	Design and Creativity Experts	Construct Validity (the degree to which variables accurately measure constructs)	Convergent and Discriminant Validity, Content and Face Validity
III. Pilot Test	5.	Student Participants	Construct Validity (the degree to which variables accurately measure constructs)	Exploratory Data Analysis, Descriptives, Factor Analysis with Cronbach's *alphas*
III. Instrument Confirmability	6.	Student Participants		Exploratory Data Analysis, Descriptive Statistics, Inter-Item Consistency Testing, Split-Half Reliability, Factor Analysis,

Figure 15 illustrates the six-step research process (adapted from Schmiedel, vom Brocke, & Recker, 2014), divided among three phases, to develop, revise, and validate a quantitative instrument; the Creative Synthesis Inventory (CSI).

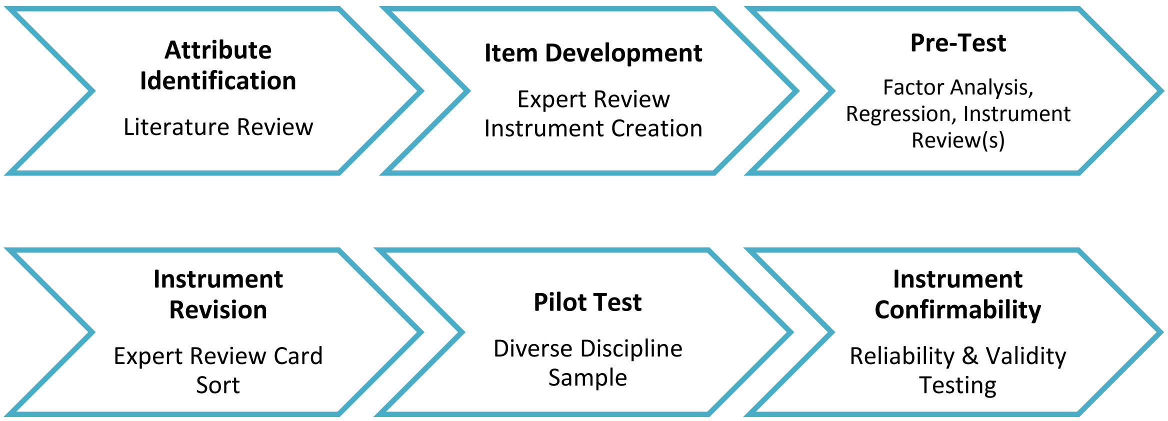

Figure 15. Research process engaged in for instrumentation development and reliability and validity testing.

Hierarchy of Terminology

A hierarchy of components, or terms, was defined and used for this study to keep level and use of terms organized (Figure 16).

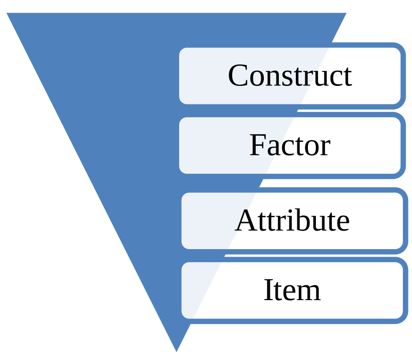

Figure 16. Hierarchy of terminology in the study.

Constructs appeared in the literature as major concepts used, encompassing a set of factors and, when applicable, attributes (e.g., Evaluation). Factors emerged as terms present within a construct (e.g., assessment of organizational qualities). Attributes when present, further defined a factor (e.g., market potential). Items were then developed and revised for use within the CSI (e.g., assess project qualities [i.e., market potential, alignment to strategic goals, competitive advantage]).

Attribute Identification and Item Development

During Phase I of the instrument development process, literature pertinent to the constructs of the creative synthesis process was reviewed during the attribute identification phase. During the item development phase, industry experts were consulted to review and refine the creative synthesis constructs.

Phase I. Attribute Identification

The review of literature investigated others' use of the constructs of creative synthesis (imagination, visualization, prototyping, evaluation) to identify corresponding factors and attributes (refer to Table 7, p. 58) for each construct. High content validity for constructs comprising creative synthesis were sought when locating the research findings of others during the literature review process.

Construct terms (imagination, visualization, prototyping, and evaluation) were combined with *creativity* and *design thinking* to locate relevant literature. While subjectivity is a consideration during the literature search, the models and research reports represent an understanding of constructs describing creative synthesis and the design thinking environments creating a context for attribute identification. During this process, a majority of literature surrounding creative synthesis constructs and design thinking appeared to have little to no relationship to one another (i.e., of the four main constructs, little association was found among each). For constructs that could be connected to design thinking (e.g., visualization), the literature mentioned the construct as a tool without presenting methods for its utilization or application.

Design thinking literature encompassed the use of the design process in problem identification and problem solving (Curedale, 2013a, 2013b). Design thinking has advanced the design management process in non-design organizations, evolving dramatically (Curedale, 2013a, 2013b; Lockwood, 2009b; Rowe, 1987) deepening meaning, methodology, application, and ROI outcomes among global organizational leaders (e.g., Apple, Google, IDEO).

Phase I: Item Development

Once the constructs were deconstructed, five industry professionals reviewed the constructs, which were then described by factors and further by attributes when possible (refer to Table 7) to confirm clarity and understanding and the validity of the construct. Industry professionals' backgrounds were in education, military strategy, nursing, and supply chain management. Reviewers examined the listings of factors and attributes making recommendations enhancing clarity and eliminating duplication. To assure wording remained simple, double-barreled items (e.g., divergent and convergent thinking) were flagged for consideration to be removed due to ambiguous, hard to understand syntax (e.g., "perspective mentally chooses starting point") and were amended for clarity of meaning (e.g., "perspective identifies starting point"; Mackenzie, Podsakoff, & Podsakoff, 2011). The researcher did not remove or adjust any flagged factors emerging from the review team until the researcher reviewed all changes, to avoid compromising the list of factors and attributes that emerged during the review of literature. The review team transformed each factor and attribute into items for the pre-test.

Pre-Test and Instrument Revision

During Phase II of the instrument development process, a pre-test was developed to begin testing and refining inter-item consistency and reliability of the construct factors and attributes.

Instrument revision was employed through the use of a Card Sort activity conducted with creativity and/or design experts to assess clarity and fit with constructs.

Phase II. Pre-Test

The creative synthesis constructs were derived from the literature with the next step in the three-phase development process to construct the pre-test for inter-item consistency and reliability of the factors and attributes. Statements were placed into a standardized format in which items began with the statement "when given a new problem/project, to what extend do you…" A six-point Likert scale (*strongly disagree = 1*, *strongly agree = 6*) was used as an effective measure to acquire data on participants' opinions, beliefs, and attitudes (DeVellis, 2012).

Two versions of the paper-and-pencil pre-test were developed to evaluate ordered (v.1A) and unordered constructs (v.1B; Appendix A: Creative Synthesis Pre-Test v.1A; Appendix B: Creative Synthesis Pre-Test v.1B). In v.1A, questions were sequenced to coincide with order of the creative synthesis process (Table 9).

Example:

- Factor: Use of tools (two-by-two matrixes, Post-it® notes, systems mapping)
- Statement: Use of tools to visually share your ideas, thoughts, and processes (e.g., matrices, post-it notes, system mapping)

In v.1B, items were randomized, using *RAND* function in Excel.

Table 9

Pre-Test v.1A: Study Variables (Ordinal), Ordered by Question Number (n = 74)

Question #	Construct	Factor	M	SD
1	Imagination	Combine ideas	4.62	.85
2		Relate ideas	4.51	.93
3		Symbols	3.89	1.58
4		Ignore environment	2.27	1.26
5		Reality to abstract	3.92	.97
6		Abstract to reality	4.43	1.01
7		Information for solution	5.30	.74
8		Gap in known and unknown	4.83	.85
9		Others knowledge	5.22	.93
10		Project whole and detail	5.03	.958
11		Perspective to find entry point	4.98	.73
12		Think solution	4.78	1.13
13		Discovery of new ideas	5.32	.71
14		Use of imagination	5.22	.90
15	Visualization	Relationships among ideas	5.36	.68
16		Manipulate ideas	4.75	1.02
17		Express ideas	3.86	1.46
18		Visualize ideas	4.98	.76
19		Use of tools	5.00	.82
20		Divergent thinking	5.08	.86
21		Convergent thinking	4.32	1.18
22		Project objectives	4.95	.97
23	Prototyping	Create prototypes	4.78	1.15
24		Test and refine	4.83	.74
25		Deepen understanding	4.78	.92
26		Unintended consequences	4.24	.98
27		Future success	4.32	.91
28		Desired outcomes	4.59	.83
29		Plausibility	4.68	.82
30		Prototype to spark conversation	4.70	.81
31		Create mock-ups	4.17	1.21
32		Feasibility of scaling	4.34	1.14
33	Evaluation	Success	5.33	.68
34		Design concept	4.83	.89
35		Team decision making	5.00	.77
36		Project qualities	5.21	.77
37		Feedback from team	5.06	.71
38		Feedback from stakeholders	4.83	.88
39		Measure quality	5.16	.86
40		Level of innovation	4.74	1.20
41		Variety of data collection	5.09	.92

Phase II. Instrument Revision

For ease of participant use and access during the instrument revision process, an electronic Card Sort process was selected. Four programs were reviewed and evaluated for cost, access, clarity, and usability. The Optimal Workshop Card Sort program was chosen and the card contents were constructed by the researcher after a profile was created.

Identification and Selection of Expert Panel

In this research study, the "expert panel… reflect[ed] the disciplines of the target population in the field study… maximize[ing] the chance that…final measurement items will be well understood" (Schmiedel et al., 2013, p. 47). In total, 46 experts were invited via an email invitation (Appendix C: Invitation for Card Sort); a total of 29 participated in the Card Sort activity. Nineteen experts completed the Card Sort activity (*N* = 19), while an additional 10 experts began the Card Sort, but elected not to complete the activity. Only completed Card Sorts were considered in the data analysis. These creativity and design experts represented a diverse range of knowledge and experience with problems, projects, and challenges within academic and professional careers (see Table 10 for summary of participants invited to the Card Sort).

To assess content validity, the Card Sort exercise was conducted with the creativity and/or design experts to assess clarity and fit with constructs (Gliner, Morgan, & Leech, 2009). An online Card Sort software was selected to conduct the Card Sort exercise with experts provided with detailed instructions at the start of the Card Sort activity (Appendix D: Card Sort Welcome and Instructions). Instructions reinforced clarity of understanding regarding the directions and procedures of the Card Sort activity. Items (original and reworded) from the pre-test were individually recorded onto electronic index cards and complete sets of items were made available to each expert.

Table 10
Summary of Participants Invited to Card Sort

# of participants invited	College	Departments
13	Health and Human Sciences	Design and Merchandising, Occupational Therapy, School of Education
10	Liberal Arts	Art and Art History, Journalism and Media Communication, Anthropology, School of Music, Theatre & Dance
8	Natural Sciences	Computer Sciences, Psychology, Mathematics
5	Business	Marketing
4	Engineering	Electrical & Computer Engineering, Mechanical Engineering
3	Agricultural Sciences	Horticulture & Landscape Architecture
2	Warner College of Natural Resources	Human Dimensions of Natural Resources
1	Veterinary Medicine & Biomedical Sciences	Biomedical Sciences

Experts agreeing to participate in the Card Sort activity were provided with a link to access the online Card Sort software where they were provided with instructions on how to complete the Card Sort process. The Card Sort activity was available to the experts for five weeks with the Card Sort activity available for expert participation during the full five-week period.

During the Card Sort activity, experts were asked to place each of the 53 items into a predetermined construct category (imagination, visualization, evaluation, prototyping). For the Card Sort exercise, experts were provided with the option to place hard-to-understand, duplicated, or ambiguous items into a fifth category to suggest those items for removal (Appendix F: Participant view of Card Sort Activity). Additionally, experts had the opportunity to create their own construct categories if they chose.

Construct and Predictive Validity

The overall goal of the Card Sort task was to improve construct and predictive validity, or the extent to which a measurement predicts subsequent performance (Vogt, 2005). During each Card Sort round, experts were asked to identify items considered ambiguous or those items hard to place in categories (Recker & Rosemann, 2010; Schmiedel et al., 2013). After the Card Sort activity was concluded two industry experts, using common logic, assessed items attributable to each construct for fit, syntax, and/or decisions. Items were eliminated if they could not be assigned to a specific factor.

Content and Face Validity

Domain and methodology experts reviewed factors following the Card Sort activity for content and face validity during instrument development to clarify content and meaning.

Pilot Test and Instrument Confirmability

During the final phase of the instrument development process, a pilot test of the CSI will be created and tested before creating and testing the CSI during Phase III, instrument confirmability.

Phase III. Pilot Test

The findings from the Card Sort exercise were considered before constructing the final Creative Synthesis Inventory (CSI). A pilot pen-and-pencil survey was administered to students engaged in courses taking place in a creative lab or classroom space, aligned with faculty engaged in the Card Sort activity (i.e., Anthropology, Art and Art History, Design and Merchandising, Electrical and Computer Engineering, Horticulture and Landscape Architecture, Journalism and Media Communications, Marketing, Mechanical Engineering, Education, and the School of Music, Theatre and Dance; Appendix G: Pilot Survey Email Recruitment to Professors). Understanding of survey directions and question syntax were reviewed with participants at the time of survey distribution (Appendix H: Survey Verbal Recruitment; Appendix I: Pilot Survey Model Consent). Necessary adjustments and revisions were made to the CSI to increase understanding (e.g. duplicated concepts removed, examples added to increase clarity of *mock-ups*).

A single pilot test was created (Appendix J: Creative Synthesis Pilot v.1) with items formatted into a standardized form; all items began with the statement "when given a new problem/project, to what extend do you…" and measured using a six-point Likert scale (*strongly disagree = 1*, *strongly agree = 6*).

Construct and Predictive Validity

The overall goal of the Pilot Test was to make a final attempt at improving construct and predictive validity, or the extent to which a measurement predicts subsequent performance (Vogt, 2005). During each Pilot Test, students were asked to provide feedback and notes of areas, words, phrases they considered confusing or hard to understand (Recker & Rosemann, 2010; Schmiedel et al., 2013). After the Pilot Test data collection concluded, items identified as confusing or hard to understand were marked for additional analysis after the Factor Analysis and reliability testing were conducted.

Phase III. Instrument Confirmability

At the conclusion of pilot testing, a final version of the CSI was constructed. Survey items for each factor were randomly distributed across the instrument to prevent item responses from potentially influencing one other (Elliott, 2013). An item coding system was used to track and ensure consistency, enabling items to be identified to their constructs (e.g., question 1 for prototyping = P1). Item coding was consistent with the variable naming structure used when entering the data into SPSS (Elliott, 2013).

Scale Development and Variables

The body of the CSI is comprised of items using a 6-point Likert scale rating of agreement characterizing the factors of creative - imagination, visualization, prototyping, and evaluation.

Items sought to define participants' agreements with factors associated with the creative synthesis process within the context of the design thinking environment. The researcher modeled the creative synthesis process, through the lens of the independent variables (imagination & visualization, discovery, prototyping, and evaluation). Table 11 identified each variable, level of measurement, and Mean and Standard Deviation by factor present in the final version of the CSI.

Table 11
Final CSI Study Variables (Ordinal), Ordered by Question Number

Question #	Characteristic	Factor	M	SD
1	Imagination &	Convert reality to abstract	4.09	1.254
2	Visualization	Associate previously separate ideas	4.42	1.041
3		Think creatively	5.25	.949
4		See connections among ideas	5.00	.933
5		Mentally manipulate ideas	4.00	1.064
6		Draw ideas w/o using words	4.00	1.535
7	Discovery	Acknowledge others knowledge	4.86	1.045
8		Stop and rethink problem/project	4.92	1.088
9		Allow for discovery/new ideas	5.14	.961
10		Use convergent thinking	4.00	1.058
11		Utilize team decision making	4.84	1.013
12	Prototyping	Explore feasibility of mock-up	3.90	1.245
13		Create mock-ups	3.68	1.389
14		Discover end use of mock-up	3.62	1.258
15		Judge impact of design concept	3.81	1.264
16	Evaluation	Test and refine for feedback	4.40	1.079
17		Assess project qualities	4.59	1.149
18		Receive external feedback	4.57	1.277
19		Measure quality from end-user	4.68	1.089
20		Judge level of innovation	4.57	1.149
21		Use variety of data collection	4.43	1.144
22		Define measures of success	4.76	1.202

Conclusion

The purpose of the study was to develop and validate a reliable quantitative instrument: The Creative Synthesis Inventory (CSI). The data collection techniques and analysis procedures detailed in this chapter were developed to effectively accomplish this objective. This instrument would now be tested in the field in diverse studies seeking to measure creative synthesis when employing the design synthesis process. Although qualitative studies have prevailed when examining design thinking factors, inclusion of a valid and reliable instrument with quantitative measurements would enrich research endeavors and assist organizations in pinpointing areas of strengths and uncovering needs for improvements in their quest for tracking their outcomes, processes, and progress toward innovation.

CHAPTER IV

DATA ANALYSIS

The goal of this study was to construct a quantitative measure for the creative synthesis processes within the design thinking environment. Diverse qualitative models emerged from the literature, however through discussions with industry experts, a lack of quantitative assessments in this area surfaced (R. Martin, personal communication, August 29, 2013; D. Kelley, personal communication, September 17, 2013). This discovery created the foundation for this research examination. The purpose of this study emerged: explore and develop a quantitative instrument measuring the constructs of the creative synthesis process. Two research questions framed the investigative process grounding this study:

RQ1: Can a quantitative instrument measure the creative synthesis process within the design thinking environment?

RQ2: Is there a difference representing diverse disciplinary backgrounds among groups in the study?

The creation of quantitative instruments may enable organizations to pinpoint strengths or needs for improvements. This discovery may also allow for greater definition in innovative outcomes and across groups representing different disciplinary backgrounds. The instrument development process was complex and required the execution of a mixed method approach with multiple phases of data collection, testing, and analysis (Elliott, 2013; Leigh, 2011; Ng & Feldman, 2012; Perkins, 2014; Schmiedel, Brocke, & Recker, 2014; Witemeyer, 2013) and offered assessment of the instrument development process (Recker & Rosemann, 2010). To answer RQ1, the development process for the CSI was divided into three phases (See Figure 15). Phase I detailed the process of attribute identification and item development. Phase II entailed pre-test and instrument revisions, and Phase III executed pilot testing and instrument confirmability testing and analyses. Phase I, discussed in Chapter III, primarily reflected the literature review process, identification of constructs, factors, and attributes (Table 6), and expert evaluation and review, resulting in the initial question development (Appendices B and C).

Pre-test and Instrument Revision

Phase II utilized a pre-test of the initial questions developed after expert review with continued instrument revision to refine constructs and relevant supporting factors and attributes.

Phase II Pre-Test

Two pre-test versions (v.1A and v.1B) included 41 items and were distributed to 74 undergraduate students in three courses in interior design, engineering, and ethnic studies in the spring 2015 semester.

Analysis of pre-test data. Data were entered into Excel tables, transferred to SPSS v.23, with coded Likert scales as strongly disagree = 1 to strongly agree = 6. Non- or duplicated responses were coded as nine. Descriptive statistics examining means and standard deviations were calculated for each attribute.

Inter-item consistency. In the development of instrumentation, Cronbach’s alpha coefficients were used to assess the reliability among factors. Chronbach’s α were calculated for each factor in both pre-test versions and evaluated for inter-item consistency (Gliner et al., 2009; Pett et al., 2003; Table 12).

Table 12
Cronbach's alpha of Individual Factors for Pre-Test v.1A and v.1B

v.1A		v.1B	
Construct	Cronbach's α	Construct	Cronbach's α
Imagination	.778	Imagination	.673
Visualization	.712	Visualization	.425
Prototyping	.865	Prototyping	.724
Evaluation	.870	Evaluation	.790

Factors demonstrating a Corrected Item-Total Correlation value between -1.0 and +1.0 indicated questions for potential elimination; several items fell outside this range and were eliminated. Those factors flagged for further examination to compare means, standard deviations, and frequencies to assess the reason for low Corrected Item-Total correlations (Table 13). These questions were reworded to eliminate ambiguity. In the next phase both the questions with low (>.3) Corrected Item-Total correlations and new questions, reworded to clarify meaning, and were included to revise the instrument and strengthen comprehension by participants eliminating early bias by the researcher.

Reliability

Spilt-half reliability was calculated for factors of the CSI for both pre-test versions to examine the consistency of individual participants' responses (Gliner et al., 2009; Lynn, 1986; Vaske, 2008; Voght, 2005). In the likelihood reliability might be underestimated attributable to splitting the number of responses in half, a Spearman-Brown coefficient (*r*) was calculated for each construct (Gliner et al., 2009; Table 14).

Table 13
Questions Reworded and Adjusted to Eliminate Ambiguity

Construct	Pre-Test	Existing Item	New Item
Imagination	v.1A	Ignore the contextual environment	Do not pay attention to the related environment
	v.1A	Recognize the gap between the known and unknown	Acknowledge what is known and what is unknown
	v.1B	Combine existing but discrete ideas	Associate existing, but previously separate ideas
	v.1B	Think using symbols	Think in pictures and figures
	v.1B	Acknowledge others' diverse knowledge for potential use in solution	Consider what others' know for potential contribution into project outcome
	v.1B	Use your imagination	Thinking creatively
Visualization	v.1A & v.1B	See relationships among your ideas	Find similarities between ideas
	v.1B	Express ideas without words and numbers	Draw ideas without using words or numbers
	v.1B	Use convergent thinking (i.e. narrow your focus and ideas)	Narrow process representing a logical thought process
	v.1B	Consider project objectives	Creating project meaning and understanding
Prototyping	v.1B	Explore desired outcome of your prototype	Discover end use possibilities of a preliminary mock-up
Evaluation	v.1B	Receive feedback from external stakeholders/clients	Ask for feedback from end users of your product

Table 14
Spearman-Brown Coefficients for Pre-Test v.1A and v.1B

v.1A		v.1B	
Construct	Spearman-Brown *r*	Construct	Spearman-Brown *r*
Imagination	.620	Imagination	.696
Visualization	.635	Visualization	.389
Prototyping	.871	Prototyping	.764
Evaluation	.852	Evaluation	.809

A low Spearman-Brown Coefficient, particularly in v.1B, suggested questions requiring addition consideration due to the possibility the item was confusing or not well understood by the participant.

Instrument Revision

During instrument revision in Phase II, a qualitative activity, the Card Sort, was deployed using a contact list for experts representing 16 disciplines across the university (refer to Table 10).

- Week One: Twenty-eight experts were invited by email to participate; seven experts completed the Card Sort process, three experts started but did not finish the activity, and 18 experts did not respond.
- Week Two: Eighteen additional experts were added to the contact list from the roster from a newly created campus committee established to oversee a creative initiative (Virtual Reality), expanding the participant list to 46 experts; an additional two experts completed the Card Sort activity; a 34 experts did not respond.
- Week Three: Twenty-eight experts received a reminder again inviting their participation; four additional experts completed the activity, three experts started but did not finish the activity, and 27 experts of the 34 above did not respond.
- Week Four, the added group of 18 were sent a second reminder; no additional experts completed the Card Sort, two experts started but did not finish the activity, and 25 experts of the total 34 did not respond.
- Week Five: all 46 experts were re-contacted and notified of a final opportunity to participate; six additional experts completed the activity, two started but did not finish the activity, and 17 of the total 46 experts did not responded.

In total 29 experts participated in the Card Sort activity (*N* = 29) with a response rate of 63%. Incomplete responses from ten experts were eliminated from the analysis due to inadequate completion. Figure 17 illustrates the participation of individuals, by week.

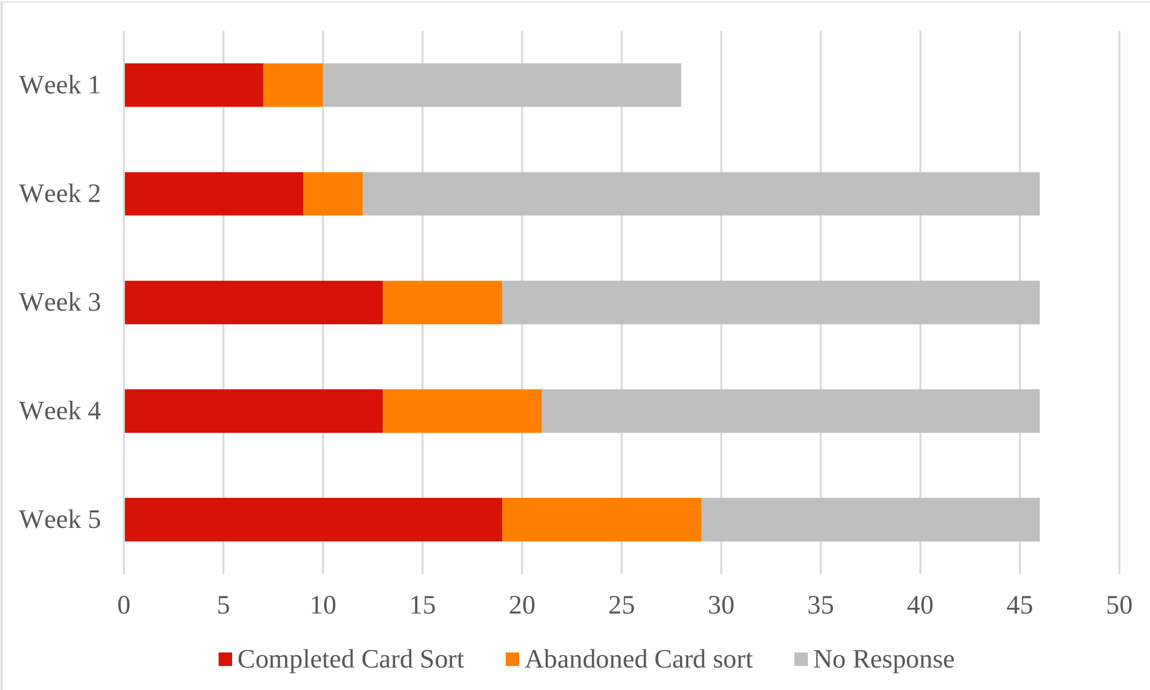

Figure 17. Week-by-week participation of experts in the card sort activity.

Analysis of Card Sort Data

The number of experts placing an item into a construct category was converted to a percentage of the total *N* (19) to create responses percentage. Response percentages were calculated for each item from the pre-test – with both the original and reworded questions – and placed into a matrix to identify strongly correlated items and constructs and weaker combinations (Appendix G: Number of Experts per Item by Construct for Card Sort Converted to % of *N*). By examining the response percentages attributed to particular construct categories of Imagination, Visualization, Evaluation, and Prototyping, assessed strengths or weakness of each item could be considered. Participants were provided with the option “to place hard to understand, duplicated, or ambiguous items into a fifth heading” during the Card Sort activity. A majority of experts categorized this fifth category broadly creating additional constructs in addition to placing unused questions. In creating new constructs, experts suggested certain items did not belong under one of the original four constructs. These additional items were grouped and assigned a percentage. Five percentage categories were coded (dark to light, highest to lowest); 0% - 20%, 21% - 40%, 41% - 60%, 61% - 80%, and 81% - 100%.

Items were removed from the construct category if at least one of the following were true:

- frequency of agreement below 20% for the construct category;
- percentage higher for an item in the fifth category (suggesting the item was hard-to-understand, duplicative or ambiguous) than a percentage in the appropriate construct category;
- percentage higher in another construct category (suggesting the item belonged under a different construct); and
- item descriptions using a construct term and rated higher in another construct category.

In two instances, when the item produced a higher percentage in another construct category, but did not use the construct term, it was moved to the new construct category. For example, the item “think using symbols,” originally placed within Imagination, was moved to Visualization, with percentages of 31.68% and 63.16%, respectively.

Finally, reworded items were used to address low Chronbach’s α, (refer to Table 12) and items with the higher percentage remained in the instrument with duplicated items removed (Table 15).

After each Card Sort item was addressed (Table 16), a CSI Pilot was created using 30 items to be tested during the Pilot Study; nine items under Imagination; seven items under Visualization; six items under Prototyping; and eight items under Evaluation (Appendix K: Creative Synthesis Pilot).

Table 15

Items Reworded and Adjusted to Eliminate Ambiguity in Card Sort Outcomes (N = 19)

Construct	Pre-Test	Existing Item	Response (%)	New Item	Response (%)
Imagination	v.1A	Ignore the contextual environment	68.42	Do not pay attention to the related environment	63.11
	v.1A	Recognize the gap between the known and unknown	31.58	Acknowledge what is known and what is unknown	21.05
	v.1B	Combine existing but discrete ideas	42.11	Associate existing, but previously separate ideas	47.37
	v.1B	Think using symbols	31.38	Think in pictures and figures	15.79
	v.1B	Acknowledge others' diverse knowledge for potential use in solution	36.84	Consider what others' know for potential contribution into project outcome	10.53
	v.1B	Use your imagination	84.11	Thinking creatively	84.21
Visualization	v.1A/v.1B	See relationships among your ideas	57.89	Find similarities between ideas	36.84
	v.1B	Express ideas without words and numbers	42.11	Draw ideas without using words or numbers	63.16
	v.1B	Use convergent thinking (i.e. narrow your focus and ideas)	36.84	Narrow process representing a logical thought process	21.05
	v.1B	Consider project objectives	10.53	Creating project meaning and understanding	38.84
Prototyping	v.1B	Explore desired outcome of your prototype	42.11	Discover end use possibilities of a preliminary mock-up	63.16
Evaluation	v.1B	Receive feedback from external stakeholders/clients	73.68	Ask for feedback from end users of your product	68.42

Table 16

Creative Synthesis Constructs from Card Sort Results for v.P1 based on response percentage (N = 19)

Item #	Item	Imagination	Visualization	Prototyping	Evaluation
1	Relate existing ideas	42.11			
2	Ignore contextual environment	68.42			
3	Convert reality to abstract	68.42			
4	Gap in known and unknown	31.58			
5	Acknowledge others knowledge	36.84			
6	Stop and rethink solution	21.05			
7	Allow for discovery/new ideas	68.42			
8(n)	Associate existing/separate ideas	47.37			
9(n)	Think creatively	84.21			
10	See relationships among ideas		57.89		
11	Mentally manipulate ideas		36.84		
12	Use of tools to share ideas		73.68		
13(n)*	Think using symbols		63.16		
14	Use convergent thinking		36.84		
15(n)	Draw ideas w/o using words		63.16		
16(n)	Create project meaning		36.84		
17(n)*	Utilize team decision making			31.58	
18	Test and refine objects			57.89	
19	Identify future success			57.89	
20	Explore plausibility			36.84	
21	Create mock-ups			68.42	
22(n)	Discover end use of mock-up			63.16	
23	Judge design concept				73.68
24	Assess project qualities				73.68
25	Receive feedback from team				57.89
26	Feedback from stakeholders				73.68
27	Assess project quality				84.21
28	Judge level of innovation				84.21
29	Use variety of data collection				47.37
30	Define measures of success				63.16

* Change of construct category

Pilot Test and Instrument Confirmability

Moving the instrument development process forward to meet the goal and purpose of this study, Phase III concentrated on a pilot-test with input from participants, with a final round of testing during final instrument confirmability.

Phase III Pilot Test

To deploy the Pilot Test, the contact list encompassing the same experts representing 16 disciplines (refer to Table 10) originally contacted for the Phase II instrument revision (Card Sort) was again utilized.

- During Week one, an email invitation to participate in the Pilot Test was sent to 42 experts; 13 experts responded, six agreed to participate, seven experts were not teaching courses during the given semester, and 29 did not respond.

- During Week two, an additional expert agreed to participate, one expert asked to be contacted the following semester, two experts were not teaching courses during the given semester, and 25 did not respond.

- During weeks three to five, no additional experts agreed, declined, or informed the researcher of their absence over the semester.

Over the five week period experts permitted their students to participate in the Pilot Test, seven experts agreed to participate, four followed through on scheduling ($N = 4$; response rate of 9.5%). Figure 18 illustrates participation by week. Two hundred and sixty-seven students completed surveys from four experts' courses. Data were collected during a three-week period with surveys assessed for completeness. Responses to two surveys were less than 60% complete and eliminated from the study ($N = 265$; response rate of 81.5%). Responses were coded into Excel files and imported into statistical software (SPSS v.23). Table 17 depicts the number of participants from each discipline.

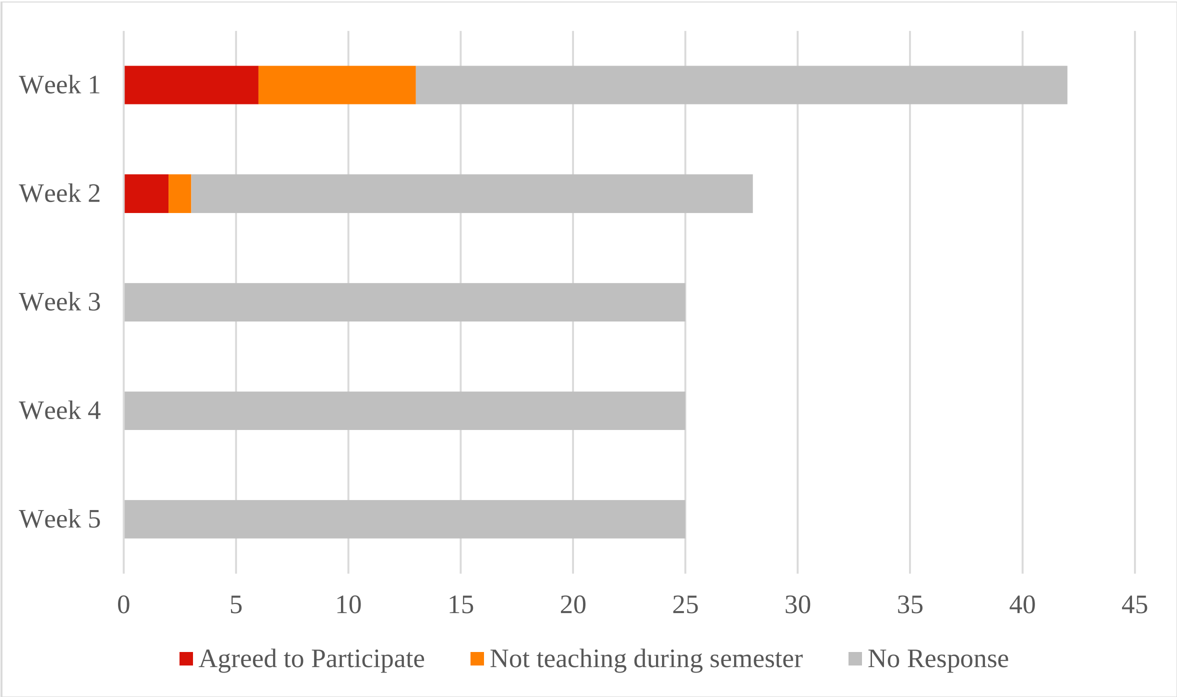

Figure 18. Week-by-week participation of experts in the pilot test.

Table 17
Summary of Participants in Pilot Instrument

# of participants invited	# of participants completing survey	College	Course
120	99	Health and Human Sciences	Clothing Adornment and Human Behavior
120	83	Health and Human Sciences	Design Foundations of Apparel and Merchandising
60	59	Business	Marketing Research
25	23	Agricultural Sciences	Digital Methods for Horticulture & Landscape Architecture

Qualitative Analysis of Pilot Test Data

Ninety-eight participants provided written feedback to specific items on the instrument; these narratives were transcribed and interpreted by item. Written comments included feedback on:

- item clarity and general understanding of terminology;
- request for examples to be provided more frequently;
- suggested rewording of items;
- reordering of items; and
- suggested changes to the Likert scale.

The most frequent feedback received were comments made on clarity of items (Figure 19). Feedback made on items were taken under consideration and resulted in two items being marked for removal; two items reordered; and six items reworded to increase understanding and clarity or expanded with examples (Table 18).

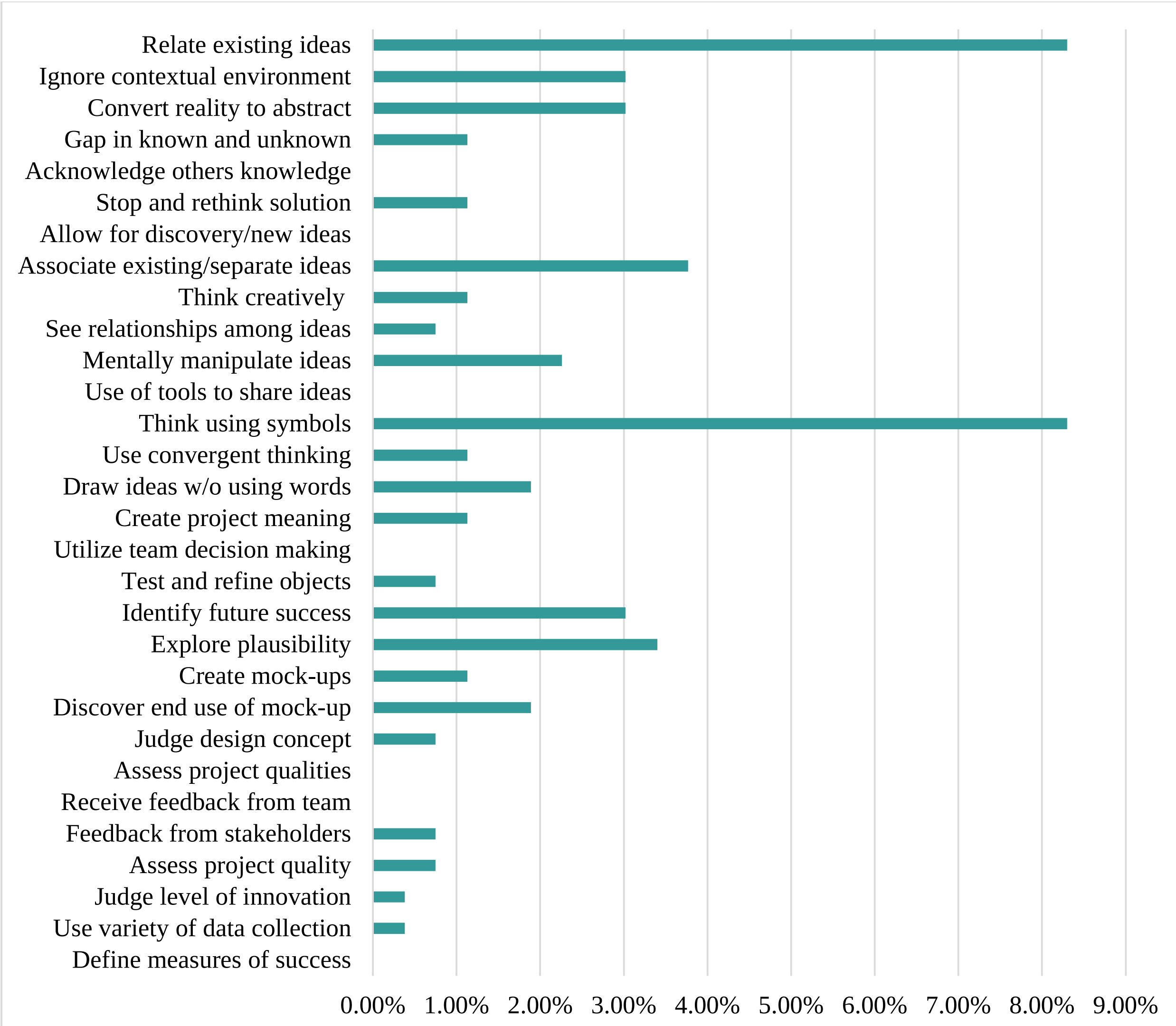

Figure 19. Percentage of participants who commented survey item was confusing or hard to understand.

Table 18

Participant Feedback by Item on Pilot Test with Actions Taken

Item #	Item	Written Feedback	Action
i1	Relate existing ideas	Item is confusing and hard to understanding	Item was marked for removal following factor analysis results
i2	Ignore contextual environment	Request to clarify "contextual environment"	Item reworded to: Ignore the contextual (surrounding) environment or space.
v1	See relationships among ideas	Suggested rewording provided by participant	Suggested rewording accepted, item now states: See relationships (connections) between your ideas.
v2	Mentally manipulate ideas	Suggested rewording	Item reworded to: Mentally manipulate ideas in your mind.
v4	Think using symbols	Request for example to clarify "symbols"	Item reworded to: Think using symbols (e.g. a visual picture used to represent ideas).
v7	Create project meaning	Suggested rewording provided by participant	Suggested rewording accepted, item now states: Create meaning and understanding in project.
P2	Test and refine objects	Suggested removal of work "objects"	Suggested remove accepted, item now states: Test and refine to gain feedback and learn rapidly.
P3	Identify future success	Item is confusing and perceived as a duplicate; request for example to clarify "mock-ups"	Item was marked for removal following factor analysis results; examples provided after using "mock-up" in all prototype questions.
p4 & p5	Explore plausibility, create mock-ups.	Item order should be reversed in order.	Items reordered.

Participants also provided feedback suggesting the need to alter the Likert scale. When the researcher agreed with the feedback provided, the scale was changed from *strongly disagree – strongly agree* to *never – always*.

Quantitative Analysis of Pilot Test Data

Data collected from the Pilot Test were entered into the statistical package; individual responses were eliminated when multiple responses were made to the same item and outliers appearing because the respondent wrote in a numeric value beyond the provided range of the six-point scale. Responses were coded with 1= *strongly disagree* to 6 = *strongly agree*, and nine for non- and duplicated responses. Descriptive statistics (mean, standard deviation, frequencies) were calculated to assess response rates for each item in the Pilot CSI (Table 19).

Factor analysis. A minimum of 220 participants was identified for a survey with 22 items to enable factor analysis (DeVellis, 2012; Perkins, 2014; Talbachnick & Fidell, 2007). With 265 participants for the Pilot Test, the sample size was considered adequate. Principle axis factor analysis with varimax rotation with Kaiser Normalization was used to assess the internal structure of the data informing decisions about factor and attribute grouping and covariation among variables (Agresti & Findlay, 1997; Leech, Barrett, & Morgan, 2008)

Assumptions were tested by a Kaiser-Myer-Olkin test (KMO), a measure of sampling adequacy, and Bartlett's test of sphericity; all assumptions were satisfied (Leech et al., 2008). Factor analysis was run, forcing factors into three, four, and five factor outputs (Appendix L: Rotated Component Matrix for Pilot Test); the four factor model, most accurately represented the constructs with a majority of factors aligning with its original and pre-identified construct. The three- and five-factor model either eliminated a construct critical to the creative synthesis process or created constructs unsupported by the literature.

Table 19
Means, Standard Deviations, and Skewness for the Pilot Test Responses

					Skewness	
Item #	Construct	*N*	*M*	*SD*	Statistic	Std. Error
I1	Relate existing ideas	259	4.36	.936	-.841	.151
I2	Ignore contextual environment	259	2.28	1.082	.964	.151
I3	Convert reality to abstract	260	4.09	1.254	-.524	.151
I4	Gap in known and unknown	263	3.34	1.141	-.770	.150
I5	Acknowledge others knowledge	264	4.86	1.045	-1.034	.150
I6	Stop and rethink solution	263	4.92	1.088	-1.087	.150
I7	Allow for discovery/new ideas	264	5.14	.961	-1.492	.150
I8	Associate existing/separate ideas	261	4.42	1.041	-.336	.151
I9	Think creatively	262	5.25	.949	-1.464	.150
V1	See relationships among ideas	263	4.90	.933	-.929	.150
V3	Mentally manipulate ideas	263	4.34	1.064	-.327	.150
V3	Use of tools to share ideas	262	4.58	1.304	-.772	.150
V4	Think using symbols	261	3.63	1.382	-.163	.151
V5	Use convergent thinking	264	4.36	1.058	-.441	.150
V6	Draw ideas w/o using words	262	3.53	1.535	-.003	.150
V7	Create project meaning	259	4.64	.972	-.621	.151
P1	Utilize team decision making	261	4.83	1.013	-.687	.151
P2	Test and refine objects	259	4.40	1.079	-.481	.151
P3	Identify future success	258	4.01	1.261	-.163	.152
P4	Explore plausibility	256	3.90	1.245	-.236	.152
P5	Create mock-ups	258	3.68	1.389	-.109	.152
P6	Discover end use of mock-up	255	3.62	1.258	-.073	.153
E1	Judge design concept	257	3.81	1.264	-.287	.152
E2	Assess project qualities	259	4.59	1.149	-.819	.151
E3	Receive feedback from team	260	4.93	.966	-1.110	.151
E4	Feedback from stakeholders	258	4.57	1.277	-.923	.152
E5	Assess project quality	259	4.68	1.089	-.705	.151
E6	Judge level of innovation	258	4.57	1.149	-.839	.152
E7	Use variety of data collection	257	4.43	1.144	-.611	.152
E8	Define measures of success	258	4.76	1.202	-.981	.152

In the four factor analysis, items were removed from the construct category if at least one of the following were true:

- item had an absolute value less than .30 across all four factors;
- item loaded on three or more factors (absolute value < .30); and
- item had an absolute value of below or near .40 and received feedback suggesting confusion and lack of clarity by participants in the Pilot Test.

Subsequently five items were removed (i.e., Items i2, i4, v3, v4, and v7). *Cronbach's α* was run on the construct groupings to ensure reliability remained at an acceptable level ($\alpha < .6$; Table 20).

Table 20
Factor Percentage and Cronbach's α with Forced Four Factor Analysis

Item #	Item	Factor %	Factor Group	Cronbach's α
P5	Create mock-ups	.847		
P4	Explore plausibility	.845		
P3	Identify future success	.787	1	.923
P6	Discover end use of mock-up	.774		
E1	Judge design concept	.712		
E4	Feedback from stakeholders	.722		
E7	Use variety of data collection	.697		
E2	Assess project qualities	.695		
E8	Define measures of success	.618	2	.867
E6	Judge level of innovation	.511		
E5	Assess project quality	.496		
P2	Test and refine objects	.394		
V2	Mentally manipulate ideas	.602		
V1	See relationships among ideas	.545		
I9	Think creatively	.508		
I8	Associate existing/separate ideas	.504	3	.720
I3	Convert reality to abstract	.481		
V6	Draw ideas w/o using words	.443		
I1	Relate existing ideas	.397		
V5	Use convergent thinking	.304		
I5	Acknowledge others knowledge	.643		
P1	Utilize team decision making	.584	4	.727
I6	Stop and rethink solution	.474		
I7	Allow for discovery/new ideas	.462		
E3	Receive feedback from team	.425		

To confirm results from the previous round of factor analysis, a third round of factor analysis was conducted and an additional three items removed due to low factor loading (Items I1, P3, and E3). Next, *Cronbach's α* was calculated on the remaining factor groupings to assess reliability at an acceptable level (α ≥ .60). In total, eight items were removed from the CSI following the Pilot Test, with construct grouping reliabilities ranging from *α* = .688 to .906 (Table 21).

Table 21
Factor Loading and Cronbach's α During Final Factor Analysis

Item #	Item	Factor loading %	Factor Group	Cronbach's *α*
E4	Feedback from stakeholders	.785		
E7	Use variety of data collection	.778		
E5	Assess project quality	.756		
E8	Define measures of success	.694	1	.867
E6	Judge level of innovation	.635		
E2	Assess project qualities	.563		
P2	Test and refine objects	.467		
P5	Create mock-ups	.887		
P6	Discover end use of mock-up	.833	2	.906
P4	Explore plausibility	.818		
E1	Judge design concept	.771		
V2	Mentally manipulate ideas	.652		
I9	Think creatively	.635		
I8	Associate existing/separate ideas	.629	3	.705
V1	See relationships among ideas	.599		
V6	Draw ideas w/o using words	.590		
I3	Convert reality to abstract	.547		
I5	Acknowledge others knowledge	.764		
I6	Stop and rethink solution	.701		
P1	Utilize team decision making	.588	4	.688
I7	Allow for discovery/new ideas	.580		
V5	Use convergent thinking	.383		

Before finalization of the CSI instrument, the order of factors in the Rotated Factor Matrix was analyzed for strength of association. The factor groupings were compared with the original factor groups and changed to better reflect the outcomes of factor analysis. The factors of Imagination and Visualization were combined into one comprised of six items (Items I3, I8, I9, V1, V2, and V6). A new factor, identified as Discovery, emerged encompassing five items

(Items I5, I6, I7, V5, and P1) focusing on the acquisition of new knowledge through learning and feedback, having attracted the activities of problem solving, knowledge acquisition, and thinking as a process generating new ideas within the design thinking environment. Factor groupings of Prototyping and Evaluation remained distinct at four items (P4, P5, P6, and E1) and seven items (P2, E2, E4, E5, E6, E7, and E8; see Table 22).

Phase III: Instrument Confirmability

Although the CSI was intended for use by groups in work environments, the use of a convenience sample comprised of students majoring in disciplines formally acknowledging their use of design thinking was considered representative of individuals in the work force who might appropriately engage with the creative synthesis process. Therefore, to confirm the reliability and validity of the finalized Creative Synthesis Inventory (CSI), the survey was administered to a convenience sample of undergraduate students (N = 264) during spring semester of 2017. These students were enrolled in courses attributed to creative disciplines utilizing creative labs or studio environment and also represented a sampling of the creative industries' work force (Florida & Goodnight, 2005).

Table 22

Revised Construct Groups after Factor Analysis

Item #	Pilot Test Item Name	Construct in Pilot CSI	Corrected Item #	Corrected Item Name	Final CSI Construct
I1	Relate existing ideas		I3	Convert reality to abstract	
I2	Ignore contextual environment		I8	Associate previously separate ideas	
I3	Convert reality to abstract		I9	Think creatively	Imagination & Visualization
I4	Gap in known and unknown		V1	See connections among ideas	
I5	Acknowledge others knowledge		V2	Mentally manipulate ideas	
I6	Stop and rethink solution	Imagination	V6	Draw ideas w/o using words	
I7	Allow for discovery/new ideas				
I8	Associate existing/separate ideas			____	
I9	Think creatively				
V1	See relationships among ideas				
V2	Mentally manipulate ideas	Visualization			
V3	Use of tools to share ideas			____	
V4	Think using symbols				
V5	Use convergent thinking				
V6	Draw ideas w/o using words				
V7	Create project meaning				
			I5	Acknowledge others knowledge	
			I6	Stop and rethink problem/project	
	____		I7	Allow for discovery/new ideas	Discovery
			V5	Use convergent thinking	
			P1	Utilize team decision making	
P1	Utilize team decision making		P4	Explore feasibility of mock-up	
P2	Test and refine objects		P5	Create mock-ups	Prototyping
P3	Identify future success		P6	Discover end use of mock-up	
P4	Explore plausibility	Prototyping	E1	Judge impact of design concept	
P5	Create mock-ups			____	
P6	Discover end use of mock-up				
E1	Judge design concept		P2	Test and refine for feedback	
E2	Assess project qualities		E2	Assess project qualities	
E3	Receive feedback from team		E4	Receive external feedback	
E4	Feedback from stakeholders		E5	Measure quality from end-user	Evaluation
E5	Assess project quality	Evaluation	E6	Judge level of innovation	
E6	Judge level of innovation		E7	Use variety of data collection	
e7	Use variety of data collection		E8	Define measures of success	
e8	Define measures of success			____	

Sampling Frame for the CSI Survey

Faculty received an email inviting class participation in a paper-and-pencil survey (Appendix K: CSI Survey Email Recruitment to Professors); if they agreed, the researcher arrived at the beginning or end of class meetings, and on various days of the week. Table 23 identifies the invited faculty experts' by college and department who participated in the Pilot Test, agreed to participate in the future (some faculty experts were on sabbatical leave or not teaching courses when first contacted), or had participated in the Card Sort process. The researcher read a verbal script (Appendix L: CSI Survey Verbal Invitation to Participate) introducing the study, provided a cover letter (Appendix M: CSI Survey Cover Letter) for each participant to read, and distributed hard copies of the survey (Appendix N: CSI Survey). Participants were then given approximately 20 minutes to complete the survey (Table 24).

Table 23
Invited Faculty Participants by College and Department

# of Participant Courses	College	Department
5	Health and Human Sciences	Design & Merchandising, Occupational Therapy
2	Engineering	Electrical & Computer Engineering, Mechanical Engineering
2	Liberal Arts	Art & Art History
1	Agricultural Sciences	Horticulture & Landscape Architecture
1	Business	Marketing
1	Natural Sciences	Computer Sciences

Table 24
Invited Student Participants in the Final CSI Instrument Confirmability Activity

# of Student Participants	College	Course
117	Health and Human Sciences	Clothing Adornment and Human Behavior
70	Business	Marketing Research
65	Natural Sciences	Introduction to Machine Learning
52	Health and Human Sciences	Merchandising Processes
22	Health and Human Sciences	Interior Design II
20	Liberal Arts	Fibers II
20	Engineering	Engineering Project and Program Management

Data Collection

- During Week one, an email invitation to have students enrolled in their classes participate in the final testing of the CSI survey was sent to 12 faculty; eight faculty responded. Of the 8 faculty, six agreed to participate, two faculty informed the researcher they were not teaching courses for the given semester, and four did not respond.
- During Weeks two through four, no additional experts agreed, declined, or informed the researcher of absence for the semester.
- In Week three, a reminder was sent to the remaining four experts asking for participation; no activity took place during Week four.
- During Week five, one additional faculty member agreed to participate with the remaining three experts not responding.

Over the five-week period encompassing the final testing of the CSI survey with students, seven faculty agreed to participate with each of the seven scheduling a time for the researcher to give the survey to class members (n = 7; response rate of 58.3%). Figure 20 illustrates participation of faculty by week.

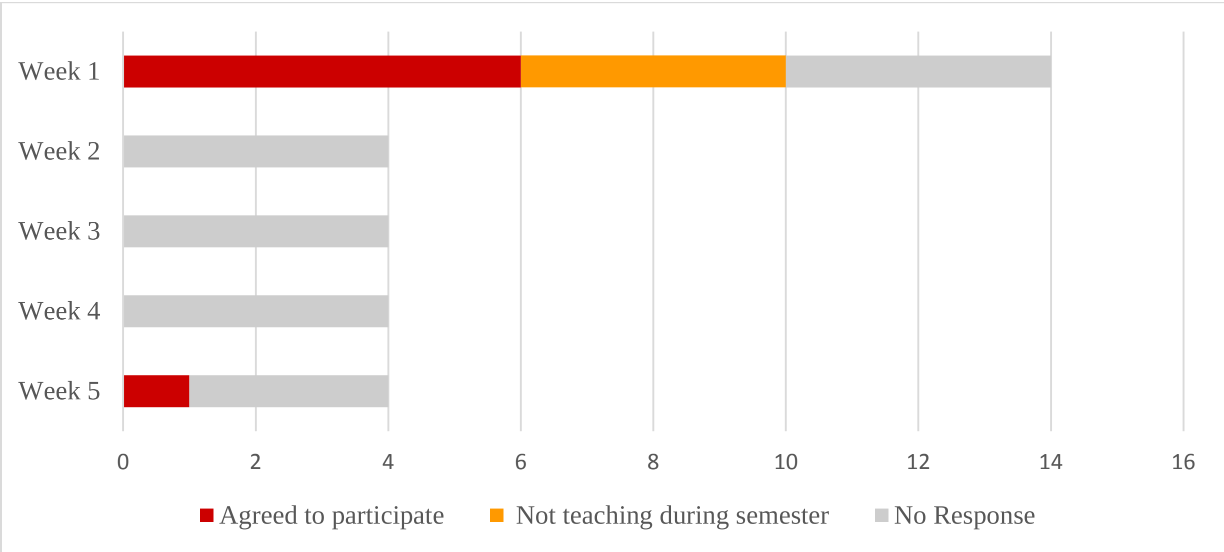

Figure 20. Week-by-week participation of faculty agreeing to the administration of the CSI survey in their classes.

In total, the researcher collected 264 completed surveys by students in the seven faculty members' courses. Survey responses were assessed for completeness with no surveys eliminated (N = 264; response rate of 72.1%).

Data collected from this pilot test were entered into the statistical software. Responses were screened and assessed for duplication. Responses added by the participants beyond the range of the six-point Likert scale (e.g., if they added their own scale) were eliminated. Responses were coded with 1= *Never* to 6 = *Always*, and 9 used for non- and duplicated responses.

Renaming Constructs and Item Numbers

Prior to quantitative analysis of the construct groupings, constructs were re-conceptualized to rename and renumber reflecting the factor analysis conducted in Phase III of the Pilot Test (Table 25).

Table 25
Reconceptualized CSI Construct Groups

Item Name	Original Construct	Item #	Revised Construct	Item #
Convert reality to abstract	Imagination & Visualization	I3	Visualize	V1
Associate previously separate ideas		I8		V2
Think creatively		I9		V3
See connections among ideas		V1		V4
Mentally manipulate ideas		V2		V5
Draw ideas w/o using words		V6		V6
Acknowledge others knowledge	Discovery	I5	Discover	D1
Stop and rethink problem/project		I6		D2
Allow for discovery/new ideas		I7		D3
Use convergent thinking		V5		D4
Utilize team decision making		P1		D5
Explore feasibility of mock-up	Prototyping	P4	Prototype	P1
Create mock-ups		P5		P2
Discover end use of mock-up		P6		P3
Judge impact of design concept		E1		P4
Test and refine for feedback	Evaluation	P2	Evaluate	E1
Assess project qualities		E2		E2
Receive external feedback		E4		E3
Measure quality from end-user		E5		E4
Judge level of innovation		E6		E5
Use variety of data collection		E7		E6
Define measures of success		E8		E7

Exploratory Data Analysis (EDA)

EDA was used examined to identify a) potential problems in the data set including outliers, non-normal distributions, problems with coding, and missing or unidentified values, and b) assess the extent to which statistical assumptions were met (Leech et al., 2008).

Descriptive statistics to examine means, standard deviations, and frequencies (Table 26) were calculated. Additionally, each variable was examined for skewness (Gliner et al., 2009).

Table 26
Descriptive Statistics for the final CSI

					Skewness	
Item #	Item	*N*	*M*	*SD*	Statistic	Std. Error
V1	Convert reality to abstract	263	3.48	1.142	.346	.150
V2	Associate previously separate ideas	264	4.01	1.009	.052	.150
V3	Think creatively	263	4.84	1.023	-.595	.150
V4	See connections among ideas	264	4.55	.930	-.571	.150
V5	Mentally manipulate ideas	263	4.15	1.079	-.115	.150
V6	Draw ideas w/o using words	262	3.43	1.493	.110	.150
D1	Acknowledge others knowledge	264	4.35	.986	-.242	.150
D2	Stop and rethink problem/project	264	4.62	1.010	-.391	.150
D3	Allow for discovery/new ideas	264	4.88	.931	-.496	.150
D4	Use convergent thinking	263	4.10	1.045	.116	.150
D5	Utilize team decision making	263	4.27	1.111	-.340	.150
P1	Explore feasibility of mock-up	264	3.04	1.353	.293	.150
P2	Create mock-ups	264	3.11	1.371	.302	.150
P3	Discover end use of mock-up	264	3.03	1.338	.321	.150
P4	Judge impact of design concept	264	3.38	1.314	.013	.150
E1	Test and refine for feedback	264	4.04	1.047	-.264	.150
E2	Assess project qualities	264	3.95	1.138	-.200	.150
E3	Receive external feedback	263	3.84	1.322	-.495	.150
E4	Measure quality from end-user	263	4.07	1.215	-.248	.150
E5	Judge level of innovation	264	4.03	1.138	-.301	.150
E6	Use variety of data collection	264	3.62	1.273	-.287	.150
E7	Define measures of success	264	4.13	1.189	-.320	.150

Quantitative Analysis of Instrument Confirmability Data

Because the CSI attempts to quantitatively measure a complex and difficult concept, several methods were used to measure validity and reliability. Following is a summary of the inter-item consistency testing (Cronbach's *α)*, spilt-half reliability (Spearman-Brown *r*), and factor analysis methods for checking validity and reliability of the final data for the CSI.

Inter-item Consistency Testing

Cronbach's α were calculated for composite scores within each construct of the CSI (Table 27). A Cronbach's α of $\geq .60$ was considered acceptable for this study (Field, 2009; Gliner et al., 2009; Morgan et al., 2007). An adjusted Spearman-Brown coefficient was calculated to adjust for underestimations in reliability (Gliner et al., 2009). *Cronbach's α* ran on all 22 items in the final version of the CSI = .868.

Table 27
Cronbach's α of Constructs in the Final CSI

Construct	Cronbach's α
Visualize	.678
Discover	.539
Prototype	.934
Evaluate	.813

Reliability

Spilt-half reliability was calculated for each of the four constructs in the final CSI to look at consistency of responses over time (Gliner et al., 2009; Lynn, 1986; Vaske, 2008; Voght, 2005). Subsequently, to examine the likelihood the reliability would be underestimated due to splitting the number of responses, the Spearman-Brown coefficient (r) was calculated (Gliner et al., 2009). Table 28 displays the Spearman-Brown coefficients for each construct (r = .662). A low Spearman-Brown coefficient for Discover (.510) was marked for further investigation.

Table 28
Spearman-Brown Coefficients for Final CSI

Construct	Spearman-Brown r
Visualize	.688
Discover	.510
Prototype	.917
Evaluate	.756

Factor Analysis

A second factor analysis was conducted using the data collected from the students (*N* = 264) using principal axis factoring with varimax rotation and a Kaiser Normalization (Leech et al., 2008). Four factors were extracted to fit the model constructs of the CSI (Visualize, Discover, Prototype, and Evaluation). KMO and Bartlett's test of assumptions were satisfied; however, the determinant testing failed. The correlation matrix when examined failed for collinearity, greater than .8, among items in the Prototype construct.

The items measuring Prototype (p1, p2, p3, and p4) were removed and the factor analysis was rerun with three factors extracted to fit the remaining model of the CSI (Visualize, Discover, and Evaluation); all assumptions were met. Absolute item values ≤ .30 were suppressed; with associations and correlations ≥ .60 desirable; associations and correlations between these parameters were examined for fit with several items accepted for the three constructs following the analyses and findings of other researchers, as indicated in Table 29 (Burton & Mazerolle, 2011; Comrey & Lee, 1992; Elliott, 2013). After this analysis, three items were removed (item v2, d2, and d4) that did not load, or cross-loaded. One item (e1) loaded on a different construct (Discover) and subsequently moved to that construct with its fit determined as more appropriate. *Cronbach's α* was calculated on the construct items to examine reliability remained at an acceptable level ($\alpha > .6$; see Table 29). Items were then reordered within the construct groups for visual clarity and sequencing of item strength (Table 30). Appendix O reflects the corrected and finalized CSI survey after data collection and analysis.

Table 29
Factor Loading and Cronbach's α for Final CSI with Prototype Items Removed

Item #	Item	Factor %	Factor Group	Cronbach's α
E2	Assess project qualities	.711		
E3	Receive feedback from stakeholders	.643		
E4	Measure quality from end-user	.663	2	.820
E5	Judge level of innovation	.443		
E6	Use variety of data collection	.617		
E7	Define measures of success	.638		
V1	Convert reality to abstract	.413		
V3	Think creatively	.593		
V4	See relationships among ideas	.547	3	.670
V5	Mentally manipulate ideas	.692		
V6	Draw ideas w/o using words	.452		
D1	Acknowledge others knowledge	.633		
D3	Allow for discovery/new ideas	.498	4	.564
D5	Utilize team decision making	.338		
E1	Test and refine to gain feedback	.335		

Comparisons of Groups

The study invited an examination of differences among groups representing different disciplinary backgrounds (courses) to examine RQ2. The data collected were examined in two distinctly different ways. One-way ANOVAs were calculated to examine the overall mean of each construct across the seven courses. A one-way ANOVA was conducted to determine if there was a statistically significant difference between each of the participant courses of different disciplinary backgrounds (Laerd Statistics, 2015). Following the one ANOVA calculations, a post hoc Tukey HSD was calculated to examine whether some courses by discipline differed from the overall construct mean (Kirk, 2013; Westfall, Tobias, & Wilfinger, 2011).

Table 30
CSI Final Constructs with Items

Item #	Item name before Factor Analysis	Item #	Item name after Factor Analysis
		Visualize	
V1	Convert reality to abstract	V1	Convert reality to abstract
V2	Associate previously separate ideas	V2	Think creatively
V3	Think creatively	V3	See connections among ideas
V4	See connections among ideas	V4	Mentally manipulate ideas
V5	Mentally manipulate ideas	V5	Draw ideas w/o using words
V6	Draw ideas w/o using words		
		Discover	
D1	Acknowledge others knowledge	D1	Acknowledge others knowledge
D2	Stop and rethink problem/project	D2	Allow for discovery/new ideas
D3	Allow for discovery/new ideas	D3	Utilize team decision making
D4	Use convergent thinking	D4	Test and refine for feedback
D5	Utilize team decision making		
		Prototype	
P1	Explore feasibility of mock-up	P1	Explore feasibility of mock-up
P2	Create mock-ups	P2	Create mock-ups
P3	Discover end use of mock-up	P3	Discover end use of mock-up
P4	Judge impact of design concept	P4	Judge impact of design concept
		Evaluate	
E1	Test and refine for feedback	E1	Assess project qualities
E2	Assess project qualities	E2	Receive external feedback
E3	Receive external feedback	E3	Measure quality from end-user
E4	Measure quality from end-user	E4	Judge level of innovation
E5	Judge level of innovation	E5	Use variety of data collection
E6	Use variety of data collection	E6	Define measures of success
E7	Define measures of success		

Second, courses were combined into two groups, those with a studio component versus courses without. A one-way ANOVA was then conducted to examine the means (*M*) of these two groups (Laerd Statistics, 2015).

In reporting and interpreting the one-way ANOVA, the data are presented in three different ways. First, results of the one-way ANOVA are presented for each construct; second, the means and stand deviations are examined; and third, the mean difference in terms of statistical significance (*p* value) is assessed, and effect size (Cohen’s d) examined (Sullivan and

Feinn, 2012); the general strength of effect size was reported using descriptions: *much larger than typical* > 1.00, *larger than typical* > .90, *large* >.80, *medium* > .60 (Gliner et al., 2009).

One-Way ANOVA

A one-way ANOVA was conducted to determine if the means of the composite scores for each construct differed among the courses: INTD376 (n = 22), ART350 (n = 19), MKT410 (n = 60), AM250 (n = 98), ENGR507 (n = 6), CS480 (n = 13), and AM270 (n = 46).

A statistically significant difference ($p < .05$) was found for Visualize ($F(6, 253) = 5.330$, $p < .001$), Prototype ($F(6, 236) = 2.987$, $p = .008$), and Evaluate ($F(6, 255) = 2.155$, $p = .048$). A statistical significance was not found for Discover ($F(6, 256) = 1.829$, $p = .094$ (Table 31).

Table 31
One-Way Analysis of Variance (ANOVA) for Visualize, Prototype and Evaluation Constructs by Courses

Source	*df*	SS	MS	*F*	*p*
Visualize					
Between Groups	6	379.888	63.315	5.330	.001
Within Groups	253	3005.415	11.879		
Total	259	3385.304			
Prototype					
Between Groups	6	427.480	71.247	2.987	.008
Within Groups	236	5629.565	23.854		
Total	242	6057.045			
Evaluate					
Between Groups	6	352.170	58.695	2.155	.048
Within Groups	255	6946.597	27.242		
Total	261	7298.767			

Means and standard deviations for each course were examined (Table 32:

- Means and standard deviations for Visualize among each course were INTD376 (M = 23.7, SD = 3.0), ART350 (M = 22.8, SD = 2.9), MKT410 (M = 19.9, SD = 3.4), AM250

(M = 20.3, SD = 3.5), ENGR507 (M = 21.3, SD = 3.1), CS480 (M = 19.8, SD = 3.5), and AM270 (M = 21.7, SD = 3.8); the maximum composite value was 30.

- Means and standard deviations for Prototype among each course were INTD376 (M = 15.7, SD = 4.7), ART350 (M = 15.8, SD = 24.2), MKT410 (M = 11.6, SD = 4.4), AM250 (M = 12.3, SD = 5.6), ENGR507 (M = 14.0, SD = 4.9), CS480 (M = 13.2, SD = 5.3), and AM270 (M = 12.8, SD = 4.9); the maximum composite value was 24.
- Means and standard deviations for Evaluate among each course were INTD376 (M = 26.0, SD = 4.0), ART350 (M = 23.3, SD = 6.3), MKT410 (M = 23.2, SD = 4.3), AM250 (M = 23.5, SD = 5.8), ENGR507 (M = 26.3, SD = 2.8), CS480 (M = 20.2, SD = 5.4), and AM270 (M = 24.3, SD = 5.4); the maximum composite value was 36.

The next step in the analysis was to conduct Post hoc Tukey HSD tests (Tables 33-35) for each construct[1] to account for differences in sample sizes. Effect sizes for *d* were calculated[2] to indicate the strength of relationship between and within groups for each construct and were reported as: *much larger than typical* > 1.00, *larger than typical* > .90, *large* >.80, *medium* > .60[3].

Visualize:

- A statistical difference ($p < .05$) was found among some courses for Visualize. Specifically, for INTD376 and MKT410 with a much larger than typical effect size (p = .001, d = 1.14); INTD376 and AM250 with a larger than typical effect size (p = .001, d = .99); and INTD376 and CS480 with a much larger than typical effect size (p = .027, d = 1.22).

[1] Sample sizes for the seven courses varied from n = 6 to n = 96.
[2] Effect sizes for Cohen's *d* is determined by calculating the mean difference between two groups, and then dividing the result by the pooled standard deviation.
[3] Effect size only reported for $p \leq .01$ and $\geq .05$.

- A statistical difference was found for ART350 and MKT410 with a larger than typical effect size (p = .001, d = .91). No other courses were different, statistically, for Visualize (Table 33).

Prototype:

- A significant statistical difference (p < .05) was for INTD376 and MKT410, with a larger than typical effect size (p = .023, d = .91), and ART350 and MKT410 with a larger than typical effect size (p = .038, d = .95).
- No other courses were statistically significant for this construct (Table 34).

Evaluate:

- A statistically significant difference (p < .05) was found among some. Specifically, INTD376 and CS480, with a much larger than typical effect size (p = .028, d = 1.26).
- No other courses were statistically significant for the evaluate construct (Table 35).

Table 32
Means and Standard Deviations for the Seven Course Groups for the Visualize, Prototype, and Evaluation Constructs

	Construct								
	Visualize			Prototype			Evaluate		
Course	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
AM250	96	20.3	3.5	93	12.3	5.6	98	23.5	5.8
AM270	46	21.7	3.8	44	12.8	4.9	45	24.3	5.4
ART350	18	22.8	2.9	17	15.8	4.2	19	23.3	6.3
CS480	12	19.8	3.5	13	13.2	5.3	13	20.2	5.4
ENGR507	6	21.3	3.1	5	14.0	4.9	6	26.3	2.8
INTD376	22	23.7	3.0	21	15.7	4.7	21	26.0	4.0
MKT410	60	19.9	3.4	50	11.6	4.4	60	23.2	4.3
Total	260	20.9	3.6	243	12.9	5.0	262	23.7	5.3

Table 33
Comparisons of Composite Scores for Post Hoc Tukey HSD for VISUALIZE

Course Number	Course Number	Mean Difference	Significance	Effect Size
INTD376	ART350	.793	.991	––
	MKT41	3.798*	.001	Much larger than typical
	AM250	3.359*	.001	Larger than typical
	ENGR507	2.348	.757	––
	CS480	3.932*	.027	Much larger than typical
	AM270	2.008	.274	––
ART350	INTD376	-.793	.991	––
	MKT410	3.006*	.022	Larger than typical
	AM250	2.566	.061	Medium
	ENGR507	1.556	.962	––
	CS480	3.139	.185	––
	AM270	1.215	.866	––
MKT410	INTD376	-3.798*	.001	Much larger than typical
	ART350	-3.006*	.022	Larger than typical
	AM250	-.440	.987	––
	ENGR507	-1.450	.957	––
	CS480	.133	1.000	––
	AM270	-1.791	.115	––
AM250	INTD376	-3.359*	.001	Larger than typical
	ART350	-2.566	.061	Medium
	MKT410	.440	.987	––
	ENGR507	-1.010	.993	––
	CS480	.573	.998	––
	AM270	-1.351	.307	––
ENGR507	INTD376	-2.348	.757	––
	ART350	-1.556	.962	––
	MKT410	1.450	.957	––
	AM250	1.010	.993	––
	CS480	1.583	.969	––
	AM270	-.341	1.000	––
CS480	INTD376	-3.932*	.027	Much larger than typical
	ART350	-3.139	.185	––
	MKT410	-.133	1.000	––
	AM250	-.573	.998	––
	ENGR507	-1.583	.969	––
	AM270	-1.924	.602	––
AM270	INTD376	-2.008	.274	––
	ART350	-1.215	.866	––
	MKT410	1.791	.115	––
	AM250	1.351	.307	––
	ENGR507	.341	1.000	––
	CS480	1.924	.602	––

*p = .05

Table 34
Comparisons of Composite Scores for Post Hoc Tukey HSD on PROTOTYPE

Course Number	Course Number	Mean Difference	Significance	Effect Size
INTD376	ART350	-.098	1.000	––
	MKT410	4.107*	.023	Larger than typical
	AM250	3.333	.075	Medium
	ENGR507	1.667	.993	––
	CS480	2.436	.794	––
	AM270	2.848	.300	––
ART350	INTD376	.098	1.000	––
	MKT410	4.205*	.038	Larger than typical
	AM250	3.431	.112	––
	ENGR507	1.765	.992	––
	CS480	2.534	.797	––
	AM270	2.947	.349	––
MKT410	INTD376	-4.107*	.023	Larger than typical
	ART350	-4.205*	.038	Larger than typical
	AM250	-.773	.972	––
	ENGR507	-2.440	.938	––
	CS480	-1.671	.928	––
	AM270	-1.258	.875	––
AM250	INTD376	-3.333	.075	Medium
	ART350	-3.431	.112	––
	MKT410	.773	.972	––
	ENGR507	-1.667	.990	––
	CS480	-.897	.996	––
	AM270	-.485	.998	––
ENGR507	INTD376	-1.667	.993	––
	ART350	-1.765	.992	––
	MKT410	2.440	.938	––
	AM250	1.667	.990	––
	CS480	.769	1.000	––
	AM270	1.182	.999	––
CS480	INTD376	-2.436	.79	––
	ART350	-2.534	.797	––
	MKT410	1.67	.928	––
	AM250	.897	.996	––
	ENGR507	-.769	1.000	––
	AM270	.413	1.000	––
AM270	INTD376	-2.848	.300	––
	ART350	-2.947	.349	––
	MKT410	1.258	.875	––
	AM250	.485	.998	––
	ENGR507	-1.182	.999	––
	CS480	-.413	1.000	––

*p = .05

Table 35
Comparisons of Composite Scores for Post Hoc Tukey HSD on EVALUATE

Course Number	Course Number	Mean Difference	Significance	Effect Size
INTD376	ART350	2.737	.646	––
	MKT41	2.783	.354	––
	AM250	2.480	.433	––
	ENGR507	-.333	1.000	––
	CS480	5.846*	.028	Much Larger than typical
	AM270	1.711	.878	––
ART350	INTD376	-2.737	.646	––
	MKT410	.046	1.000	––
	AM250	-.257	1.000	––
	ENGR507	-3.070	.871	––
	CS480	3.109	.647	––
	AM270	-1.026	.991	––
MKT410	INTD376	-2.783	.354	––
	ART350	-.046	1.000	––
	AM250	-.304	1.000	––
	ENGR507	-3.117	.804	––
	CS480	3.063	.470	––
	AM270	-1.072	.944	––
AM250	INTD376	-2.480	.433	––
	ART350	.257	1.000	––
	MKT410	.304	1.000	––
	ENGR507	-2.813	.860	––
	CS480	3.367	.307	––
	AM270	-.768	.983	––
ENGR507	INTD376	.333	1.000	––
	ART350	3.070	.871	––
	MKT410	3.117	.804	––
	AM250	2.813	.860	––
	CS480	6.179	.203	––
	AM270	2.044	.972	––
CS480	INTD376	-5.846*	.028	Much Larger than typical
	ART350	-3.109	.647	––
	MKT410	-3.063	.470	––
	AM250	-3.367	.307	––
	ENGR507	-6.179	.203	––
	AM270	-4.135	.158	––
AM270	INTD376	-1.711	.878	––
	ART350	1.026	.991	––
	MKT410	1.072	.944	––
	AM250	.768	.983	––
	ENGR507	-2.044	.972	––
	CS480	4.135	.158	––

*$p = .05$

One-Way ANOVA: Studio and Non-Studio Courses

To investigate differences among courses with a studio component versus courses without a studio component or delivered via lecture format, a one-way ANOVA was conducted. Courses were split into two groups; the first group included INTD376, ART350, ENGR507 (n = 47) delivered in a studio format; the second group - MKT410, AM250, AM270, CS480 (n = 217) were without the studio component (Laerd Statistics, 2015).

Between groups, a statistically significant difference ($p < .05$) was found for Visualize ($F(1, 252) = 22.829$, $p < .001$) and Prototype ($F(1, 236) = 15.651$, $p < .001$). Statistical significance was not found for Discover ($F(1, 255) = .583$, $p = .446$) or Evaluate ($F(1, 254) = 2.045$, $p = .154$; Table 36).

- Visualize: The mean and standard deviation for courses with a studio component was M = 23.3, SD = 2.9); and M = 20.4, SD = 3.5 for courses without a studio component.
- Discover: The mean and standard deviation for courses with a studio component was M = 17.8, SD = 2.7; and M = 17.4, SD = 2.6 for courses without a studio component.
- Prototype: The mean and standard deviation for courses with a studio component was M = 15.7, SD = 4.4; and M = 12.3, SD = 4.9 for courses without a studio component.
- Evaluate: The mean and standard deviation for courses with a studio component was M = 24.7, SD = 5.3; and M = 23.3, SD = 5.3 for courses without a studio component (Table 37).

Table 36
ANOVA Comparing Studio and Non-Studio Courses for Visualize, Discover, Prototype, Evaluate

Source	***df***	**SS**	**MS**	***F***	***p***
Visualize					
Between Groups	1	277.021	277.021	22.829*	.001
Within Groups	252	3057.896	12.135		
Total	253	3334.917			
Discover					
Between Groups	1	4.250	4.250	.583	.446
Within Groups	255	1859.976	7.294		
Total	256	1864.226			
Prototype					
Between Groups	1	370.344	370.344	15.651*	.001
Within Groups	236	5584.211	23.662		
Total	237	5954.555			
Evaluate					
Between Groups	1	57.608	57.608	2.045	.154
Within Groups	254	7155.951	28.173		
Total	255	7213.559			

* $p < .05$

Table 37
Means and Standard Deviations Comparing Studio and Non-Studio Courses for Visualize, Discover, Prototype, Evaluate

	Construct Name											
	Visualize			Discover			Prototype			Evaluate		
Course	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Studio	40	23.3	2.9	41	17.8	2.7	38	15.7	4.4	40	24.7	5.3
Non-Studio	214	20.4	3.5	216	17.4	2.6	200	12.3	4.9	216	23.3	5.3
Total	254	20.9	3.6	257	17.5	2.6	238	12.8	5.0	256	23.6	5.3

Before concluding the one-way ANOVA analysis, AM250 was removed from the non-studio group due to its classification as an all-university core curriculum course to control for non-major specific enrollment. Between groups, results remained the same, with a statistically significant difference ($p < .05$) found for Visualize ($F(1, 162) = 16.858$, $p < .000$) and Prototype ($F(1, 148) = 14.610$, $p < .000$), but not for Discover ($F(1, 164) = .188$, $p = .665$) or Evaluate ($F(1, 162) = 3.494$, $p = .063$). Therefore, the original studio (INTD376, ART350, ENGR507) and non-studio (MKT410, AM250, AM270, CS480) groupings remain for consideration in the study. The differentiation between studio and non-studio courses allows for studio or lab time as 2 hours for each credit hour, perhaps aiding in time spent on task, or increased student-instructor interaction, or engaging in hands-on assignments, which may have an impact on creative outcomes.

Conclusion

Ultimately, the goal of this study was to develop quantitative measures to effectively assess the creative synthesis process within the design thinking environment. Through a six-step process with three phases, the Creative Synthesis Inventory (CSI) measures have been tested and refined through a process of re-evaluation at each phase.

In Phase I, factors and attributes were identified for four constructs typically ascribed to the design thinking process through a review of literature and conversations with leading industry expert researchers. Item development incorporated review by five research experts to create the first version of the CSI. During Phase II, a 41-item pre-test (pilot) was given to 74 participants. Revisions to this pre-test instrument resulted in 30 items collapsed from a 53 item Card Sort completed by 19 industry experts.

In Phase III, the Pilot Test, which included 30 items, was administered to 265 student participants. A new construct, Discover, emerged during this phase and items were reconceptualised, rearranged, and renamed to address this new addition. Next, during instrument confirmability, a 22-item CSI was given to 264 participants. After this round of analysis, the final CSI encompassed four constructs: Visualize, Discover, Prototype, and Evaluate incorporating 19 items.

A one-way ANOVA was conducted on the seven courses (representing different disciplinary backgrounds) to determine if a statistically significant difference ($p < .05$) could be observed among participant groups. Statistically significant differences were revealed for the Visualize ($p = .001$), Prototype ($p = .008$), and Evaluate ($p = .048$) for the seven courses.

Post hoc Tukey HSD tests further revealed significant differences ($p < .05$ level) were among some courses for the Visualize, Prototype, and Evaluate constructs. Table 38 summarizes the constructs with paired courses as derived from the ANOVA, with statistically significant differences among courses of $\leq .05$.

Table 38
Summary of Statistically Significant Differences and Effect Sizes of Courses Representing Different Disciplinary Backgrounds

Construct	Course	Significance	Effect Size
Visualize	INTD376 & MKT410	.001	Much larger than typical
	INTD376 & AM250	.001	Larger than typical
	INTD376 & CS480	.027	Much larger than typical
	ART350 & MKT410	.001	Larger than typical
Prototype	INTD376 & MKT410	.023	Larger than typical
	ART350 & MKT410	.038	Larger than typical
Evaluate	INTD376 & CS480	.028	Much larger than typical

A second one-way ANOVA was conducted to determine if there were statistically significant differences between studio-based and non-studio, lecture style courses. Between groups analysis found a statistically significant difference ($p < .05$) for the Visualize ($p < .001$) and Prototype ($p < .001$) constructs. Studio-based courses had higher scores among the constructs, suggesting students' use factors and attributes belonging to both the Visualize and Prototype constructs more often than non-studio, lecture style courses. This is reflected in higher *p*-values and effect sizes (Table 38).

CHAPTER V

DISCUSSION AND CONCLUSIONS

Initiated by Lockwood's discussion of design thinking, creativity, and innovation and their effects on new business growth (2009b), this research project initially sought to quantitatively measure the contributing factors and attributes in organizations within the process of creative synthesis enabling people to produce greater innovation. Creative synthesis was defined as the process or leap of faith and intuition heading to achieve an effective and creative problem solution, incorporating creative thinking initially drawing upon imagination and visualization of a problem, joined with prototyping and evaluation to produce strategic solutions.

While models depicting the components of the design thinking process were available for examination (Borja de Mozota, 2006; Design Management Institute, 2015; Junginger, 2009; Lockwood, 2009a; Martin, 2010), pinpointing where in the process an organization might find itself (DMI, 2015), a preference by upper management for financial performance indicators impacting bottom-line performance underscores the need for quantitative measures to effectively compare performance (Design Management Institute, 2015; Rae, 2016).

Personal conversations with industry experts followed an extensive search of the pertinent literature and failed to locate quantitative measures for design thinking. Quantification assisting in pinpointing weaknesses, or strengths of human capital in providing innovative services or products would benefit organizations from measures allowing numeric comparisons. Therefore, the study's purpose shifted toward the development of a quantitative instrument. Further reinforcement surfaced during execution of the study; for the third year in a row, *design-*

centric organizations, versus non-design centric, received higher levels of return on investments (ROI), receiving in excess of 200% in the American Stock Market's S&P 500 (Rae, 2016).

Study Findings

Study findings encompass instrument validation, factor emergence, and differentiation among disciplines. In addition, the conceptual model is revised to reflect these findings.

Validation of the Instrument

The development of the CSI was adapted from the research process by Schmiedel, vom Brock, and Recker's (2014) and their creation of a quantitative instrument focused on business process modelling creating an economic foundation for organizations. The process for the CSI, conducted in three phases, used checkpoints and a mixed method approach to achieve acceptable reliabilities resulting in the validation of a 19 item instrument (Appendix Q). The study findings affirm the recognition of discrete factors found in the creative synthesis process, with potential to impact the organizational skills of employees when well-versed in constructs of the CSI thereby increasing the presence of design thinking in organizations.

Emergence of Discovery

In the beginning of this project, the construct of Discovery was loosely recognized in some creative problem solving design and design thinking processes (Borja de Mozota, 2006; Junginger, 2009) as an influence on innovation. However, Discovery is not recognized in business/non-design problem solving where the concept of investigating user needs is reflected within the design thinking constructs of empathy, in which the focus is learning from others. In the design process, Discovery invites evidence-based research paired with in-depth knowledge of the organization and user processes. Discovery's potential influence on innovation in design thinking outcomes has been absent (Badding, Leigh, & Williams, 2014).

During factor analysis conducted on the Pilot Test data(Phase III), this new construct emerged. Items loading as a group created the context for Discovery and addressed this previously recognized gap in the literature (Badding, Leigh, & Williams, 2014) encompassing:

- Acknowledging others' knowledge;
- Allowing for the discovery of new information and new ideas;
- Employing evidence-based research;
- Utilizing team decision making; and
- Testing and refining products after feedback.

To establish reliable and valid measures assessing the creative synthesis process within the design thinking environment, research is needed to refine and cultivate the factors and attributes attributed to Discovery (Owen, 2007). Similar to other constructs within the creative synthesis process, the idea of Discovery is intertwined with ideation, prototyping, and evaluation making it difficult to clearly extract the construct, and its factors and attributes from the literature. The impact potential of Discovery on critical thinking is obvious when investigating unmet needs of users in organizations seeking to increase effectiveness (Csikszentmihalyi, 1996; IDEO, 2015; Malinin, Williams, & Leigh, 2016; Schön, 1983).

Tools do exist to help organizations increase feedback, think critically and creatively, subsequently increasing effectiveness in performance. Activity maps (Curedale, 2016, p. 184), benchmarking (p. 191), and ideation decision maps (p. 217) are examples of tools to aid organizations during Discovery in the creative synthesis process (Curedale, 2016). The economic perspective presented by Cohen and Levinthal (1989, 1990) and Zahara and George, (2002) in the creativity research literature invited the need for greater quantitative strategy in acquiring knowledge and its economic impact.

Discovery, emerging after iterations of data analysis reinforced its presence in the creative synthesis process within the design thinking environment. For example, Method Cards used by a financial investment's innovation lab and derived from the Stanford d.school's BootlegMethod Card v1.0 (Institute of Design at Stanford, 2015) at best indirectly embraces Discovery, within the Ideate step. And as Archer (1979) suggests the process can be handicapped by limiting knowledge acquisition.

The study's conceptual model (Figure 16) was revised to reflect the findings of this study. First, Imagination and Visualization were combined into one construct during factor analysis. The presence of Discovery also emerged presenting itself as a new construct. Both of these changes are represented on the left side of the model. The remaining constructs, Prototype and Evaluate, were confirmed during the final phase of analysis and remained the same. Abstract ideas and concrete objects are acknowledged in the conceptual model by the dashed lines between the constructs. The fluidity of thinking and doing within the Creative Synthesis process is represented as the solid arrows within the constructs (Figure 21).

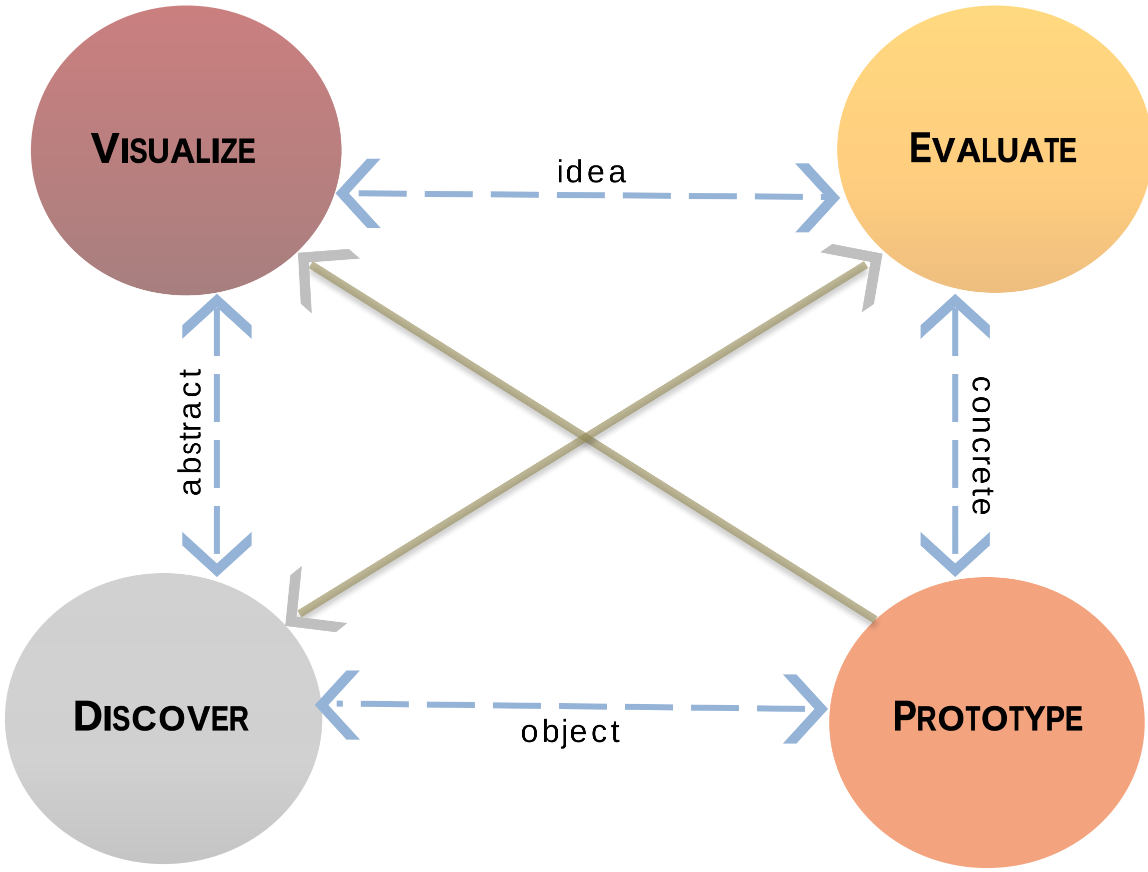

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Figure 21. The model of the creative synthesis process within the design thinking environment.

Differentiation by Discipline

As the statistical analyses concluded, the researchers further investigated the data using two approaches to investigate difference among disciplines using course format/delivery as a delineator. First, using the composite scores for each of the four constructs, all seven courses were examined through a single factor ANOVA for statistically significant differences. While Discover showed no difference, statistical significant was found in only course pairs for Visualize, Prototype, and Evaluate. Of note the pairs appeared to reflect opposite course delivery/instructional formats with those offering studio and those with non-studio lecture-based raising the question of differences based on amount of time spent in the classroom; studio-based courses may also foster more frequent use of factors found in the design thinking environment due to longer periods of class meeting time, increased time ratio of student to instructor, and potentially smaller course enrollments (Table 39).

Table 39
Statistically Significant Differences among Courses

	Courses	
Construct	Studio Delivery	Non-Studio Delivery
Visualize	INTD376	MKT410* CS480** AM250*
	ART350	MKT410**
Discover	--	--
Prototype	INTD376 ART350	MKT410** MKT410**
Evaluate	INTD376	CS480**

* *p = .001, ** p = .05*

Next, individual course responses were analyzed (single factor ANOVA) by dividing courses by course delivery/instructional approach (studio component versus courses without a studio component). Findings suggested no differences in Discovery and Evaluate but statistical significance were found for Visualize and Prototype among courses.

Significance of the Study

Organizations seeking to increase their design thinking environments to foster creativity and innovation to grow (Martin, 2013), but with no tools to quantitatively measure their progress, the outcome of this study is timely. The development of an instrument capable of measuring the creative synthesis process within a design thinking environment closes the gap for organizations and industry experts looking for a valid and reliable quantitative tool. The CSI was intended to enable organizations and consultants to reliably identify the degree and location of specific factors and attributes to constructs within the creative synthesis process. Although tested among university students, the future of the CSI would engage organizational participants for further testing of the CSI so that it may reliably be utilized at the individual, group, or organizational level. The CSI would ultimately link specific activities and/or actions to the measures to assist in aligning the training needs of organization pinpointing viable actions.

A number of other outcomes emerged from this study:

a) Discovery emerged as a new construct and was confirmed as an important component to the creative synthesis process. This new construct provides evidence to lingering questions of its existence in the design thinking environment.

b) A new model of the creative synthesis process was developed and depicts the dichotomies in the design thinking environment between thinking and doing, abstract and concrete, and idea and object.

c) The importance of feedback opportunities in learning was also brought into focus with the application of design thinking in solving complex problems where there may be multiple disciplinary perspectives necessary to solve societal, multi-faceted problems.

d) The creative synthesis process presents a way to approach complex, or *wicked,* problems within the design thinking environment. Wicked problems were conceptualized by Horst Rittel in the 1960s as an explanation for the multifaceted nature of finding problem solutions in the social professions. Rittel argued the *cognitive style* of science and the *occupational style* of engineering were inadequate in satisfying the needs of problems presented in the social sciences. The types of problems inherent in societal (i.e., planning) challenges were not clear, lacking foreseen or distinct end goals. He further found identifying the problem as the same as finding the solution - “the problem [cannot] be defined until the solution has been found” (Rittel & Webber, 1973, p. 160). Lockwood (2009a) suggested design thinking be directed at solving wicked problems or problems too complex to be approached in a simple manner because design “has no special subject matter of its own apart from what a designer conceives it to be” (Buchanan, 1992, p. 16).

Wicked problems solved within the design thinking environment promote long-term organizational survival through improved performance (Martin, 2010) and creative strategy.

e) Finally, significant differences appeared in the two course delivery/instructional approach formats (studio versus non-studio courses) suggesting further investigation of the utilization of factors and attributes found in the design thinking environment when working through a problem or a project or other demonstrated problem solving outcome in studio and non-studio based courses.

Higher usage of factors and attributes related specifically to the Visualize and Prototype constructs in studio courses are consistent with other research findings that suggest making tangible products aid people in finding creative outcomes when working through a project or problem (Plattner, Meinel, & Leifer, 2016; Royalty & Roth, 2016). These findings may also suggest that if an individual (i.e., consultant, professor, industry expert) is aiming to increase the creative ability of those they are working with, they should do so by utilizing a problem solving or project based tasks achievable through the creation of a solution that is tangible (i.e., ask participants to solve a problem by making something). Royalty and Roth (2016) further support this idea by finding that people seeking to increase their creative skills illustrate greater creative capacity after undertaking creative training. These people were also more likely to use and communicate the factors of design thinking to their peers, transferring knowledge of design thinking processes through informal means. In addition, Smith (2005) studied whether students could be trained to be creative, finding training improves what creativity.

Study Limitations

This study attempted to develop a measure for the creative synthesis process in distinctive way using the context of the design thinking environment, not found in the empirical literature. Thus, as an exploratory study, certain inherent limitations must be addressed.

The Discover construct that emerged during Phase III was not a part of Phases I and II. Therefore, this construct may require further exploration and analysis to its reliability and validity of items.

Collecting demographic information would have reinforced more robust testing and analysis among the participants/respondents. Demographic information (e.g., age, gender, and years in academic discipline) might have aided in further pinpointing strengths and weaknesses among groups to better understand significant differences and similarities.

Participants sampled during the pre-test, pilot-test, and instrument confirmability were university students, and to the best of the researcher's knowledge, not employed full-time in an organization at the time of sampling. The CSI was developed for potential use in organizations; participation by individuals in the workforce may indicate different findings, as well as be impacted by their longevity in the workforce.

Finally, the categorization of course delivery/instructional approach was determined by course descriptions, and in the future a closer look at assignments and projects might be included to determine construct presence.

Recommendations for Future Research

The entire CSI should be retested and examined for reliability and validity to measure construct growth and refinement with business organizations. Organizations would desirably include private, public, and government entities. Further, strategies engaging activities and tasks of groups in the organization would also be linked to factors and constructs. Conducting a study in the workplace, with organizations encompassing diverse industries, employing diverse disciplines, and engaged in diverse work would allow for applied testing of the CSI in numerous ways to highlight different components of the business process model impacted by design thinking.

The Discover construct offers an opportunity for expanded examination of meaning and application to confirm greater reliability, working with industry experts to revisit and refine the construct. This factor has not been a component of prior research, therefore, using qualitative methods such as the Card Sort activity would benefit the refinement of this construct.

New research emerged fostering the process of creativity and encompassing additional factors (e.g., individual creative confidence) foundational to the success of design thinking in organizations (Plattner, Meinel, & Leifer, 2016).

Constructs and/or questions which are proprietary from the research conducted by Schmiedgen, Spille, Koppen, Rhinow, and Meinel (2016) could be translated and potentially compared with constructs of the CSI to facilitate, strengthen, and produce more well-rounded and inclusive quantitative measures (Elliot, 2013).

Simply stated, use of the CSI administered over time will be needed to validate the importance of design-led organizations cementing design thinking’s inclusion in business processes (Design Management Institute, 2015; Lockwood, 2009b). Tailored with additional measures to each organizations specific product or services, the CSI can become part of an annual performance productivity review.

Conclusion

The instrument development process is complex and immensely challenging. The CSI begins the process for open-sourcing of quantitative performance measures useful to diverse organizational types. The methodology used here required a mixed method approach with multiple phases of data collection, testing, and analysis, incorporating findings from the creativity and design thinking literature. Much of this literature is opaque in part due to the diversity of design thinking's application as well as the language used in different industries. The development of both a reliable and valid scale required the cooperation of dozens of professional and industry experts and the time of over 600 student participants/respondents to make this endeavor come to fruition.

This research project required considerable structure, boundaries, and clear definitions of how creativity and design thinking are viewed and used, with an understanding there are many other ways to view concepts with which the researcher worked.

Despite one of four constructs potentially requiring more work to improve internal structure over time, this project was a success. As design thinking continues to take a more mature and strategic position in organizations of all types, the development of a quantitative measure capable of capturing the creative synthesis process within design thinking environments could not be more timely as organizations are challenged to increase creative capacities to outperform competitors. My aspirations is to use the CSI in concert with qualitative design thinking models to provide organizations with a comprehensive strategy in seeking to implement, grow, and/or refine creativity and innovation in their organization.

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APPENDIX A: IRB APPROVAL LETTER

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 eprotocol
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	July 27, 2016	
TO:	Leigh, Katharine	
	Kamberelis, George, Gloeckner, Gene, Badding, Sarah	
FROM:	Swiss, Evelyn, CSU IRB 2	
PROTOCOL TITLE:	The Creative Synthesis Inventory (CSI)	
FUNDING SOURCE:	NONE	
PROTOCOL NUMBER:	16-6484H	
APPROVAL PERIOD:	Approval Date: July 27, 2016	Expiration Date: March 18, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: The Creative Synthesis Inventory (CSI). The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu
Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu

Evelyn Swiss

Swiss, Evelyn

Approval of pilot assessment and revised email recruitment for faculty. No increase in risk is assessed with these changes.

Approval Period:	July 27, 2016 through March 18, 2017
Review Type:	EXPEDITED
IRB Number:	00000202

Page: 1

APPENDIX B: CREATIVE SYNTHESIS PRE-TEST VERSION 1A

Colorado State University

Instructions: Please complete the questions, while referencing the statement below. Please use black or blue ink to fill in the bubbles completely.

When given a new problem/project, to what extent do you	Strongly Disagree	Moderately Disagree	Mildly Disagree	Mildly Agree	Moderately Agree	Strongly Agree
	1	2	3	4	5	6
Combine existing but discrete ideas.	O	O	O	O	O	O
Relate/Associate existing but discrete ideas.	O	O	O	O	O	O
Think using symbols.	O	O	O	O	O	O
Ignore the contextual environment.	O	O	O	O	O	O
Convert reality into an abstract.	O	O	O	O	O	O
	1	2	3	4	5	6
Convert the abstract into reality.	O	O	O	O	O	O
Consider the information necessary for the solution.	O	O	O	O	O	O
Recognize the gap between the known and unknown.	O	O	O	O	O	O
Acknowledge others' diverse knowledge for potential use in solution.	O	O	O	O	O	O
Acknowledge inter-play between whole project and the details of the project.	O	O	O	O	O	O
	1	2	3	4	5	6
Invoke your perspective to identify your entry point (or starting point).	O	O	O	O	O	O
Stop and rethink the problem (project) before expressing your solution.	O	O	O	O	O	O
Allow yourself to be open to the discovery of new ideas.	O	O	O	O	O	O
Use your imagination.	O	O	O	O	O	O
See relationships among your ideas.	O	O	O	O	O	O
	1	2	3	4	5	6
Mentally manipulate ideas into new combinations.	O	O	O	O	O	O
Express ideas without words and numbers.	O	O	O	O	O	O
Visualize ways to utilize and integrate your ideas.	O	O	O	O	O	O
Use tools to visually share your ideas, thoughts, and processes (e.g. matrixes, post-it notes, system mapping).	O	O	O	O	O	O
Use divergent thinking (i.e. expand your ideas).	O	O	O	O	O	O
	1	2	3	4	5	6
Use convergent thinking (i.e. narrow your focus and ideas).	O	O	O	O	O	O
Consider project objectives.	O	O	O	O	O	O
Use ideation and visualization to create a prototype.	O	O	O	O	O	O
Tested and refine your objects to gain feedback and learn quickly.	O	O	O	O	O	O
Increase and deepen understanding of end user through engagement or observation.	O	O	O	O	O	O
	1	2	3	4	5	6
Identify unintended consequences through the use of a prototype.	O	O	O	O	O	O
Identify future success through the use of a prototype.	O	O	O	O	O	O
Explore desired outcome of your prototype.	O	O	O	O	O	O
Explore plausibility of your prototype.	O	O	O	O	O	O
Utilize the prototype to spark conversation to gain feedback.	O	O	O	O	O	O

V. 1a April 2015

When given a new problem/project, to what extent do you	Strongly Disagree	Moderately Disagree	Mildly Disagree	Mildly Agree	Moderately Agree	Strongly Agree
	1	2	3	4	5	6
Create mock-ups.	O	O	O	O	O	O
Evaluate the feasibility of scaling.	O	O	O	O	O	O
Judge the design concept.	O	O	O	O	O	O
Utilize team decision-making.	O	O	O	O	O	O
Assess project qualities (i.e. market potential, alignment to strategic goals, competitive advantage).	O	O	O	O	O	O
	1	2	3	4	5	6
Receive feedback from users within the team.	O	O	O	O	O	O
Receive feedback from external stakeholders/clients.	O	O	O	O	O	O
Measure quality from end user perspective, seeking to understand usefulness: value intention, perception, ease of use, and universal application.	O	O	O	O	O	O
Judge the level of innovation.	O	O	O	O	O	O
Use a variety of data collection approaches to seek information from end-user.	O	O	O	O	O	O
Define measures of success.	O	O	O	O	O	O

APPENDIX C: CREATIVE SYNTHESIS PRE-TEST VERSION 1B

Colorado State University

Instructions: Please complete the questions, while referencing the statement below. Please use black or blue ink to fill in the bubbles completely.

When given a new problem/project, to what extent do you	Strongly Disagree	Moderately Disagree	Mildly Disagree	Mildly Agree	Moderately Agree	Strongly Agree
	1	2	3	4	5	6
Convert the abstract into reality.	O	O	O	O	O	O
Identify future success through the use of a prototype.	O	O	O	O	O	O
Use divergent thinking (i.e. expand your ideas).	O	O	O	O	O	O
Use your imagination.	O	O	O	O	O	O
Create mock-ups.	O	O	O	O	O	O
	1	2	3	4	5	6
Think using symbols.	O	O	O	O	O	O
Utilize the prototype to spark conversation to gain feedback.	O	O	O	O	O	O
Receive feedback from users within the team.	O	O	O	O	O	O
Acknowledge others' diverse knowledge for potential use in solution.	O	O	O	O	O	O
Allow yourself to be open to the discovery of new ideas.	O	O	O	O	O	O
	1	2	3	4	5	6
Recognize the gap between the known and unknown.	O	O	O	O	O	O
Measure quality from end user perspective, seeking to understand usefulness: value intention, perception, ease of use, and universal application.	O	O	O	O	O	O
Define measures of success.	O	O	O	O	O	O
Ignore the contextual environment.	O	O	O	O	O	O
Combine existing but discrete ideas.	O	O	O	O	O	O
	1	2	3	4	5	6
Use convergent thinking (i.e. narrow your focus and ideas).	O	O	O	O	O	O
Explore plausibility of your prototype.	O	O	O	O	O	O
See relationships among your ideas.	O	O	O	O	O	O
Convert reality into an abstract.	O	O	O	O	O	O
Utilize team decision-making.	O	O	O	O	O	O
	1	2	3	4	5	6
Judge the design concept.	O	O	O	O	O	O
Increase and deepen understanding of end user through engagement or observation.	O	O	O	O	O	O
Consider project objectives.	O	O	O	O	O	O
Use a variety of data collection approaches to seek information from end-user.	O	O	O	O	O	O
Identify unintended consequences through the use of a prototype.	O	O	O	O	O	O
	1	2	3	4	5	6
Assess project qualities (i.e. market potential, alignment to strategic goals, competitive advantage).	O	O	O	O	O	O
Explore desired outcome of your prototype.	O	O	O	O	O	O
Evaluate the feasibility of scaling.	O	O	O	O	O	O
Mentally manipulate ideas into new combinations.	O	O	O	O	O	O

V. 1b April 2015

When given a new problem/project, to what extent do you	Strongly Disagree 1	Moderately Disagree 2	Mildly Disagree 3	Mildly Agree 4	Moderately Agree 5	Strongly Agree 6
Acknowledge inter-play between whole project and the details of the project.	O	O	O	O	O	O
Use ideation and visualization to create a prototype.	O	O	O	O	O	O
Visualize ways to utilize and integrate your ideas.	O	O	O	O	O	O
Relate/Associate existing but discrete ideas.	O	O	O	O	O	O
Stop and rethink the problem (project) before expressing your solution.	O	O	O	O	O	O
Tested and refine your objects to gain feedback and learn quickly.	O	O	O	O	O	O
	1	2	3	4	5	6
Consider the information necessary for the solution.	O	O	O	O	O	O
Use tools to visually share your ideas, thoughts, and processes (e.g. matrixes, post-it notes, system mapping).	O	O	O	O	O	O
Receive feedback from external stakeholders/clients.	O	O	O	O	O	O
Express ideas without words and numbers.	O	O	O	O	O	O
Judge the level of innovation.	O	O	O	O	O	O
Invoke your perspective to identify your entry point (or starting point).	O	O	O	O	O	O

 V. 1b April 2015

APPENDIX D: EMAIL INVITATION FOR CARD SORT

Dear Participant,

My name is Sarah Badding and I am a researcher from Colorado State University in the School of Education. We are conducting a research study examining the attributes surrounding design thinking within the organizational environment. The title of our project is The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking. The Principal Investigator is Gene Gloeckner, Ph.D., School of Education and the Co-Principal Investigators are Katharine E. Leigh, Ph.D., Department of Design and Merchandising, and myself.

We would like you to participate in a card sorting exercise, to help assist in the content validity process of constructing quantitative measures for the creative synthesis process. You have been chosen as an expert reviewer because of your experience and knowledge in creativity and design thinking, and your input is invaluable to us.

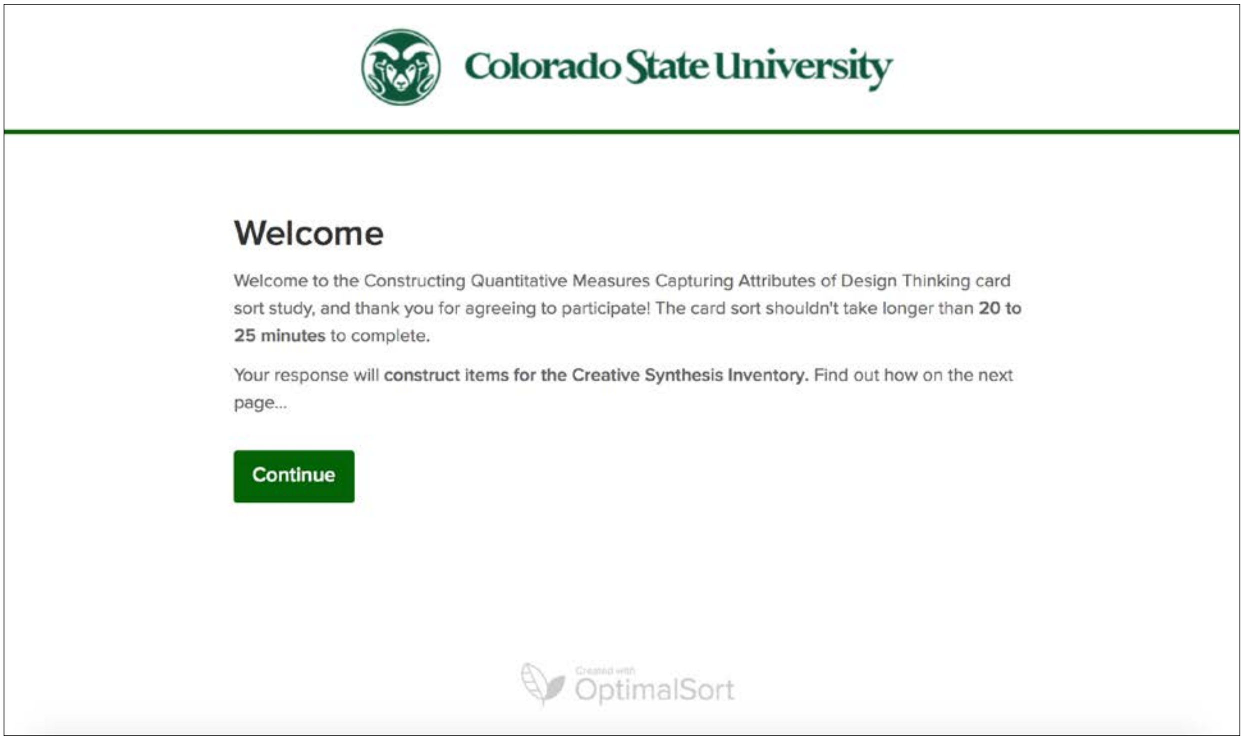
If you would like to participate please go to: https://CSI.optimalworkshop.com/optimalsort/attributesofdt

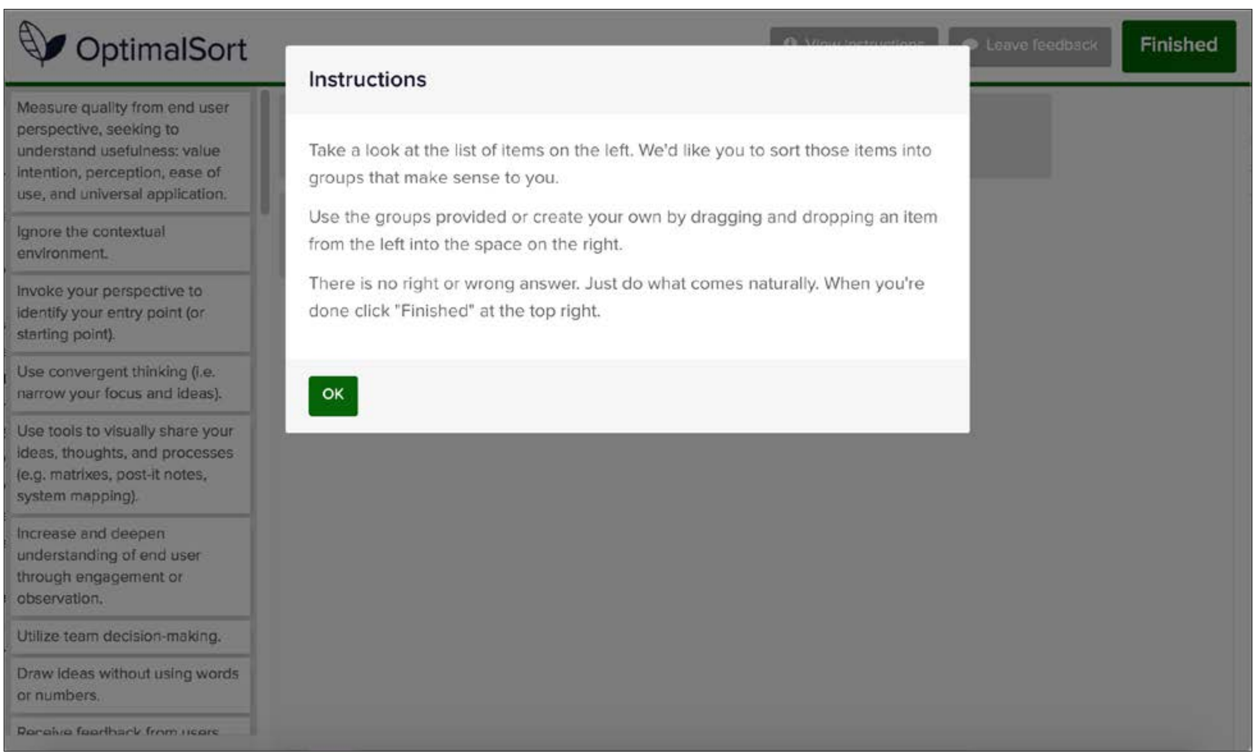
If you would like to participate or have any questions, please reply to this email informing me of your willingness to do so. Your acceptance of this invitation will serve as your consent to participate. Additionally, you may reach me at 720.466.9421 or at 970.491.7293. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970.491.1553.

Sincerely,

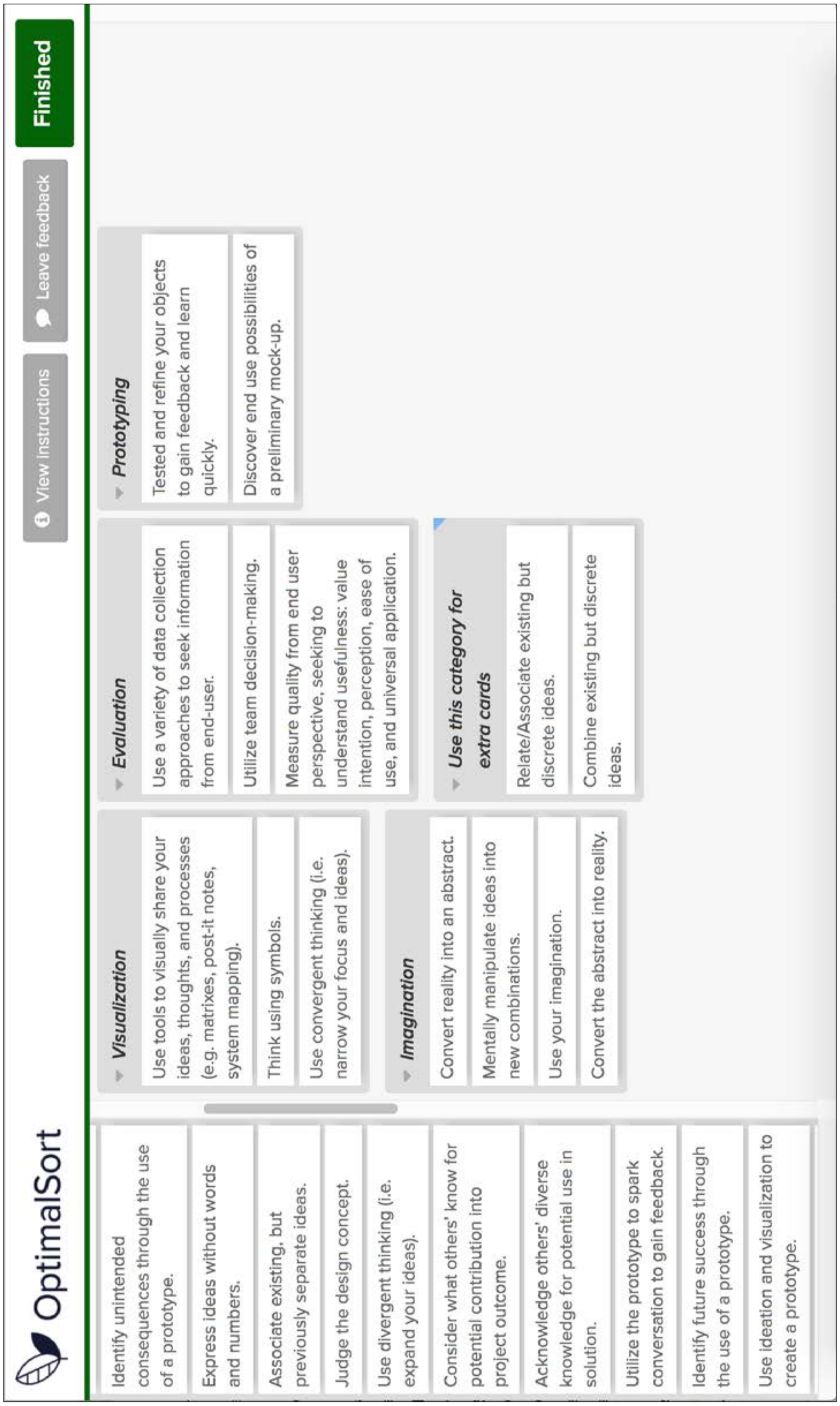
Sarah Badding, Ph.D. Candidate
Co-Principal Investigator
(720) 466.9421
Sarah.Badding@colostate.edu

APPENDIX E: CARD SORT WELCOME AND INSTRUCTIONS





APPENDIX F: PARTICIPANT VIEW OF CARD SORT ACTIVITY



APPENDIX G: NUMBER OF EXPERTS (N=19) PER ITEM BY CONSTRUCT CONVERTED TO % OF *N* FOR CARD SORT ACTIVITY

Item #	Question	Imagination	Visualization	Prototyping	Evaluation	Removed/Misc Sorted Cards
1	Combine ideas	42.11	36.84	5.26	0	5.26
2	Relate ideas	42.11	21.05	5.26	26.32	5.26
3	Symbols	31.38	63.16	0	0	5.26
4	Ignore environment	68.42	10.53	0	0	21.05
5	Reality to abstract	68.42	15.79	5.26	0	10.53
6	Abstract to reality	15.79	26.32	47.37	0	10.53
7	Information for solution	5.26	21.05	15.79	26.32	31.58
8	Gap in known and unknown	31.58	10.53	5.26	31.58	21.05
9	Others knowledge	36.84	0	10.53	10.53	42.11
10	Project whole and detail	10.53	36.84	5.26	31.58	15.79
11	Perspective to find entry point	10.53	31.58	15.79	5.26	36.84
12	Think solution	21.05	31.58	5.26	26.32	15.79
13	Discovery of new ideas	68.42	5.26	5.26	5.26	15.79
14	Use of imagination	84.21	15.79	0	0	0
15	Relationships among ideas	31.58	57.89	0	0	10.53
16	Manipulate ideas	36.84	36.84	5.26	5.26	15.79
17	Express ideas	52.63	42.11	0	0	5.26
18	Visualize ideas	15.79	73.68	5.26	0	5.26
19	Use of tools	5.26	73.68	5.26	0	15.79
20	Divergent thinking	73.68	5.26	0	5.26	15.79
21	Convergent thinking	15.79	36.84	10.53	15.79	21.05
22	Project objectives	15.79	10.53	15.79	31.58	26.32
23	Create prototypes	10.53	15.79	68.42	0	5.26
24	Test and refine	5.26	0	57.89	21.05	15.79
25	Deepen understanding	15.79	10.53	5.26	31.58	36.84
26	Unintended consequences	10.53	0	21.05	57.89	10.53
27	Future success	5.26	5.26	57.89	21.05	10.53
28	Desired outcomes	5.26	15.79	42.11	31.58	5.26

29	Plausibility	15.79	5.26	36.84	36.84	5.26
30	Prototype to spark conversation	10.53	0	36.84	42.11	10.53
31	Create mock-ups	10.53	10.53	68.42	5.26	5.26
32	Feasibility of scaling	15.79	15.79	15.79	47.37	5.26
33	Design concept	0	0	15.79	73.68	10.53
34	Team decision making	21.05	5.26	31.58	21.05	21.05
35	Project qualities	0	0	10.53	73.68	15.79
36	Feedback from team	0	0	21.05	57.89	21.05
37	Feedback from stakeholders	5.26	0	10.53	73.68	10.53
38	Measure quality	0	0	5.26	84.21	10.53
39	Level of innovation	0	5.26	0	84.21	10.53
40	Variety of data collection	10.53	0	5.26	47.37	36.84
41	Success	0	15.79	10.53	63.16	10.53
new	No attention to environment	63.16	0	0	0	36.84
new	Acknowledge known and unknown	21.05	15.79	0	31.58	31.58
new	Associate existing/separate ideas	47.37	31.58	0	0	21.05
new	Think with pictures/figures	15.79	84.21	0	0	0
new	What others know	10.53	10.53	10.53	47.37	21.05
new	Think creativity	84.21	10.53	0	0	10.53
new	Similarities between ideas	26.32	36.84	0	21.05	10.53
new	Draw ideas	26.32	63.16	10.53	0	0
new	Narrow process	10.53	21.05	15.79	21.05	31.58
new	Create project meaning	21.05	36.84	10.53	10.53	21.05
new	Discover end use	5.26	10.53	63.16	5.26	15.79
new	Feedback from end users	0	0	15.79	68.42	15.79

APPENDIX H: PILOT SURVEY EMAIL RECRUITMENT TO PROFESSORS

Dear Professor,

I'd like to introduce myself and my dissertation research project. My name is Sarah Badding and I am a doctoral candidate in the School of Education at CSU. The title of my project is The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking. The Principal Investigator is Gene Gloeckner, Ph.D., School of Education and the Co-Principal Investigators are Katharine E. Leigh, Ph.D., Department of Design and Merchandising, and myself. This study examines the attributes surrounding the environment of design thinking, to assist organizational project and teams in identifying creative strengths and weaknesses intended to improve team/organization performance.

We would like to ask your permission for your students in one of your courses to participate in both a pilot survey and final survey gathering feedback to create and finalize this instrumentation assessing attributes of design thinking. The pilot consists of 30 questions and students' participation will take approximately 20 minutes to complete; students' participation in this survey would be voluntary. I propose to pilot test in early fall in a class you select, followed in the beginning of the spring semester with a final survey version.

If you would allow students in one of your classes to participate in the pilot and final survey, please confirm your willingness to do so by replying to this email with course number(s), number of students enrolled, class location, day and time(s) and identify a convenient meeting date, time, and place in your response.

If you have any questions you may reach me at sarah.badding@colostate.edu, 720.466.9421, or at 970.491.7293. This project protocol has been approved by CSU IRB on May 17, 2015. If you have any questions about your rights as a volunteer in this research, please contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970.491.1553.

Sincerely,

Sarah Badding, Ph.D. Candidate
Co-Principal Investigator
(720) 466.9421
Sarah.Badding@colostate.edu

APPENDIX I: SURVEY VERBAL RECRUITMENT

VERBAL RECRUITMENT SCRIPT/CONSENT

Good Morning/Afternoon. My name is Sarah Badding, and I am a Ph.D. Candidate here, at CSU, in the School of Education, also CO-PI of this research project. I am here to invite you to participate in a study investigating design thinking. The study is entitled: *The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking.*

I am working with Gene Gloeckner, PI, from the School of Education and Katharine E. Leigh, CO-PI from the department of Design and Merchandising.

Students from Liberal Arts, Engineering, and Health and Human Sciences are invited to participate in this study by completing and providing feedback to an anonymous survey of approximately 20 minutes. Your participation in this research is voluntary and you may stop participating and withdraw your consent at any time without penalty.

You will help me to better define the design thinking environment. There are no known risks associated with this survey and your survey responses will remain anonymous. Your names or email address will not be recorded on the surveys. Your responses will not be linked to personal information, and the instructor of this course will not know who participated in the study. Additionally, your decision to or to not participate has no impact on your grade.

The intent of the research study is to gather your feedback to create and finalize a survey studying attributes surrounding the design thinking environment. When we report data, data will be aggregated to maintain participant anonymity.

If you are willing to participate in the research study after reading the consent form, please sign and date the consent form before completing the survey provided. Please follow the directions detailed at the top. As a reminder, please do not include or write down any personal information on the survey sheet. Surveys will be collected in the envelope at the front of the room.

Thank you for your time and for helping the researchers to investigate the design thinking environment. We appreciate your willingness to participate.

If you have questions about the study please contact me at: 970-491-7293 or by email at sarah.badding@colostate.edu. You may also contact the faculty involved in this study. You can contact Gene Gloeckner at 970.491.766, or Katharine E. Leigh at 970.491.5042. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; or at 970.491.1553.

APPENDIX J: CSI SURVEY COVER LETTER

Colorado State University
Fort Collins, Colorado 80523
970-491-7293
FAX: 970-491-8032

Date (will be updated when dates are known)

Dear Participant,

My name is Sarah Badding, and I am a Ph.D. Candidate here, at CSU, in the School of Education, also CO-PI of this research project. You are invited to participate in a study investigating design thinking. The study is entitled: *The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking*, and you will help me to better define the design thinking environment

I am working with Gene Gloeckner, PI, from the School of Education and Katharine E. Leigh, CO-PI from the department of Design and Merchandising.

We would like you to participate in this study by completing and providing feedback to an anonymous survey. Participation will take approximately 20 minutes. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty.

There are no known risks associated with this survey and your survey responses will remain anonymous. Your names or email address will not be recorded on the surveys. Your responses will not be linked to personal information, and the instructor of this course will not know who participated in the study. Additionally, your decision to or to not participate has no impact on your grade.

If you are willing to participate in the research, please complete the survey provided. Please follow the directions detailed at the top. As a reminder, please do not include or write down any personal information on the survey sheet. Surveys will be collected in the envelope at the front of the room.

If you have questions about the study please contact me at: 970-491-7293 or by email at sarah.badding@colostate.edu. You may also contact the faculty involved in this study. You can contact Gene Gloeckner at 970.491.766, or Katharine E. Leigh at 970.491.5042. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; or at 970.491.1553.

Sincerely,

Gene Gloeckner	Katharine Leigh	Sarah Badding
Professor	Professor	PhD Candidate

APPENDIX K: CREATIVE SYNTHESIS PILOT

Creative Synthesis Inventory
assessing the design thinking environment

Colorado State University

Instructions: The statements below reference characteristics of Creative Synthesis. Don't spent a lot of time thinking about your decision, simply mark your initial choice of agreement. A space for feedback or comments for each questions is provided.

When given a new problem/project, to what extent do you…	Strongly Disagree 1	Moderately Disagree 2	Mildly Disagree 3	Mildly Agree 4	Moderately Agree 5	Strongly Agree 6
Relate/associate existing but discrete ideas. *Feedback about question:*	○	○	○	○	○	○
Ignore the contextual environment. *Feedback about question:*	○	○	○	○	○	○
Convert reality into an abstract thought or idea. *Feedback about question:*	○	○	○	○	○	○
Recognize the gap between the known and unknown. *Feedback about question:*	○	○	○	○	○	○
Acknowledge others' diverse knowledge for potential application in solution(s). *Feedback about question:*	○	○	○	○	○	○
	1	2	3	4	5	6
Stop and rethink the problem/project before expressing your solution(s). *Feedback about question:*	○	○	○	○	○	○
Allow yourself to be open to discovery of new ideas. *Feedback about question:*	○	○	○	○	○	○
Associate previously separate ideas. *Feedback about question:*	○	○	○	○	○	○
Think creatively. *Feedback about question:*	○	○	○	○	○	○
See relationships among your ideas. *Feedback about question:*	○	○	○	○	○	○
	1	2	3	4	5	6
Mentally manipulate ideas into new combinations. *Feedback about question:*	○	○	○	○	○	○
Use tools to visually share your ideas, thoughts, and processes (e.g., matrixes, post-it notes, system mapping). *Feedback about question:*	○	○	○	○	○	○
Think using symbols. *Feedback about question:*	○	○	○	○	○	○
Use convergent thinking (i.e., narrow your focus and ideas). *Feedback about question:*	○	○	○	○	○	○
Draw ideas without using words or numbers. *Feedback about question:*	○	○	○	○	○	○

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	1	2	3	4	5	6
Create project meaning and understanding. *Feedback about question:*	O	O	O	O	O	O
Utilize team decision making. *Feedback about question:*	O	O	O	O	O	O
Test and refine objects to gain feedback and learn rapidly. *Feedback about question:*	O	O	O	O	O	O
Identify future success through the use of mock-ups (a physical, to scale example). *Feedback about question:*	O	O	O	O	O	O
Explore feasibility of your mock-up(s). *Feedback about question:*	O	O	O	O	O	O

	1	2	3	4	5	6
Create mock-up(s). *Feedback about question:*	O	O	O	O	O	O
Discover end-use possibilities from preliminary mock-up(s). *Feedback about question:*	O	O	O	O	O	O
Judge the impact of the mock-up(s) to achieve design concept. *Feedback about question:*	O	O	O	O	O	O
Assess project qualities (i.e., market potential, alignment to strategic goals, competitive advantage). *Feedback about question:*	O	O	O	O	O	O
Receive internal feedback with in team. *Feedback about question:*	O	O	O	O	O	O

	1	2	3	4	5	6
Receive external feedback from stakeholders/client(s). *Feedback about question:*	O	O	O	O	O	O
Measure quality from end user perspective, seeking to understand usefulness (e.g., value intention, perception, ease of use, and universal application). *Feedback about question:*	O	O	O	O	O	O
Judge the level of innovation. *Feedback about question:*	O	O	O	O	O	O
Use a variety of data collection approaches to seek information from client and/or end-user. *Feedback about question:*	O	O	O	O	O	O
Define measures of success (e.g., project objectives, problem solutions, and return on Investment). *Feedback about question:*	O	O	O	O	O	O

Additional feedback/comments about survey:

 V. P1 2016

APPENDIX L: ROTATED COMPONENT MATRIX FOR PILOT TEST

Rotated Factor Matrix (3 Factors)

	Factor		
	1	2	3
Assess project quality	.695		
Feedback from Stakeholders	.694		
Define measures of success	.678		
Use variety of data collection	.627		
Utilize team decision making	.587		
Receive feedback from team	.563		
Assess Project Qualities	.495	.391	
Test and refine objects	.490		
Create project meaning	.474		.456
Judge level of innovation	.469		.338
Acknowledge others knowledge	.440		
Use convergent thinking	.434		
Ignore contextual environment			
Create mock-ups		.853	
Explore plausibility		.832	
Discover end use of mock-ups		.790	
Identify future success		.775	
Judge design concept	.351	.736	
Mentally manipulate ideas			.592
See relationships among ideas			.566
Think Creatively			.542
Associate existing/separate ideas			.522
Allow for discovery/new ideas	.360		.487
Convert reality to abstract			.466
Relate existing ideas			.434
Draw ideas w/o using words			.399
Gap in known and unknown	.312		.374
Stop and rethink solution			.358
Think using symbols			.308
Use of tools to share ideas			

Rotated Factor Matrix (4 Factors)

	Factor			
	1	2	3	4
Create mock-ups	.847			
Explore plausibility	.845			
Identify future success	.787			
Discover end use of mock-ups	.774			
Judge design concept	.712	.378		
Feedback from Stakeholders		.722		
Use variety of data collection		.697		
Assess project quality		.695		
Define measures of success		.618		.304
Judge level of innovation		.511	.371	
Assess project qualities	.367	.496		
Test and refine objects		.394		.303
Use convergent thinking		.334		.304
Mentally manipulate ideas			.602	
See relationships among ideas			.545	
Think creatively			.508	
Associate existing/separate ideas			.504	
Convert reality to abstract			.481	
Draw ideas w/o using words			.443	
Create project meaning		.368	.419	.345
Relate existing ideas			.397	
Gap in known and unknown			.369	
Think using symbols			.351	
Use of tools to share ideas				
Acknowledge others knowledge				.643
Utilize team decision making		.345		.584
Stop and rethink solution				.474
Allow for discovery/new ideas			.410	.462
Receive feedback from team	.306	.406		.425
Ignore contextual environment				

Rotated Factor Matrix (5 Factors)

	Factor				
	1	2	3	4	5
Explore plausibility	.850				
Create mock-ups	.845				
Identify future success	.795				
Discover end use of mock-ups	.773				
Judge design concept	.710	.365			
Feedback from Stakeholders		.729			
Assess project quality		.704			
Use variety of data collection		.697			
Define measures of success		.587		.347	
Judge level of innovation		.523	.373		
Assess project qualities	.363	.473			
Test and refine objects		.393			
See relationships among ideas			.622		
Think creatively			.578		
Mentally manipulate ideas			.557		
Associate existing/separate ideas			.552		
Allow for discovery/new ideas			.434	.420	
Relate existing ideas			.397		
Convert reality to abstract			.382		
Gap in known and unknown			.316		
Utilize team decision making		.310		.629	
Acknowledge others knowledge				.628	
Stop and rethink solution			.316	.440	
Receive feedback from team	.305	.385		.436	
Create project meaning		.327	.330	.375	.320
Use convergent thinking		.306		.326	
Ignore contextual environment					
Think using symbols					.731
Use of tools to share ideas					.456
Draw ideas w/o using words					.395

APPENDIX M: CSI SURVEY EMAIL RECRUITMENT TO PROFESSORS

Dear Professor,

Hello again! I contacted you in the Fall semester of 2016, to introduce myself and my dissertation research project. My name is Sarah Badding and I am a doctoral candidate in the School of Education at CSU. The title of my project is The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking. The Principal Investigator is Gene Gloeckner, Ph.D., School of Education and the Co-Principal Investigators are Katharine E. Leigh, Ph.D., Department of Design and Merchandising, and myself. This study examines the attributes surrounding the environment of design thinking, to assist organizational project and teams in identifying creative strengths and weaknesses intended to improve team/organization performance.

We would like to ask your permission for your students in one of your courses to participate in the final survey for my dissertation research. The survey consists of 22 questions and students' participation will take approximately 15 minutes to complete; students' participation in this survey would be voluntary.

If you would allow students in one of your classes to participate in this final survey, please confirm your willingness to do so by replying to this email with course number(s), number of students enrolled, class location, day and time(s) and identify a convenient meeting date, time, and place in your response.

If you have any questions you may reach me at sarah.badding@colostate.edu, 720.466.9421, or at 970.491.7293. This project protocol has been approved by CSU IRB on May 17, 2015. If you have any questions about your rights as a volunteer in this research, please contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970.491.1553.

Sincerely,

Sarah Badding, Ph.D. Candidate
Co-Principal Investigator
(720) 466.9421
Sarah.Badding@colostate.edu

APPENDIX N: CSI SURVEY VERBAL INVITATION TO PARTICIPATE

VERBAL RECRUITMENT SCRIPT/CONSENT

Good Morning/Afternoon. My name is Sarah Badding, and I am a Ph.D. Candidate here, at CSU, in the School of Education, also CO-PI of this research project. I am here to invite you to participate in a study investigating design thinking. The study is entitled: *The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking.*

I am working with Gene Gloeckner, PI, from the School of Education and Katharine E. Leigh, CO-PI from the department of Design and Merchandising.

Students from Liberal Arts, Engineering, and Health and Human Sciences are invited to participate in this study by completing and providing feedback to an anonymous survey of approximately 20 minutes. Your participation in this research is voluntary and you may stop participating and withdraw your consent at any time without penalty.

You will help me to better define the design thinking environment. There are no known risks associated with this survey and your survey responses will remain anonymous. Your names or email address will not be recorded on the surveys. Your responses will not be linked to personal information, and the instructor of this course will not know who participated in the study. Additionally, your decision to or to not participate has no impact on your grade.

The intent of the research study is to gather your feedback to create and finalize a survey studying attributes surrounding the design thinking environment. When we report data, data will be aggregated to maintain participant anonymity.

If you are willing to participate in the research study after reading the consent form, please sign and date the consent form before completing the survey provided. Please follow the directions detailed at the top. As a reminder, please do not include or write down any personal information on the survey sheet. Surveys will be collected in the envelope at the front of the room.

Thank you for your time and for helping the researchers to investigate the design thinking environment. We appreciate your willingness to participate.

If you have questions about the study please contact me at: 970-491-7293 or by email at sarah.badding@colostate.edu. You may also contact the faculty involved in this study. You can contact Gene Gloeckner at 970.491.766, or Katharine E. Leigh at 970.491.5042. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; or at 970.491.1553.

APPENDIX O: CSI SURVEY COVER LETTER

Colorado State University
Fort Collins, Colorado 80523
970-491-7293
FAX: 970-491-8032

Date (will be updated when dates are known)

Dear Participant,

My name is Sarah Badding, and I am a Ph.D. Candidate here, at CSU, in the School of Education, also CO-PI of this research project. You are invited to participate in a study investigating design thinking. The study is entitled: *The Creative Synthesis Inventory (CSI): Constructing Quantitative Measures Capturing Attributes of Design Thinking*, and you will help me to better define the design thinking environment

I am working with Gene Gloeckner, PI, from the School of Education and Katharine E. Leigh, CO-PI from the department of Design and Merchandising.

We would like you to participate in this study by completing an anonymous survey. Participation will take approximately 20 minutes. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty.

There are no known risks associated with this survey and your survey responses will remain anonymous. Your names or email address will not be recorded on the surveys. Your responses will not be linked to personal information, and the instructor of this course will not know who participated in the study. Additionally, your decision to or to not participate has no impact on your grade.

If you are willing to participate in the research, please complete the survey provided. Please follow the directions detailed at the top. As a reminder, please do not include or write down any personal information on the survey sheet. Surveys will be collected in the envelope at the front of the room.

If you have questions about the study please contact me at: 970-491-7293 or by email at sarah.badding@colostate.edu. You may also contact the faculty involved in this study. You can contact Gene Gloeckner at 970.491.766, or Katharine E. Leigh at 970.491.5042. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; or at 970.491.1553.

Sincerely,

Gene Gloeckner	Katharine Leigh	Sarah Badding
Professor	Professor	PhD Candidate

APPENDIX P: CREATIVE SYNTHESIS INSTRUMENT CONFIRMATION

Creative Synthesis Inventory
assessing the design thinking environment

Colorado State University

Instructions: The statements below reference characteristics of Creative Synthesis. Do not spend a lot of time thinking about your decision, simply mark your initial choice of agreement.

When given a new problem/project, to what extent do you	*Never*	*Rarely*	*Sometimes*	*Normally*	*Often*	*Always*
	1	2	3	4	5	6
Convert reality into an abstract thought or idea.	O	O	O	O	O	O
Acknowledge others' diverse knowledge for potential application in solution(s).	O	O	O	O	O	O
Stop and rethink the problem/project before expressing your solution(s).	O	O	O	O	O	O
Allow yourself to be open to discovery of new ideas.	O	O	O	O	O	O
Associate previously separate ideas.	O	O	O	O	O	O
	1	2	3	4	5	6
Think creatively.	O	O	O	O	O	O
See relationships among your ideas.	O	O	O	O	O	O
Mentally manipulate ideas into new combinations.	O	O	O	O	O	O
Use convergent thinking (i.e., narrow your focus and ideas).	O	O	O	O	O	O
Draw ideas without using words or numbers.	O	O	O	O	O	O
	1	2	3	4	5	6
Utilize team decision making.	O	O	O	O	O	O
Test and refine to gain feedback and learn rapidly.	O	O	O	O	O	O
Create mock-up(s), (e.g., a physical to scale replica or prototype created and tested before problem/project is finalized).	O	O	O	O	O	O
Explore feasibility of your mock-up(s), (e.g., a physical to scale replica or prototype).	O	O	O	O	O	O
Discover end-use possibilities from preliminary mock-up(s).	O	O	O	O	O	O
	1	2	3	4	5	6
Judge the impact of the mock-up(s) to achieve design concept.	O	O	O	O	O	O
Assess project qualities (i.e., market potential, alignment to strategic goals, competitive advantage).	O	O	O	O	O	O
Receive external feedback from stakeholders/client(s).	O	O	O	O	O	O
Measure quality from end-user perspective, seeking to understand usefulness (e.g., value intention, perception, ease of use, and universal application).	O	O	O	O	O	O
Judge the level of innovation.	O	O	O	O	O	O
	1	2	3	4	5	6
Use a variety of data collection approaches to seek information from client and/or end-user.	O	O	O	O	O	O
Define measures of success (e.g., project objectives, problem solutions, and return on investment).	O	O	O	O	O	O

APPENDIX Q: CREATIVE SYNTHESIS FINALIZED SURVEY

Creative Synthesis Inventory
assessing the design thinking environment
©Badding 2017

Instructions: The statements below reference characteristics of Creative Synthesis. Do not spend a lot of time thinking about your decision, simply mark your initial choice of agreement.

When given a new problem/project, to what extent do you...	*Never*	*Rarely*	*Sometimes*	*Normally*	*Often*	*Always*
	1	2	3	4	5	6
Convert reality into an abstract thought or idea.	O	O	O	O	O	O
See connections among your ideas.	O	O	O	O	O	O
Mentally manipulate ideas into new combinations.	O	O	O	O	O	O
Draw ideas without using words or numbers.	O	O	O	O	O	O
Think creatively.	O	O	O	O	O	O
	1	2	3	4	5	6
Acknowledge others' diverse knowledge for potential application in solution(s).	O	O	O	O	O	O
Allow yourself to be open to discovery of new ideas.	O	O	O	O	O	O
Utilize team decision-making.	O	O	O	O	O	O
Test and refine to gain feedback and learn rapidly.	O	O	O	O	O	O
Create mock-up(s), (e.g., a physical to scale replica or prototype created and tested before problem/project is finalized).	O	O	O	O	O	O
	1	2	3	4	5	6
Explore feasibility of your mock-up(s), (e.g., a physical to scale replica or prototype).	O	O	O	O	O	O
Discover end-use possibilities from preliminary mock-up(s).	O	O	O	O	O	O
Judge the impact of the mock-up(s) to achieve design concept.	O	O	O	O	O	O
Assess project qualities (i.e., market potential, alignment to strategic goals, competitive advantage).	O	O	O	O	O	O
Receive external feedback from stakeholders/client(s).	O	O	O	O	O	O
	1	2	3	4	5	6
Measure quality from end-user perspective, seeking to understand usefulness (e.g., value intention, perception, ease of use, and universal application).	O	O	O	O	O	O
Judge the level of innovation.	O	O	O	O	O	O
Use a variety of data collection approaches to seek information from client and/or end-user.	O	O	O	O	O	O
Define measures of success (e.g., project objectives, problem solutions, and return on investment).	O	O	O	O	O	O