Creativity in the Twenty First Century

Frédéric Darbellay
Zoe Moody
Todd Lubart *Editors*

Creativity, Design Thinking and Interdisciplinarity

Springer

Creativity in the Twenty First Century

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Aims and Scope

"Creativity in the Twenty-First Century Book Series" repositions "creativity" as a boundary-crossing discipline that is essential to learning and teaching, social-economic dialogues, academic discourses and cultural practices, as well as technological and digital communications. The series serves as a timely platform, bringing together like-minded scientists and researchers around the world to share their diverse perspectives on creativity and to engage in open and productive inquiries into promoting creativity for a more peaceful and harmonious world. Researchers and practitioners from all continents are invited to share their discipline-specific insights, research orientations and cultural practices, as well as to pose new questions on what creativity is, how to promote it, which directions to pursue, who should participate, and so on.

The book series is led by emerging eminent and senior scientists, researchers, and educators in the fields of creativity, psychology, the cultural sciences and education studies. They create networks of sharing and spread innovative publishing opportunities within the communities of practice. They invest considerable time and effort in deepening creativity expertise, structuring creativity programs, and organizing creativity activities for the communities of interest. The book series aims not only to "glue together" like-minded scientists (community of practice) to share benefits of creativity theorizing, research and practice, but also to encourage non-experts (community of interest) in all societies to become supporters and spokespersons of positive engagement in creative learning, teaching and dialogues.

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Contents

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Introduction: Thinking Creativity, Design and Interdisciplinarity in a Changing World

The World Changes

Creativity, *Design Thinking*, and *Interdisciplinarity*, these are three concepts that emerge in fields of study and practice apparently different but deeply complementary in the end. These three concepts come into strong resonance insofar as they seem naturally to share and convey the same spirit of openness, collaboration, and innovation. This seemingly natural link is reinforced by the spirit of our time (our *Zeitgeist*) characterized by social, intellectual, and academic conditions that are conducive to interdisciplinary communication and creativity in education, research, business, social and cultural practices. Think and act creatively, at the interface and beyond the disciplines, in an agile and insightful way of design thinking to analyze, understand, and solve complex theoretical and/or practical problems: these ways of thinking, doing, and being reflect a current trend that is clearly oriented toward openness and cross-fertilization of knowledge across multiple domains. Creativity, design thinking, and interdisciplinarity can be considered in this context as major trends of the early twenty-first century, even if they are not—and may not become—dominant in an academic, economic, and social contexts where the disciplinary order still imposes its prerogatives. Detection of these background trends makes it possible to amplify their status of *weak signals* (Ansoff, 1975). This appeal to interdisciplinarity, creativity, and design is largely noticeable in our academic, economic, and cultural environment and must be attentively and anticipatively heard and noticed. This book aims to contribute to this exercise of epistemological and strategic intelligence that shows the strength and potential of so-called weak signals but whose echoes are increasingly stronger. It is time to think about links between these trends, and renew thought and practice in a more interconnected perspective, in order to strengthen ties between communities of researchers and practitioners working in and on creativity, design, and interdisciplinarity. If this book has an originality, it is that of proposing a space of reflection that meets the expectations and questions of a large community of researchers and practitioners who work either on or with design thinking, creativity, or inter- and transdisciplinarity, or at the interface between these areas.

The values of dialogue and openness are borne by more or less para-academic organizations, such as the P21 (*The Partnership for 21st Century Learning*[1]) which promotes the 4C abbreviation (Communication, Collaboration, Critical Thinking, Creativity), four key competences to position and develop in a constantly changing learning society. In the same vein, the World Economic Forum Future of Jobs Report[2] highlights the 10 top skills that will be needed for students and workers in the digital and transdisciplinary world of tomorrow. By 2020, these competencies should include ability to solve complex problems, critical thinking, creativity, ability to coordinate with others, negotiation, cognitive flexibility, or emotional intelligence. It is a question of thinking differently, thinking in a more collaborative, creative, and interdisciplinary way, whether in academic research, teaching or with a view to professional integration into jobs of the future that are as yet unknown and to be invented. The trend is toward sound reflexivity on ways of thinking, being and doing, learning to learn with agility throughout one's life, and solving complex problems in a rapidly changing world and not simply accumulating an endless list of disciplinary knowledge.

It is not only para-academic or non-governmental institutions that are aware of these values, movements, and attitudes that move the lines between boundaries. Research funding agencies have become aware of the need to promote and develop interdisciplinary and creative research, understood as a means of advancing knowledge and accelerating scientific discoveries. Among other national, European, and international funding agencies, the US National Science Foundation (NSF)[3] promotes and supports innovative research projects that require the involvement of several disciplines while exceeding their strict limits to develop new or emerging fields. The NSF relies on a relatively consensual definition of interdisciplinarity and widely shared among the research community in interdisciplinary studies. It is thus defined in a National Academies report:

> Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (Committee on Facilitating Interdisciplinary, Research, 2005, p. 2).

Building upon interdisciplinarity, the NSF takes a step even further to strengthen collaboration, creativity, and innovation, inviting researchers to take risks and to

[1]See: http://www.p21.org: «P21, The Partnership for 21st Century Learning (formerly the Partnership for 21st Century Skills), was founded in 2002 as a coalition bringing together the business community, education leaders, and policymakers to position twenty-first century readiness at the center of US K-12 education and to kick-start a national conversation on the importance of twenty-first century skills for all students».

[2] See: http://reports.weforum.org/future-of-jobs-2016/.

[3] See : https://www.nsf.gov

submit transformative research projects that can transform existing scientific paradigms. Relying on the 2007 report 'Enhancing Support of Transformational Research at the National Science Foundation', the National Science Board presents its findings and recommendations for NSF to enhance its ability to identify and fund transformative research. NSF has adopted the following working definition:

> Transformative research involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice or leads to the creation of a new paradigm or field of science, engineering, or education. Such research challenges current understanding or provides pathways to new frontiers.[4]

A permeable interface is clearly perceptible between interdisciplinarity and new forms of research qualified as 'transformative,' 'innovative,' 'high-risk,' 'creative,' 'frontier,' or 'breakthrough' research. Beyond the official boasting and the multitude of reports that point to the need for interdisciplinarity and creativity, the basic idea that emerges here is why and how interdisciplinarity can be creative, why and how creativity is interdisciplinary and likely to tackle the decompartmentalization between disciplines, and finally what is the role of design thinking in this game, in the new ways of developing and practicing research.

A Dialogic and Trialectic Vision

Interdisciplinarity, creativity, and design thinking are objects of study that are constitutive of rather autonomous fields of research but whose connections can be highlighted. These three theoretical and practical objects relate, respectively, to interdisciplinary studies, creativity studies, and design studies, each field claiming itself a certain interdisciplinary openness. Indeed, interdisciplinarity is a crosscutting theme: Creativity is not reduced to a strictly psychological approach, it is also social, cultural, economic, and finally, design does not belong solely to designers; it is studied by specialists from several disciplines. Each of these areas of research has reached an advanced stage of development. They are structured, with some flexibility, around relatively specific theories, concepts, and methods. And they make sense within scientific communities, research networks, and national and international associations that are not necessarily connected. These states of significant scientific development are more and more documented in handbooks that testify to the production, importance, and coherence in the diversity of these different scientific communities. Progress in research on interdisciplinarity, for example, is presented in publications that describe a structured body of knowledge, while avoiding a disciplinary paradigm that would be sterilizing for the development of the field (see, e.g., Darbellay & Paulsen, 2008; Frodeman, Thompson Klein, &

[4] See: https://www.nsf.gov/about/transformative_research/definition.jsp.

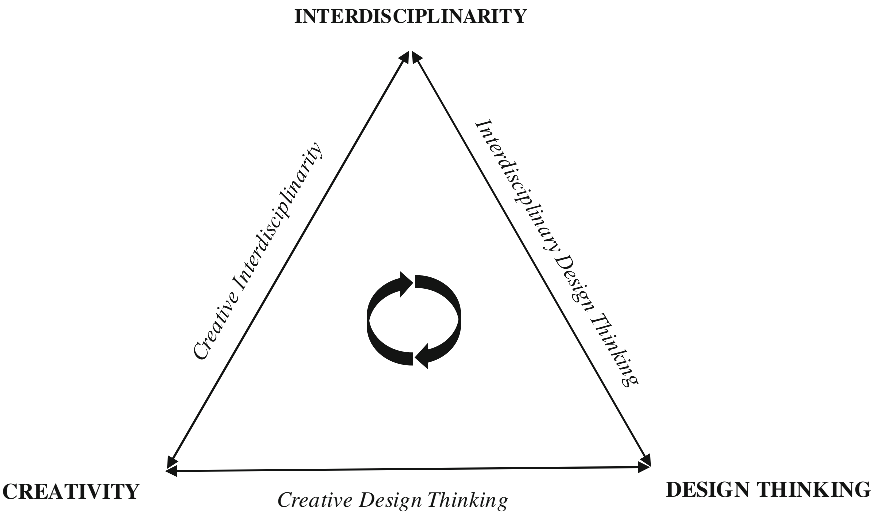

Fig. 1 Interdisciplinarity, creativity, design thinking

Mitcham, 2010; Hirsch Hadorn et al., 2008; Repko, Szostak, & Buchberger, 2013). Similarly, studies on creativity have reached this level of manual setting, presenting this interdisciplinary field of studies in the complementarity of theoretical, conceptual, and methodological approaches (see Glăveanu, 2016; Kaufman & Sternberg, 2010; Runco, 1997; Runco & Pritzker, 2011). As for design, it also federates researchers from different disciplinary horizons which make it an object of study. The journal *Design Studies* (The Interdisciplinary Journal of Design Research[5]) is particularly emblematic of the fertility of this field of research. More specifically, design thinking is the subject of numerous publications, guides, and manuals defining the stakes, methods, and fields of application (see Brown, 2009; Cross, 2011; Plattner, Meinel, Leifer, 2010).

The aim of our collective book is not to present a state of the art or advancement in each of the areas, but to propose points of contact and articulation between these fields of study that meet around convergent interests. Figure 1 illustrates this linkage between the three fields of study.

It is a matter of opening a constructive dialogue between these three fields of study which have not been closely linked yet. By mobilizing a principle of *dialogical* thinking (Morin & Le Moigne, 1999), the interrelationships between interdisciplinarity, creativity, and design thinking are not contradictory or antagonistic, but associated with a complementary way without being resolved into a unifying superior synthesis. This dialogical vision makes it possible to envisage a trialectic dynamic in the interactive movement between the three poles of Fig. 1. The objective here is to offer researchers a space to explore possible recursive

[5] See: www.journals.elsevier.com/design-studies.

relations between these domains. This opening to a circular causality and not a simple juxtaposition between fields of studies makes it possible not to exclude one or the other pole of this triad. According to the third included principle ('tiers inclus,' Lupasco, 1951), each domain is likely to contribute to the development of the other two and vice versa. Let us briefly define each field of study and show how they can connect as in a Möbius strip.

Interdisciplinarity

If the desire to create bridges between disciplines is an integral part of the history of science (Gusdorf, 1983), it can be agreed that the thematization of the issues of interdisciplinarity in the production of knowledge emerged in the 1960s and 1970s (Thompson Klein, 1990). Although definitional subtleties can be debated endlessly, a consensus around the definition of interdisciplinarity—as already indicated above—has spread widely in the scientific community (see Darbellay, 2005; Huutoniemi, Thompson Klein, Bruunc & Hukkinena, 2010; Piaget, 1972; Thompson Klein, 1990). Unlike the multidisciplinary approach which most often reproduces divisions between disciplines by simple addition/juxtaposition, interdisciplinarity attempts rather bring together two or more established disciplines, so that they interact dynamically with each other. Based on a multidisciplinary vision of knowledge, this interaction between disciplines aims at questioning whether to transgress the boundaries between them. With the objective of analyzing and understanding the complexity of an object of study or solving a theoretical or practical problem, this first phase of interaction should lead to a fine articulation and integration of the various complementary points of view in a negotiated and global perspective among the partners involved in the research process. Interdisciplinarity, which goes beyond the mere juxtaposition of disciplinary points of view, involves the collaboration and integration of specific disciplines in relation to a common object.

The process of dialogue between disciplines requires that each researcher deploys the analytical skills and tools of one's own discipline while opening one's mind to the methods of other disciplines. The object of knowledge is complex and emerging; it is at once more than the mere sum of disciplinary knowledge and irreducible to one discipline. The collaborative approach and the integration of disciplinary knowledge can take place at different levels: for example, borrowing or transferring concepts, theories, or methods between more or less distant fields; mechanisms of hybridization, transgression, or transformation in contact and crossing between disciplines; or the creation of new fields of research by coupling two or more disciplines. With the power of the ideas that drive interdisciplinary work (open-mindedness, thinking outside the disciplinary box, transgression of borders, hybridization, exploratory divergence and convergence–integration, etc.), interdisciplinarity presents several points of contact with the creative process (Darbellay, Moody, Sedooka & Steffen, 2014). We therefore name this link

Creative interdisciplinarity (see Fig. 1). Interdisciplinarity, insofar as it is conceived and practiced as an innovative approach between and beyond disciplinary boundaries, joins the theoretical and practical developments of creativity. In the same vein, interdisciplinarity connects with design thinking, not only because it is diffused through many disciplinary fields and practices and because it calls for an interdisciplinary approach, but more fundamentally still because the way of thinking of the designer in the broad sense also aims at the conception and solution of complex problems in an innovation perspective centered on human experiences which is not limited to disciplinary boundaries.

Creativity

Creativity can be broadly defined as the ability to produce ideas or products that are both original and adapted to the context and constraints of specific tasks (Sternberg & Lubart, 1999). Creativity refers to a process that is both general/generic and relatively specific depending on its areas of application (Plucker, 1998). According to a multivariate model, which by definition is complex and involves several interrelated variables, the creative process mobilizes several resources at the confluence of several research domains. The creative process involves—by degree and variable weighting according to individuals and areas of expertise—conative, cognitive, and emotional factors specific to each individual, which are in dynamic interaction with the environmental context in which the creative activity takes place. The analysis and understanding of creativity in an interdisciplinary, global, and integrated perspective can only be achieved by taking into account all these dimensions and their interrelations. Creativity is thus an object of study perfectly eligible for an interdisciplinary approach, and it diffuses cross-borderly in educational, economic, social, and cultural issues. As stated above, creativity connects with interdisciplinarity, not only in the sense that it is an interdisciplinary field at the interface of psychology, sociology, management, etc., but also in the sense that it participates to interdisciplinarity and is likely to contribute to its development. Based on work concerning divergent-exploratory thinking, convergent-integrative thinking, generation of new ideas and cognitive flexibility, creative personality traits (openness to new experiences, tolerance to ambiguity, risk-taking), and cognitive styles (Lubart, Mouchiroud, Tordjman & Zenasni, 2003), advances in studies on creativity are numerous and very much in line with interdisciplinary knowledge production mechanisms (Darbellay, 2015). From a trialectic perspective, if the link can be woven between creativity and interdisciplinarity, as depicted on the double arrow in Fig. 1, creativity, like interdisciplinarity, is brought to connect with design thinking.

Design Thinking

Design thinking is a process that focuses on collecting user-need feedback, experimenting, generating prototype models, gathering feedback, and redesigning in a cyclical way. Design thinking is a way of thinking that was first developed and applied to design tasks (e.g., create a new toothbrush design), but then was enlarged to other kinds of problem-solving. Design is, by nature, a creative activity in the sense that it is generative, leading to a production (a design concept, a prototype). However, not all design thinking leads to highly creative output. Thus, there are degrees of creative success. We designate this link between creativity and design by the expression *Creative design thinking*. Creative design thinking focuses on the creative (original and adaptive) aspects of this process. When engaged in design thinking, some outcomes are more creative than others, more or less disciplined or undisciplined. How can creativity and interdisciplinarity be fostered when engaged in a design thinking process by designers, researchers, students, etc.? Design thinking is also a way to approach and solve problems that may extend beyond the more traditional design-oriented activities. When seeking ideas (outcomes) in general (outside the specific design domain), design thinking can be used as a method/tool to help people get the most creative ideas. Thus, creative design thinking can serve outside its original context, in different disciplines and areas of activity. This would be a transfer from design as a creative process to other disciplines, to accelerate the flow and generation of ideas between and beyond disciplines in the treatment of complexity, innovation, and discovery. This process takes meaning beyond disciplinary boundaries; it transcends disciplines and allows the development of interdisciplinary and collaborative work.

Collective Intelligence in Action

The contributors to this book were asked to look at these complex links between interdisciplinarity, creativity, and design thinking, links that are not yet evident in the scientific community. The researchers gathered here come from different fields of study on interdisciplinarity (*interdisciplinarity studies*), creativity (*creativity studies*), and design thinking (*design studies*), as well as various disciplinary anchors in these fields (from psychology, sociology, epistemology, etc.). Thus, they represent a multidisciplinary configuration and each one has engaged in this new reflection by opening up to other perspectives. All the contributions try to work on this dialogical approach. Each does it with nuance sometimes focusing on either creativity, design thinking or interdisciplinarity, but without losing sight of the connection to other areas. In this perspective, the book is structured in two complementary movements. The first is to reflect on the possible articulations and convergences between creativity, design thinking, and interdisciplinarity (*Thinking About Creativity, Design Thinking and Interdisciplinarity*, Part I). Muratovski opens a first way by showing that the concept of design is constantly evolving in an increasingly complex economic and social world. The first chapter takes care to examine current trends in the field of design and its progressive opening to interdisciplinarity (*Towards Evidence-Based Research and Cross-Disciplinary Design Practice*, Chap. 1). Beyond the simple execution of a project, designers have increasingly mastered various research methods ranging from ethnology and development to case studies, action research, and human-centered design. From the perspective of innovation, the use of evidence-based research that transcends disciplinary boundaries allows better implementation of accountability, transparency, and trust in designers' work. Based on the lessons learned from the literature on creative design, Szostak shows that the interdisciplinary research process is akin to a creative design process (*Interdisciplinary Research as a Creative Design Process*, Chap. 2). Following similar steps and using similar strategies, the two processes combine conscious and subconscious thinking. Interdisciplinary researchers who aspire to be more creative and interdisciplinary instructors who want to encourage students creativity are here advised on how to integrate creative practices into different stages of the interdisciplinary research process. It goes without saying that this development of interdisciplinary creativity is not without psychological or institutional obstacles. The costs and benefits of these strategies need to be weighed in the interests of integration and global understanding.

Ambrose continues the reflection by highlighting the major challenges, problems, and opportunities generated by globalization in the twenty-first century (*Large-Scale Interdisciplinary Design Thinking for Dealing with 21st-Century Problems and Opportunities*, Chap. 3). Addressing these issues requires creative and interdisciplinary reflection and collaboration to enable individuals and teams to remedy the dogmatism that hinders the perception of complexity. It is necessary to combat dogmatism in all its forms and, in particular, disciplinary dogmatism. Dogmatism is an obstacle to interdisciplinary and creative work. The use of visual metaphorical artistic design serves as a strategy to simplify and synthesize complex ideas and reinforce interdisciplinary reflection on creative design. In the same anti-dogmatic vein, Thompson Klein explores the relationship between creativity, design, and transdisciplinarity, with an emphasis on collaborative research (*Creativity, Design, and Transdisciplinarity*, Chap. 4). Beyond differences and conceptual nuances, the three terms are related to shared characteristics, those of novelty, crossing boundaries, generativity, synthesis, criticism, and reflexivity. Transdisciplinary approaches generate new hybrid modes of inquiry and action that bridge gaps between critical theory and projective design, and between social, political, and normative practices and concerns. Conceptual forms of thought also rely on the creative dimensions of practice, fostering relational knowledge while being open to subjectivity and unexpectedness. The resolution of transdisciplinary problems is reinvigorated as a creative art of invention, accentuating discovery and learning. The divergence–convergence processes are also exploited to show how they generate new approaches through combinatorial innovation.

In fifth chapter (*Cross-disciplinary Creativity and Design Thinking*, Chap. 5), Tan presents cross-disciplinarity as a process that places humans at the center of scientific and cultural practices. Creativity and design thinking are once again highlighted as renewal operators capable of answering complex and practical problems. Cross-disciplinary creativity is likely to favor design thinking. The mechanisms of creativity (convergence, divergence, emergence) join the humanistic values of design thinking (harmony, authoritative conversation, and respect). The principles of interaction, continuity, and complementarity contribute to the emergence of a creative synthesis to find ethical solutions to complex problems. Worwood and Plucker (*Domain Generality and Specificity in Creative Design Thinking*, Chap. 6) point also to the growing importance of design thinking in professional and educational environments (from maker spaces to prototyping laboratories, to design thinking in teaching). By examining the existing literature on the creativity and domain specificity, they link up with creative design thinking. Between similarities and differences, design thinking is considered in its generality and especially in creative contexts.

The second movement of the book extends the theoretical reflection while highlighting the processes and actions that characterize creative design thinking from an interdisciplinary perspective (*Thinking Outside the Box: Interdisciplinary Process and Action in Creative Design Thinking*, Part. II). Creativity is an essential dimension of the innovative design process. Nelson and Botella (*The Multivariate Approach and Design of the Creative Process*, Chap. 7) recall that many authors have proposed models to describe creative practices, both at the macro-level (the stages involved in a creative process) and at the micro-level (the underlying cognitive processes). Without normative or prescriptive will, it is a question of structuring the creative work in order to ensure an optimal deployment of the creative potential. In this perspective, the authors present the multivariate approach that situates creativity at the point of interaction between several resources (cognitive, conative, emotional, and environmental factors). In chapter eight, Nagai and Taura discuss the concept of design thinking as a factor of innovation (*Critical Issues of Advanced Design Thinking: Scheme of Synthesis, Realm of out-frame, Motive of Inner Sense, and Resonance to Future Society*, Chap. 8). In particular, they investigate the characteristics of design through the generation of concepts for a deeper understanding of human creativity driven by design (design creativity). They address also the essential characteristics of individual creative thinking, which is a fundamental skill in interdisciplinary group work. Group work is conceived from a co-creative and interdisciplinary perspective, the aim of which is to stimulate social innovation for qualitative changes in society.

Design thinking is intimately linked to a project logic, as Vial explains (*The Specificity of the Project in Design Thinking*, Chap. 9). There is a specificity of the concept of a design project that takes on meaning in a projective logic. The theory and methodology of the project benefit currently from the contribution of Information Technology (IT), fostering an agile methodology that inspires innovative designers. Design thinking is not only thinking, but also action and realization in a perspective of design doing (*From Design Thinking to Design Doing*, Chap. 10). Craftsmen and designers work through their bodies. Design is a kind of fabrication, a creative process by nature intrinsically disordered and not necessarily and at all times guided by strict rules and methodologies. For Juelsbo, Tanggaard, and Glăveanu, the process of creation is made of order and disorder in a co-constructive dynamic. There is then a need for methodologies to teach designers these complementary principles and to obtain their adhesion. Creative design thinking can finally help get the most creative ideas, but it is through the active realization of these ideas in everyday life that these ideas take on meaning. Hatchuel, Le Masson, and Weil propose to think about creativity beyond a simple psychological phenomenon and an ability to be acquired (*C-K Theory: Modelling Creative Thinking and Its Impact on Research*, Chap. 11). They envisage a more rigorous formalization of this process of ideation and generation of knowledge. The authors present the recent advances in design theory, namely C-K theory or concept-knowledge theory. This theory assumes that creative thinking can be formally described and experimentally tested. The C-K theory introduces new interdisciplinary notions involved in any creative process: 'concept undecidability,' 'knowledge independence,' 'generic expansions,' and 'knowledge reordering.' It is a question of describing and understanding the important operators which underpin the generative and expanding logic of creative thinking. The C-K theory aims also to stimulate transdisciplinary research through the development of a science of design and the modeling of creative logic in all disciplines. In the final chapter, by Hatchuel, Le Masson, and Weil, creativity is addressed in its potential development through innovative technologies (*Technological Innovation in Group Creativity*, Chap. 12). The advantages and disadvantages of the brainstorming paradigm are read in light of this new perspective. Key factors of effectiveness are highlighted: cognitive stimulation, social comparison, and group facilitation. At the same time, it is a matter of countering production blocking, social loafing, and self-censorship. The authors highlight furthermore a new efficiency factor for creativity, namely the fun factor: The use of innovative technology in itself introduces enjoyment, which seems to increase commitment and creative performance. The authors show also how the use and choice of avatars in virtual brainstorming positively influence the creative process and offer new tools to support group creativity.

In the continuity and articulation of the two parts of the book, two interwoven movements, readers are invited to immerse themselves in reflections both theoretical and practical, at the interface of creativity, design thinking, and interdisciplinarity.

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Part I
Thinking About Creativity, Design Thinking and Interdisciplinarity

Chapter 1
Towards Evidence-Based Research and Cross-Disciplinary Design Practice

Gjoko Muratovski

Abstract As the world changes, problems that businesses and society are facing are becoming more complex. Design, as a field that sits between business and society, as well as culture and technology, continues to progress and to mature as a profession. As a result, the concept of design (what design is and does) constantly changes, evolves, and expands. In return, design today is being recognized as a field whose primary purpose is to help businesses, communities, and individuals in new and innovative ways. Through a review of the current trends in the field of design, this chapter highlights why design thinking, which in the past has often been driven by tacit knowledge, intuition, and personal preference, is now increasingly being enhanced with proficiency in cross-disciplinary, evidence-based research. This approach to design represents a willingness to look beyond the immediate concern of elementary project execution. Designers who are proficient in research methods that range from ethnography and case study development to human-centred design research and action research can be invaluable to any sector that seeks innovation. The use of evidence-based research capable of transcending disciplinary boundaries projects a greater sense of accountability and transparency and can create more confidence in the work that designers produce.

Keywords Evidence-based research · Cross-disciplinary design
Design-led innovation · Design thinking · Design practice

Introduction

As leading businesses and global organizations started gaining new understanding of the value of design, their internal culture and attitude towards design began to change. Financial companies and management consultancies that have never before

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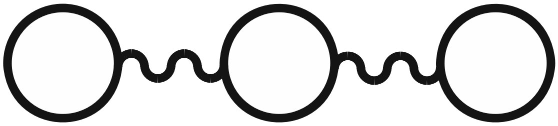

Fig. 1.1 Evolution of the primary objective in the field of design

been associated with design are now creating their in-house design teams and including design in their portfolio of services. Large corporations that in the past used design in a limited capacity now rapidly increase their in-house design capabilities and appoint designers in executive roles. Venture capital firms and start-up companies also started recognizing the value that designers can bring to the business development stages of their investments. Even global organizations and international foundations started placing design on their agendas.

From a field of making and styling, design has evolved into one that embodies the idea of 'problem-solving' at its core and has went beyond that. In recent times, things have continued to evolve further and the next stage for design is increasingly being defined as one that deals with 'problem finding' (Fig. 1.1). As a result, the role of design in business and society is changing. In many cases, we can see designers successfully contributing to a range of organizations on a strategic level by being involved in decision-making processes and strategic planning (Muratovski, 2016a, p. 18).

Design as a Strategic Resource

Design and business are intrinsically linked together. Contemporary design emerged out of the needs of the industrial economy in the mid-nineteenth century, and design and business have been connected ever since. Early designers came from many backgrounds, and they were introduced to the profession because of their ability to contribute artistically or constructively to the industry's needs for the development of products and advertising communications. Over time, as business models began to evolve, the field of design evolved as well. Designers moved from being stylists, to becoming professional 'problem solvers' (Muratovski, 2011a).

With time, for many leading businesses, simply developing goods and services was no longer seen as enough in a highly competitive global market. As a result, the new stage of business innovation was focused on creating experiences and developing systems for living, working, and entertaining. This called for new currents of thinking that would challenge existing business models by using an approach, which is now referred to as 'disruptive innovation'—an innovation that can transform and revolutionize an existing market, product, or a sector, by replacing complexity and high cost with simplicity, convenience, accessibility, and affordability (Christensen, 1997). In their pursuit of disruptive innovation, many businesses started looking at the process of design as a source of inspiration. After several successful design-led innovations (e.g. Apple's iPhone and Nintendo's Wii game console), design quickly emerged on the top of the corporate agenda, but with one crucial point of difference: design is now seen as a field of thinking, rather than making (Muratovski, 2010).

Design is good for business, and more and more businesses now recognize this to be true. Large businesses that are well known for their design-led approach to business started placing even more emphasis on the importance of design and started introducing designers to executive roles in order to demonstrate their commitment to design-led innovation (e.g. Apple, Nike, Coca-Cola, IBM). However, it has to be noted that these designers have been promoted to executive roles not simply because they are designers, but because of their ability to align design with business interests and to communicate in business terms how design can add value (Muratovski, 2016a, p. 18).

As design is increasingly being recognized as a strategic resource, the sphere of influence that designers have in business and society is changing. What used to be a field dominated by an array of independent design studios and large design agencies is now increasingly becoming one that is corporatized and centralized. As big corporations started to see design as a critical corporate asset, they also began to understand that design is not something that should be delegated to third-party design firms on an on-going basis. The growing trend for integrating design into the overall corporate strategy, the need for confidentiality, and the concern of issues related to the ownership of the intellectual property mean that serious businesses can no longer outsource something that is seen as a strategic resource. That is why major businesses—including many of the Fortune 500 companies—started investing in their own design capabilities (Lockwood, 2015).

As a result of this, we have seen a surge in interest in developing corporate in-house design teams within a range of financial management businesses (e.g. Bloomberg, PwC, Deloitte, Accenture, BCG, McKinsey, Fidelity Investments, Capital One, Barclays, Xero). These businesses now see design as a catalyst for innovation in sectors where design has never been seen in such a capacity before. In line with this, many of these leading business consultancies have acquired well-known design consultancies (e.g. The Difference, Optimal Experience, Aqua Media, Fjord, Strategic & Creative, Lunar, Adaptive Path), mainly for strengthening their own digital media capabilities, but also for adding design consulting services to their portfolios. Then, it should also be noted that at the same time, designers have become increasingly entrepreneurial. More and more designers are now being involved with developing new business models and growing existing businesses. This entrepreneurial spirit marks a new era for both design and business. From design of products, spaces, and communications, designers have ventured into a new area: businesses design (Muratovski, 2016a, p. 4). In this capacity, design has proven itself valuable to new types of businesses that offer services that never before existed (e.g. Facebook, Airbnb, Snapchat, Behance, Tumblr, Instagram). In fact, in many cases we can see designers not only contributing to the business development process, but also acting as co-founders of successful start-up companies (see Maeda, 2015; Fabricant, 2014). The role that design can play when launching or developing new businesses has also been recognized by a range of venture capital firms who now use designers to work with their portfolio of clients (e.g. Google Ventures, Khosla Ventures, Coca-Cola Founders).

The examples above show that having design embedded into the corporate culture can certainly make a difference to the bottom line. That is why even well-established, conservative financial businesses that have never before been associated with design are now building their own design teams and recruiting designers as executives. They do so in order to remain competitive in the marketplace by integrating design thinking capabilities within their organization, create better user experiences (UX) for their clients, and develop better user interfaces (UIs) for their products (Muratovski, 2016a, p. 19).

The role of design as a strategic resource goes beyond the corporate sector. Contemporary problems associated with globalization, terrorism, epidemics, overpopulation, environmental issues, multiculturalism, and financial stability demand new solutions and unconventional approaches, and design is increasingly being seen as an agent of positive change (Muratovski, 2010). That is why design is now recognized as an important factor that could contribute to social innovation and sustainability. As a result, number of leading global organizations and foundations are placing design on their agendas and are launching design-led initiatives in a range of contexts (e.g. United Nations, The World Bank, The Rockefeller Foundation, Bill & Melinda Gates Foundation, The Clinton Foundation). All of this is placing design in a unique position, never before seen in its history (Muratovski, 2016a, p. 19).

The New Generation Design

Design today is no longer about designing objects, visuals, or spaces; it is about designing systems, strategies, and experiences (Fig. 1.2). It is because of this way of working that design is now largely recognized as a vehicle for corporate innovation and accepted as an agent for social change. What makes designers working on this level different to traditional designers is that they are no longer trying to resolve problems provided to them in a design brief, and they are trying to prevent problems from occurring in the first place by developing the design brief themselves.

While the need for designers with traditional technical and artistic skills is still constant within the design industry, more and more designers are acquiring a new set of skills that come outside the field of design. By gaining knowledge in everything from psychology and human behaviour to business development, designers now operate on a level that merges social sciences with entrepreneurship. Armed with a new set of skills and attitudes, designers are increasingly asserting themselves as opinion makers, critical thinkers, and strategic planners with a global influence. This way of working has brought forward the role of the designer as a business leader at the highest corporate echelons; it has led the

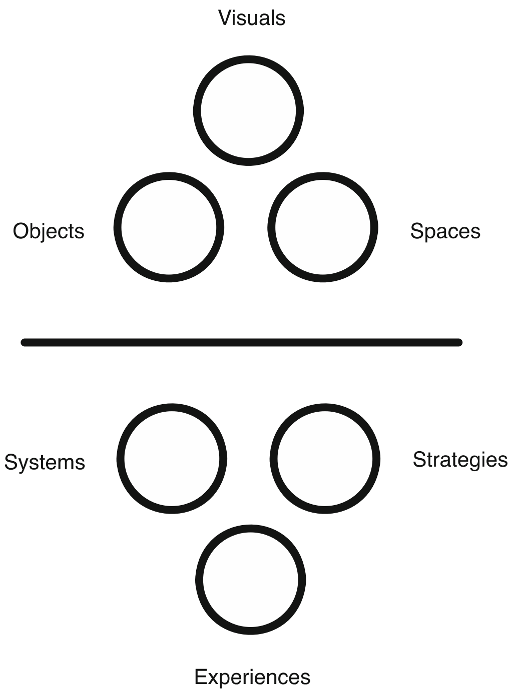

Fig. 1.2 Change of focus in design outcomes

establishment of a new genre of in-house design teams and has helped introduce design as a key factor in global politics. All of this has enabled a new generation of designers to actively participate in the strategy planning processes that determine what kind of designs should be produced, for whom, and why; rather than just focusing on investigating form and style, as it has been the case in the past (Muratovski, 2016a, p. 21).

The use of cross-disciplinary, evidence-based research in design represents a willingness to look beyond the immediate concern of elementary project execution. Designers who are proficient in research methods that range from ethnography and case study development to human-centred design and action research can be invaluable to any sector that seeks innovation. Designers, armed with data from their research, can now introduce new and innovative solutions that might have been previously overlooked or perhaps considered too risky without the supporting evidence. That is why research proficient designers are increasingly assigned with decision-making powers and are invited to participate in the strategy planning process.

If we look at the scope of the projects that contemporary designers already work on, we can see that many already act as social scientists and business strategists; even though they may be unaware of this and are often undereducated for such tasks. Yet, on day-to-day basis, designers identify problems, select appropriate goals, plan, and deliver outcomes that involve complex social, political, and economic issues (Friedman, 2012, pp. 144–146). The inclusion of formal research in the process of design is helping designers to understand their tasks better and to make informed decisions that can lead to more effective design solutions (Muratovski, 2006, p. 259; Muratovski, 2012, pp. 46–47).

Design Thinking

An increased introduction of critical thinking in the field of design is creating a range of new opportunities for a new generation of designers. Rather than presenting themselves as artistic service providers who operate on the surface of the problem, many designers have already begun to redefine themselves as strategic planners capable of understanding complex issues and devising creative solutions. A number of global trend indicators have already identified the potential of design to act as a major force that can improve local economies, environments, and human life by integrating design in fields such as finance, construction, sustainability, health, housing, and public organizations. These new trends indicate that designers' tasks have begun to shift from 'product creation' to 'process creation' and that research is becoming increasingly important, especially since new design knowledge is being appropriated from the fields of social sciences, environmental studies, business management, and beyond (Muratovski, 2012, p. 46). This way of working has led to the idea of 'design thinking'.

Then again, even though the concept of design thinking is now a broadly accepted term, there is still a level of vagueness associated with it and many people (including many designers) may struggle explaining what this is and what this involves. The confusion comes mainly because different design disciplines use different methodologies and because there is no universal way on how to 'think' like a 'designer'. Nevertheless, one of the most commonly referred definitions on design thinking is the one by Brown, the President and Chief Executive Officer at IDEO.[1] According to him, "Design thinking is a human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success" (Brown, 2015).

In a similar fashion, Formosa (2012), a founding partner of the New York-based consultancy Smart Design, sees design thinking as a new approach to problem-solving that relies on innovation and research when it comes to the development of new products and services. Then again, as Formosa points out, innovation does not necessarily mean invention. Rather, innovation should be seen as a new and unique way of thinking, even when it comes to existing problems.

[1]IDEO is an award-winning global design firm that takes a human-centred, design-based approach to helping organizations in the public and private sectors innovate and grow.

With time, the ability of design to deliver innovation and act as a driver of commercial success or social change is likely to increase further. But in the meantime, as members of a relatively new discipline, many designers yet need to establish themselves as thinkers and consultants capable of addressing contemporary multifaceted problems. This, however, is not an easy task. On one hand, the field is being shunned by other disciplines that claim to be better equipped to deal with complex business and social problems than designers. This argument is mostly based on the fact that many designers do not have the same investigative and analytical skills that others, more established disciplines, have. On the other hand, traditional designers question whether this disciplinary evolution is necessary or even desirable, especially since many design programs are still based in art schools. However, what many fail to understand is that design is an ever-evolving field that ultimately acts as a reflection of society. As the fabric of society changes, so does design. Therefore, in order for design not to be marginalized or left behind as a discipline, designers will need to find a way to remain relevant and collaborate with other fields. For many, this will mean stepping outside their comfort zone. But in return, this way of thinking has the potential to change the traditional design outputs and to produce outcomes that are no longer mere artistic refinements, but meaningful contributions to society, the environment, and the economy. One way to achieve this is by making informed design decisions, which means grounding design in research (Muratovski, 2016b).

Evidence-Based Research

To many people, the word research connotes some kind of mystique and it suggests an activity that is somehow exclusive and removed from everyday life and practice. Most people are unsure what researchers do, why they conduct research, what is the purpose and the benefit of their research, and how research contributes to people's lives. To add to this confusion, 'research' is a commonly misused word that bears many meanings in everyday life. We hear the word used in a context of various activities. For example, people often use research to describe the process of looking for an item or information, or when reading about something they do not know. Businesses often mention research in their sales pitches when they want to promote some kind of innovative product, even when they have slightly modified an existing product to which they might have added some new features. Many of these activities use the word research incorrectly. The correct way to describe such activities includes terms such as information gathering, documentation, self-enlightenment, or product development; none of these are equal in meaning to research (Leedy & Ormrod, 2010, p. 1).

The *Oxford Dictionary* describes research as a 'systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions'.[2] This implies working to a fixed plan and according to an established form of procedures. Then again, few designers feel the need to learn how to conduct research in this particular manner because many designs do not need rigorous research in order to be developed or produced. The methods of design vary greatly and can range from being highly structured to interpretive and lateral, and this often depends on the personal preferences of the designer. Some of these methods can be investigative in nature, but this investigation is often self-exploratory and focused on the immediate processes of design. For many designers, this way of working is sufficient and the story ends here. Nevertheless, this way of working also limits the potential contribution that designers can make to their own discipline, society, business, and to industry. If designers would like to develop themselves as professionals of broader significance, then they will need to learn how to incorporate a more scientific approach to practice. This, however, is not an easy task. Unlike design, research is not an intuitive process. In fact, it is quite the opposite; it is a process that requires conscious reasoning, and there are rigorous rules that need to be followed in order for the research to be verified and recognized as valid. This in return calls for a significant culture change in the field of design (see Muratovski, 2016b).

Defining research in a context of design is also problematic. A young discipline such as design is inevitably faced with many conflicting ideas and philosophies, and general understanding of what design research entails is often a cause of debate (Buchanan, 2001, p. 17). For some designers, design practice itself is perceived as a research process and design methods are sometimes equalled to research methods (see Downton, 2003, pp. 1–12).[3] For others, doing research into design processes is synonymous to doing design research.[4]

In the past, designers rarely participated in research that determines what kind of designs should be produced, for whom, or why? Many traditional designers with some notable exceptions choose to focus on investigating design methods that can deliver better form, style, or function. On the other hand, design-driven companies with a focus on innovation use evidence-based research as a part of the design process. IKEA's children's department, for example, operates in this way since 1979:

> In order to understand children and how their world is different from ours, we at Children's IKEA bring in renowned professors who know about childhood development, child safety, human behaviour, and psychology. Then we test every child's toy and piece of furniture we sell, run risk analysis, and document the results all against the world's toughest safety standards (Bengtsson, 2013, p. 299).

[2]Research. (2016). In Oxford English Dictionary. Retrieved from http://www.oxforddictionaries.com/definition/english/research [Accessed 25 June 2016].

[3]For an alternative view on this issue, see Friedman (2003, p. 519).

[4]For specific comments on this see Dorst (2008, p. 6).

Then again, some might argue that the process of experimentation that allows designers to develop unique set of skills or creative outputs is a form of research. However, this process is not always systematic, nor it necessarily leads to establishing facts or new solutions. What this process does, however, is helping designers develop a particular style of work. In some cases, this process can follow research criteria and then this can be described as an elementary form of design research. In a sense, research which is focused on only one particular area: the methods of conducting design practice.

Evidence-based research, on the other hand, comes in many forms ranging from quantitative market research to personal interviews, experimental design analysis, and qualitative research. The great benefit of this type of research is that it can help designers to gain a keen understanding of various phenomena, people, cultures, and belief systems, and this kind of knowledge can be indispensable in the real world. As such, evidence-based research represents a willingness to look beyond the immediate concern of crafting a project. This type of research can challenge existing assumptions and provide a sound and up-to-date overview of potential business development opportunities.

Cross-Disciplinary Design Practice

The world is becoming an increasingly complex place. Negative trends like unsustainable population growth, ageing, global terrorism, and increased stress between people and technology are taking their toll on society. Other critical uncertainties like globalization, natural disasters, environmental depletion, and global epidemics are still present and will continue to pose relevant problems in the years to come (Muratovski, 2012, p. 46). Such multifaceted problems often referred to as 'wicked problems' in the design community (see Rittel & Webber, 1973) demand new solutions and unconventional approaches in order for us, as a global society, to improve or even maintain our quality of life as it is.

All of this impacts the field of design in a profound way, both in terms of practice and education. While the demand for designers with technical skills is still constant within the industry, society today demands a new generation of designers who can design not only products and communications, but systems for living as well. For many designers, this means a shift from providing artistic services to becoming strategic planners and professional 'thinkers' that can work across disciplines. However, in order for designers to rise to these challenges, they will need to become capable of understanding human needs and behaviour, and they will need to develop new problem-solving skills (Muratovski, 2012, pp. 46–47). This leads us to consider a cross-disciplinary model of design practice that brings together (a) multidisciplinary, (b) interdisciplinary, and (c) transdisciplinary ways of working (Fig. 1.3).

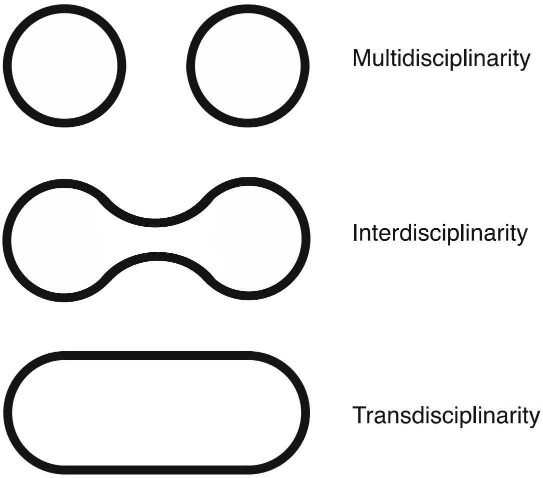

Fig. 1.3 Cross-disciplinary approaches in design

(a) **Multidisciplinarity**

Multidiscipliranity, according to Darbellay (2014, p. 165), represents an interaction between two or more unconnected disciplinary viewpoints, in succession and in isolation from each other. This way of working is often the traditional model of working that brings together different disciplines, but it does not allow for any real interaction between them.

(b) **Interdisciplinarity**

Interdisciplinary way of working brings together two or more different disciplines in a more complex manner. This way of working allows for a more collaborative and integrative approach to practice. This can include transferring or borrowing concepts or methods from other fields, hybridization between disciplines, or even the creation of new fields of research and practice by combining two or more disciplinary approaches (Darbellay, 2014, pp. 165–166).

(c) **Transdisciplinarity**

Transdisciplinary way of working calls for a 'fusion of disciplines': a way of working in which designers have 'transgressed' or 'transcended' their own disciplinary norms and have adapted ways of working from other disciplines (see Lawrence & Després, 2004). This is a case when designers have achieved a sufficient level of knowledge to enable them to work across disciplines in new and innovative ways. This approach is most suitable for working on complex problems for which no single discipline can provide the necessary methods on its own to frame them or resolve them. Working in this way requires an extensive amount of knowledge of research methods and methodologies, as well as many years of experience. However, designers capable of working in a transdisciplinary mode will be able not only to work with cross-disciplinary teams, but also to lead such teams (Muratovski, 2011b).

Regardless of the benefits of working in a cross-disciplinary fashion, implementing this in practice can be challenging. In the process, designers may encounter problems establishing collaboration with non-designers due to lack of knowledge of other disciplines, divergent standards, different methodological approaches, or simply due to negative attitudes and prejudices (Muratovski, 2011a, b). Other issues can range from problems of terminology, conflicting evaluation procedures, and different ways of reporting (Aagaard-Hansen, 2007; Muratovski, 2011b). Then again, many potential challenges can be addressed by applying several practical solutions. As a first step, cross-disciplinary teams will need to obtain 'mutual knowledge' about their own disciplines. Insight into the basics of discipline-specific methodologies can be helpful in the process of understanding and respecting the position of other disciplines (Aagaard-Hansen, 2007).

Due to its complex nature, the management of cross-disciplinary practice poses another challenge. Historically, some disciplines have been perceived as being more influential than others, either because of access to funds or by virtue of status. In return, disciplinary boundaries are often propped up by attitudes rather than reason. Negotiating this 'power' balance can be the most challenging task for a design leader of a cross-disciplinary team (Aagaard-Hansen, 2007; see also Muratovski, 2011a, b).

Conclusion

In the nineteenth and early twentieth century, design was used as a tool that can make products and communications more appealing to the masses, either through beautification or by improved functionality. Things are somewhat different today, and design is increasingly being seen as a strategic resource of broader significance. This is due to the introduction of research within the field of design and the willingness of some to look beyond the constraints of their own discipline. Nevertheless, for many others, design is still perceived as a kind of 'mythical gift' that allows designers to provide creative solutions to everyday problems. While some might find this appealing, the mystique that surrounds the notion of how design works puts into question the accountability, responsibility, and validity of the profession (Swann, 2002, p. 49; see also Buchanan, 1999, pp. 63–66).

The difference between design today and design in the past is that now, in a post-industrial economy, designers are expected to replace the old ways of working based on a strong sense of individualism, common sense, trial and error, and personal experience with new principles and practices. The world today needs designers that are not only aesthetically sensitive, but also culturally aware, inquisitive, and able to think both logically and laterally. Designers need to have an ability to analyse problems and organize information related to how people interact with information, technology, knowledge, cultures, environments, objects, and society. Their work should be centred on designing purposefully for specific people and situations, rather than producing self-initiated artistic endeavours. They should be curious about the needs of other people, and not only about themselves. All of this suggests that the social construct of the meaning of design has changed, and the word ‘design’ now denotes evidence-based, cross-disciplinary approach whose purpose is to help businesses, communities, and individuals (Muratovski, 2016a, p. 22).

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Author Biography

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Chapter 2
Interdisciplinary Research as a Creative Design Process

Rick Szostak

Abstract Lessons are drawn from the literature on creative design for the interdisciplinary research process. It is argued that the interdisciplinary research process is a creative design process. It follows a similar set of steps and can/should employ many of the same strategies. Both processes are thought to blend conscious and subconscious thinking. Interdisciplinary researchers who aspire to be more creative, and interdisciplinary instructors wishing to encourage creativity among students, are given advice on how to integrate creative practices into various steps in the interdisciplinary research process. Potential psychological, institutional, and skill-based barriers to creativity are addressed. Several strategies are outlined that are conducive to creativity in the early conscious information gathering/evaluation steps of the interdisciplinary research process. The costs and benefits of such strategies are discussed. Quite different strategies for encouraging creative subconscious integration of the information collected are then outlined. These integrative insights must then be consciously evaluated: It is important not to expect perfection but not to ignore potential side-effects. Perhaps most importantly it is argued that persuading others of the value of one's comprehensive understanding is a critical component of the interdisciplinary research process, and that this step also requires the blending of conscious and subconscious processes.

Keywords Creativity · Design · Interdisciplinarity · Subconscious
Persuasion · Interdisciplinary research process

Introduction

The literature on the interdisciplinary research process (IRP; see Repko & Szostak, 2016; Bergmann et al., 2012; Association for Interdisciplinary Studies (AIS), 2013) seeks to identify useful strategies for performing various steps in interdisciplinary

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research. It recognizes that interdisciplinary research—and especially the critical steps of *creating* common ground and integrating insights—is inherently creative. The interdisciplinary researcher is urged to combine conscious and subconscious thought processes in creating an integrative understanding.

The literature on interdisciplinary research has drawn on a number of related literatures: on common ground theory from psychology, on the science of teams in sociology, on learning and cognition, and many others. But the creative aspects of interdisciplinary research have seen less attention than the more logical and conscious elements of the research process. The purpose of this chapter, then, is to explore whether the literature on creative design (and the separate literatures on creativity and design on which this builds) can be drawn upon to suggest useful strategies for interdisciplinary researchers. The chapter itself then is integrative: It connects these distinct literatures in a way that adds to what we already know about how best to pursue interdisciplinary research. It thus responds belatedly to Klein's (1990) call for «exploring the connections among creativity, problem solving, and the interdisciplinary process» (p. 196).

The chapter first defines creativity and explores how the interdisciplinary research process compares to processes outlined in the literatures on both creativity and design. It then surveys how various steps in the interdisciplinary research process might be adjusted in order to encourage creativity among both researchers and students.

Defining Creativity

Creativity is generally defined in terms of both novelty and utility. For an idea or object to be creative in a social sense, it must also be communicated and judged to be appealing. In some fields, additional elements such as elegance may be added to the definition of creativity. Notably, since there can be degrees of novelty, usefulness, and elegance, we can also speak of degrees of creativity: Some acts are more creative than others (Simonton, 2013). In many fields, creativity is seen to involve the combination of previously unconnected ideas. Though it may seem that scientific creativity is different from other types of creativity, Spooner, (2004), following Dunbar recognizes that «most researchers see scientific creativity as being composed of the same mental processes that guide all other forms of creativity» (1999, p. 525). Interdisciplinarity creativity might then be defined as a novel and useful solution to a question or problem, which generally involves drawing connections among previously disparate ideas.

The Creative Process and the IRP

The interdisciplinary research process has several steps: asking a suitable research question, gathering insights from relevant disciplines and evaluating these, mapping interdisciplinary linkages, creating common ground among these insights, integrating disciplinary insights, developing a more comprehensive insight, and then testing, reflecting and communicating (Repko & Szostak, 2016). The first and last steps of this process are generally thought to be rational, conscious activities, while the steps in the middle associated with creating common ground and integrating draw much more heavily on the subconscious.

It cannot be stressed too much that the literatures on both creativity and design also envision multi-step processes where subconscious activities are concentrated in the middle (we shall find below that there is scope for creativity also in persuading others toward the end of the process, and recommend this to interdisciplinarians as well). With respect to creativity, a four-step process outlined by Wallas in 1926—preparation, incubation, illumination, and verification—infuses most/all more recent models of creative processes (Spooner, 2004). Wong and Siu (2012) agree that the various creative processes outlined in the literature are broadly similar. Linkner (2011), for example, has five steps: ask, prepare, discover, ignite, and launch. *The Hermann Brain Dominance Instrument* (Herrmann, 1992) also has five steps, with different parts of the brain involved in each: interest, preparation, incubation, illumination, and application. Hermann associates each step with quite different mental processes: For example, Illumination is associated with theta waves, the kind that accompanies meditation or waking up, whereas preparation and verification involve beta waves.

The literature on the design process typically suggests four steps: problem identification, analysis, synthesis, and evaluation. Again, the conscious mind dominates the first and last steps, while the subconscious is critical for the third. Naturally, some versions are more complicated, with additional steps. But the same progression from identifying a problem through gathering and evaluating information to creating something new and then examining this creation is pursued. Mumford, Giorgini, Gibson, and Mecca (2013) thus develop a model that consists of eight steps: problem definition, information gathering, information organization, conceptual combination, idea generation, idea evaluation, implementation planning, and solution monitoring. Though the terminologies used are different, the processes imagined in the three fields are obviously quite similar.

The literatures on creativity, design, and integration concur in a further important respect: They all recognize the importance of iteration, that is, revisiting earlier steps as one proceeds. The literatures on creativity and design differ from the IRP, though in stressing how one creative process feeds into another. The IRP literature has tended to treat individual research processes in isolation (albeit appreciating that they are internally iterative) and could usefully reflect on how one research project might set the stage for others.

The literatures on creativity and design also agree that teachers and students should be aware of the multi-step processes involved; though Doppelt (2009) warns that students should not follow this slavishly. Advocates of the IRP still struggle against a widespread belief that interdisciplinary research is something one can do without consciously pursuing an interdisciplinary research process.

Pasteur (1854/1937, p. 131) warned us over a century ago that creative insights come only to the prepared mind. The literatures on creativity and design discuss in some detail how one can set the stage for creativity while one is gathering relevant information (see also Welch, 2007). The next sections of this chapter draw lessons for the first steps of the IRP.

Asking a Question

The IRP begins with several guidelines for identifying a good interdisciplinary research question: It should be clear, jargon-free, manageable, and beyond the capability of any one discipline to address. The literature on creativity suggests further considerations. And Sill (1996), following others, warns us that:

> The most important part of the creative process may not be the creative product, which in the case of integrative thinking is the integrated thought itself, but rather may well be the framing, discovery, or envisioning of the creative question. (1996, p. 125)

Recall that there are degrees of creativity. If we ask a question of the type "How does A affect B?", we limit the potential for creativity far more than if we ask "How might we alter B?". The second question encourages us to identify novel connections. The first question is, however, much more manageable. An undergraduate with severe time constraints may wish to emphasize manageability, but should appreciate the cost. A scholar wishing to solve/alleviate an intractable problem or gain a reputation may instead prefer to lean toward creativity. The advice then is to word the question in such a way that does not guide one to pursue a narrow range of answers. A creativity-encouraging question is one for which even the broad outline of the answer is not obvious. But questions can be too broad also: "How to make the world better?" may give the subconscious mind no traction. The creativity-enhancing question should at least give us some idea of where to look for relevant information. As we gather information we may develop a more focused question, but not so focused that it eliminates opportunities for creativity.

Scholars of creativity, like scholars of the IRP, appreciate the advantage of a problem-based focus (Doppelt, 2009; Sill, 1996). Sill (1996) suggests that the first step to creativity is asking "What is the real problem?" which invites placing what appears to be the problem in a broader context. For example, understanding why some groups of students are underperforming in school may require looking far beyond the school for answers.

Linkner (2011) advises us to look ahead to the very end of the process. As we shall see, one key aspect of creativity is convincing others that our idea is useful. Linkner thus urges us to reflect not only on the problem itself but on the barriers to its solution, the audience we will need to convince, and the communication techniques we envision. The point here is that there is little value in developing ideas that will never be utilized. But Linkner does not want to discourage us from acting but rather to focus our efforts on developing ideas that we think we can "sell." This may require even greater creativity than simply addressing the problem. Linkner finds it useful both at the start and throughout the creative process to ask not just

"Why?" but also "What if?" and "Why not?". Klein, in this volume (Chap. 4), likewise recommends continued reflection on the question: "Transdisciplinary process is not simply a matter of bringing disciplines to a problem. It entails continually learning what the problem is through critical reflection" (p. 64).

Researchers wishing to pursue creativity, then, should frame their question in a way that guides research but does not constrain answers, grapples with the true nature of the problem at hand, and reflects the environment in which any creative insight will need to be adopted.

Identifying Relevant Disciplines, Theories, Methods, and Phenomena

One element of creativity deserves emphasis here: Creative solutions are to at least some extent "surprising." The ideas that are the most surprising—but also useful—will generally be judged the most creative. There is an important trade-off here, then, between looking where relevant information is most likely and looking where surprising connections are most likely. The advice we give to students—to identify the most relevant disciplines to their research question—is surely valid. But more advanced scholars should recognize that they are more likely to make a surprising connection by looking in less obvious places. A discipline with only a tangential interest in the problem at hand may hold a critical insight into its solution. Moreover, the greater the range of insights—and thus combinations—that one identifies, the more likely one is to be creative (Wong & Siu, 2012).

How do you identify possible surprises? One strategy involves brainstorming the broader context of the problem. One should start out by being open to seemingly crazy ideas. Those ideas that seem like they might have some merit may guide researchers to look in disciplines that would otherwise escape their attention. Brainstorming can thus be contrasted with a more rational identification of the most likely influences.

Literature Search

It should be noted that our present state of "information overload" can itself be a barrier to creativity. McGuinness (2011) worries that some shy away from searching for relevant information because of a sense that there is simply too much. Yet there are at least three distinct literatures in the field of information science—literature-based discovery, undiscovered public knowledge, and serendipity—that each recognize that important scholarly discoveries often come from juxtaposing distinct ideas from different scholarly fields. Szostak, Gnoli, and López-Huertas (2016) discuss how systems of knowledge organization could be changed in order to enhance such juxtapositions in particular and interdisciplinary research more generally; they also provide much insight along the way into the structure of existing systems and how these might be navigated. The interdisciplinary researcher should appreciate that locating the right set of literature—that is connected but in a way that nobody has appreciated—is an important source of creative insights. They should also appreciate that our present systems of library classification do not make it easy to locate distinct but related literatures. The researcher thus needs to reflect deeply on just what sorts of related information might be useful and where they might be hiding.

Evaluating Insights

The IRP provides several strategies for evaluating disciplinary insights—the conclusions generated in disciplinary research—before these can be integrated into a novel and more comprehensive understanding. The strategy with the greatest implication for creativity involves asking of each insight what is left out: What variables, theories, or methods addressed by other disciplines were excluded from view as this insight was developed? (Note that we capture here elements of "What if?" and "Why not?"). Such a strategy guides the researcher to identify connections that are missed in the existing literature.

Again we face a trade-off. We might identify a variable studied by sociologists that fairly obviously deserves attention in a theory posited by economists. We might identify other phenomena whose importance is less obvious. We can make a useful contribution to scholarly understanding by focusing only on the first type of omission—and a contribution that is novel and useful and thus creative. But we may be able to produce a far more creative insight if we reflect a bit more on those phenomena whose importance is less obvious. We are trying to give our subconscious processes a range of possibilities to play with and should be careful not to exclude possibilities that our subconscious may find useful. Creativity necessarily embraces complexity.

Repko and Szostak (2016) provide tables of phenomena studied in various disciplines, types of theories applied, and methods applied. These tables are generally employed in a very conscious process of identifying the most relevant phenomena, theories, and methods. Their role in stimulating creativity deserves also to be highlighted: They potentially provide the subconscious with a broad set of possible connections. The goal for the creative researcher, then, is to look through such tables not just for the obviously relevant items but the "just might be relevant" items. Some may imagine a conflict between the structure of detailed and fairly exhaustive classification and the freedom associated with creativity, but structure can set the stage for novelty.

Note that we do not throw away an insight simply because it has limitations. Rather we ask if other insights can perhaps address these limitations. Again this process will sometimes be straightforward. At other times it will be less obvious how a limitation can be addressed. This situation also becomes grist for our subconscious. In engineering, the Pugh Method involves employing creative thinking to suggest how flaws in various designs might be addressed in order to identify the optimal design. Engineers, it might be noted, do not seek perfection, but recognize that there will be imperfections in any design. In interdisciplinarity, as in design, we need to embrace the idea of ever-better solutions to challenges as we build on previous understandings.

Last but not least, we should be open to surprises. When we encounter a piece of information that is surprising we should carefully examine why this is so. SuperGlue was discovered by accident while researchers were pursuing a quite different project. Many on the research team saw this unexpected stickiness as a problem, but their supervisor recognized that they had a solution to a quite different problem (a recognition, it might be noted, fueled by a breadth of interest and knowledge). We should be willing to let surprises carry us in new directions. In the case of SuperGlue, an entirely new research question was generated (Darbellay, Moody, Sedooka, & Steffen, 2014). Surprises are a regular feature of research and have historically triggered many creative acts (Darbellay et al. mention also Post-it notes, Viagra, and Velcro), but we need to consciously (or subconsciously; see below) appreciate their importance.

Mapping

The IRP recommends visually mapping the connections among phenomena that appear relevant to the research question. This exercise aids the researcher in clarifying insights and in identifying connections not only among phenomena but among disciplines, theories, and methods. Such an exercise in visualization likely also encourages creativity. Creative insights generally *emerge* in the form of imagery: We picture our creative solution in some way (Spooner, 2004), likely because our subconscious operates sublingually. Images are still important as our conscious mind develops the creative insight: «We have re-defined design as being the process of composing a desirable figure toward the future» (Taura & Nagai, 2010, p. 8). If we accept that creative insights are generally visual (and always abstract and symbolic), then it makes sense to prepare our mind visually to achieve these.

How detailed should we get in our mapping? Yet again there is a trade-off between including only those phenomena that seem of great importance to the problem at hand versus attempting a much broader coverage. The literature on engineering design suggests a fairly broad coverage so that potential side-effects of a design are more readily appreciated.

Buzan (2010) has studied creative thinkers across many societies. He recommends a process called mind mapping, where the focal question/problem is placed in the middle of a piece of paper and connections are made to main ideas and thence to subsidiary ideas. Buzan's mind map is similar to the maps recommended in the IRP—though the concepts placed on it need not be variables: We could thus add the theories and methods identified above, and any concepts uncovered in our research.

But his purpose is different: to fire the imagination. Given that creative ideas are (generally) combinations of previous but unconnected ideas, if we place a set of relevant ideas on a piece of paper and then “free-think” about possible connections among them, we greatly enhance the possibility of a creative breakthrough. Buzan recommends using different colors or symbols to identify connections. Even on the sort of map currently recommended in the IRP one could usefully contemplate connections among variables not seemingly related. But Buzan urges us toward a “messier” map where we place every seemingly relevant idea on the same piece of paper, let our subconscious view the whole, and set the stage for the discovery of novel connections.

Mind mapping is intended as an exercise that links conscious and subconscious processes. Studies have shown that multiple parts of the brain are working when contemplating a mind map. The mind consciously identifies the concepts that are placed on the paper. The subconscious then takes them in as a whole and can imagine novel connections. The idea is to not over-structure the diagram but let the brain structure it. As Sill says of creativity in general, “Creativity is found in the human ability to move beyond existing patterns to restructure the patterns themselves, and, as a result, to make a more sophisticated game” (1996, p. 296).

If our task is to restructure existing patterns then it may be invaluable to recognize the stability-enhancing patterns at the heart of each discipline, such as equilibrium between supply and demand in markets in economics, a supportive set of cultural attitudes toward social stratification in sociology, schemas that allow individuals to navigate daily life in psychology, rules of atomic attraction in physics or chemical reactions in chemistry. Such disciplinary systems may of course allow for some types of predictable but manageable change. Interdisciplinary linkages may be part of a wider systemic stability (as when cultural attitudes accept a certain degree of economic inequality) but are often the sources of change as when household technology and new service sector occupations encouraged changes in attitudes toward gender. The implication here is that these stability-enhancing disciplinary patterns should be an important component of our understanding of disciplinary perspective, and interdisciplinary researchers should appreciate that interdisciplinary understandings will often disrupt discipline-level conceptions of stability (see Szostak, 2017).

Teamwork

Since we have identified the act of inspiration above with subconscious activity—and will see below the importance of relaxation and time in generating creative ideas—we may wonder whether truly creative ideas will emerge during team meetings. The literature on teams is divided, with some in the field lauding “brainstorming” and others expressing skepticism. It may be best to understand brainstorming not as “inspiration” but as “illumination”: It juxtaposes diverse ideas in a way that the subconscious minds of group members can then process. How often do we leave a meeting and later on think “Oh, I wish I had said that?”. It is important, then, that team research allow lots of time for individual reflection. Such a strategy has the further advantage that teams do not overly narrow the connections that a team member might make by routinizing and criticizing (Paulus & Korde, 2013).

The literature on teams recognizes the value of bringing different types of people together. It is not good enough to simply ensure that one has the necessary range of disciplinary experts. It is useful, for example, to have a mix of optimists and pessimists. Analysis of the brain suggests that there are important cognitive differences across people (though we can change our cognitive types by exercising different parts of our brain): Some are particularly good at synthesis and imagination; some have strengths in analysis; some have leadership or organizational skills; some are good at connecting people and appreciating feelings. All of these can play a useful role at different stages in the creative process. It would be a mistake to only gather imaginative types. It is often thought, for example, that Enrico Fermi was far more important to the Manhattan Project (which created the atomic bomb) than General Lesley Groves who was its commander. But without the organization of knowledge and experimental data across several fields, Fermi would not have been able to create.

Students and researchers can usefully reflect on what type of thinker they are. They can then perhaps exercise different parts of their brain in order to develop other cognitive capabilities (see below). Or they can have an idea what types of people they should seek to collaborate with. We can, when teaching the IRP, use class discussions to (among other things) celebrate the advantages of bringing different types of thinking to bear on a particular question.

Skills and Attitudes

We have focused so far on how individuals or groups can assemble the ideas that will be drawn upon in the creative act. But the literatures on creativity, design, and the IRP also talk about important skills and attitudes. All, notably, appreciate that creative skills and attitudes can be taught. The first thing to stress both here and in any course on the IRP, then, is that we have to move past the naïve idea of the occasional creative genius in order to appreciate that we all have creative potential.

Sternberg (2006) talks about three broad types of creative skill: The synthetic skills to draw new connections, the analytical skills to separate good from bad ideas, and the persuasive skills to overcome the resistance to novelty. The first set of skills can be developed through the sort of practices urged above; the other two will be addressed below. One of Sternberg’s observations deserves special attention: Students with creative skills do better in educational environments in which creativity is valued, but perform worse when memorization and rote learning is stressed. If we want to encourage creativity in our students, we need to reflect this in our pedagogy and grading rubrics.

Interdisciplinary scholars can celebrate the fact that "perspective taking," an oft-noted interdisciplinary skill, is widely recognized as an important creative skill. Nor is this skill important just in human science. Spooner, (2004) speaks of a chemist imagining himself as a molecule. Einstein said that he had developed his theories of relativity by placing himself inside mass and energy; he imagined viewing clocks from a set of trains traveling at different speeds. There are numerous examples of this sort of perspective taking in the history of science.

Sternberg (2006) notes that people must decide that they want to exercise creative skills. It is often easier in life to go along with the crowd than to innovate. It is invaluable then to discuss with our students what sort of thinkers they aspire to be. If they want to take risks and be tolerant of ambiguity they need to practice such attitudes. Self-confidence is of critical importance here (Weisberg, 1993). Only as students learn that they have creative skills are they likely to embrace creative attitudes. Children are inherently creative but schooling tends to crush the creativity out of us all; we need to re-inspire our natural creativity.

Importantly, attitudes need to be internalized. The intermediate step(s) in the creative process occur largely subconsciously. While our subconscious is best suited to drawing novel connections, it is also guided by our emotions (Sill, 1996). If a person is not really committed to being creative their subconscious will not generate creative ideas. The person may not be consciously aware that they are avoiding creativity. They may be afraid of failure or afraid of ridicule. Note in this respect that both Isaac Newton and Charles Darwin withheld their theories for decades due to (in these cases conscious) fear of ridicule. An academic may subconsciously decide that they are content with a series of uncontroversial contributions, rather than risk a controversial insight. This outcome is particularly likely if they are not emotionally connected to the problem at hand. It is then important that the person comes either to care deeply about certain problems or comes to value novelty for its own sake. Intrinsic motivation is likely far more important for creative processes than extrinsic motivation (Sternberg, 2006).

The risk of ridicule is something that advocates of the IRP should confront directly. The simple fact is that disciplines discipline: Novel ideas are not always given a fair hearing precisely because they threaten existing belief sets and practices. There is, to be sure, a growing body of academics that self-identify as interdisciplinary in orientation. Yet interdisciplinary researchers can be confident that integrative insights will meet some resistance. It is best to confront this possibility consciously rather than allow one's subconscious to decide whether the risk is worthwhile. Our efforts at the institutional level to instantiate quality interdisciplinarity within the academy can alleviate but not eliminate the emotional barriers to interdisciplinarity. This chapter has hopefully alleviated one concern: That a formal research process can impede creativity.

One way to conquer one's fears is to confront them. It may be useful to purposely generate crazy ideas just to show that the world does not end when you do so. The worst that can happen is often far less than what we have feared. Bouncing crazy ideas off someone we trust may encourage us to develop more.

It should also be stressed that ignorance itself is stressful. As psychologists know, we all develop schemas that guide us through our daily lives and give us some sense of control. The creative insight is only possible if we have first recognized a problem that we care about (see above) and for which we lack an attractive solution. The creative insight will generate a greater feeling of relief than the discomfort associated with the previous tension. But if we do not consciously address that discomfort we may again subconsciously avoid it. Self-confidence again comes into play: We are more likely to appreciate our ignorance if we are confident that we can overcome this. Self-confidence comes into play also in later stages: We need to appreciate the weaknesses in our insights, and we need to be able to recognize when certain avenues of inquiry result in failure, for failure is an almost inevitable part of any creative process.

We all know as scholars that being published a few times (or teaching a few courses) helps us have confidence as we embrace a new topic. So we can think of ways to give students confidence through little exercises that allow them to achieve little bits of creativity, or by challenging them to use creative techniques in their private lives.

The Creative Act Itself

We noted at the outset that creative acts tend to occur when we are not consciously thinking about the problem. Creative individuals thus have to divert themselves. Both meditation and exercise can induce the alpha waves that Hermann (1992) associates with creative acts. Purposely slowing one's breath may also help. Several recent studies suggest that mindfulness meditation enhances creativity (e.g., Colzato, Ozturk & Hommel, 2012). Hobbies that take your mind off work can be useful. Calming music is often suggested.

We are very conscious of our senses of sight and hearing. Our senses of touch, smell, and taste operate much more subconsciously: We often have trouble describing what we perceive through these senses. Activating these other senses may thus deactivate conscious processes. It could be that the subconscious draws connections across senses. Aromas are recommended in particular as a means to encourage creativity.

Creative writing courses often urge a process in which one just writes, trying to let the subconscious mind speak directly through one's fingers. The trick is to try not to consciously guide the writing. Writers may then find that they had ideas of which they were unaware. And writers may generate different ideas on different occasions, which can then be combined into a particularly compelling text. The same approach is not as commonly recommended for non-fiction writing. But if we accept that there are commonalities across all types of creativity, then it may prove useful there as well. We perhaps all know colleagues who are such perfectionists that they have trouble committing themselves to any text at all: The idea of writing provisional texts that are intended to be creative may be particularly important for them.

These various strategies may strike many interdisciplinary researchers as bizarre. They are quite distinct from such practices as close reading, critical thinking, and careful analysis. But if researchers will truly appreciate that the IRP is a creative process, then they need to follow strategies that get their entire brain working on their problem.

Nor should we just pursue these strategies when we arrive at step 8 in the IRP. Research shows that we can increase the number and length of the dendrites—which transmit electrical signals—in parts of our brain by exercising that part of our brain; while stress decreases dendrites (Fuchs & Flügge, 2014). If we wish to be occasionally creative, we should regularly pursue practices that encourage creative brain processes.

The time element deserves special attention. Interdisciplinary research takes time (especially as we iterate between conscious and subconscious processes). Carving out time to allow the subconscious to dominate is no easy task, especially when we face tight deadlines. Nor can we hope that it will do so when we are too tired to read or write: Though we sometimes get ideas while half-asleep the subconscious mind also works best when we have energy. We should also be aware of the opposing danger: that we are too relaxed in our overall approach to research and do not do all of the preparatory analysis to set the stage for inspiration. Either way, failure to organize our time may be a subconscious plot to avoid failure. Procrastination is common among creative types; the successfully creative develop strategies to overcome it.

There is a further temptation: Humans may keep busy simply to avoid the existential angst that can be associated with having time on our hands and thus the ability to reflect on what is missing in life. Creativity demands a willingness to spend time alone with ourselves.

More Comprehensive Understanding

The post-inspiration steps in the IRP diverge a bit more than earlier steps from those recognized in the creative design literature. The literature on creativity tends to stress two stages: A critical evaluation process, in which the ideas thrown up by the subconscious are carefully evaluated and clarified, and a communication/selling stage in which others are convinced of the value of the creative ideas that we do develop. We will address communication/selling below. The “critical evaluation” stage is represented in the IRP by disparate steps such as constructing a more comprehensive understanding, reflecting, and testing.

The IRP could make more explicit the fact that our subconscious may present us with numerous ideas. Linkner (2011) stresses that inspiration often comes in little sparks rather than one big eureka; we need to nurture the sparks. Many of these ideas will not be useful. But one or a few may prove very useful. We thus need to envision a conscious process of careful selection of our better ideas, and then careful development of these. We must take care that we do not too quickly jettison ideas at the first recognition of problems with these. The most creative ideas rarely burst from our subconscious ready to be applied in the world. As Klein notes in this volume (Chap. 4), we need a research heuristic that blends divergent thinking—which recognizes many possible solutions—and convergent thinking which identifies linkages.

We mentioned above how Newton and Darwin held back their ideas for years. They both knew that they could not "prove" their theories. Indeed, biologists still struggle to understand how certain complex organs emerged through natural selection, and physicists have come to appreciate that Newtonian mechanics is a special case of more general theories of mass and energy. We need, like Newton and Darwin, to evaluate whether our novel ideas have more strengths than weaknesses. And this will require the exercise of judgment. But if we demand perfection we will never create anything.

One of the critical revision tasks stressed in the design literature is identifying potential side-effects. These may be identified when testing an idea in the real world, and paying close attention to outcomes. As noted above with respect to the side-effects of previous designs, we can see these side-effects as invitations to modify ideas rather than jettison them (Darbellay et al., 2014). Modification may require further acts of creativity.

Communication

The literature on creative design places great emphasis on this step. A creative idea is only useful if it is actually applied, and this means that others have to be convinced that it is a good idea. Sternberg (2006) thus associates creativity more with successfully arguing for novel ideas than with developing these. He notes that in both art and science there have been countless examples of work that is celebrated today but was rejected at first. But the creators persevered and only over time convinced others of the value of their creative insights.

Scholars should appreciate that persuading others is just as important as having good ideas in the first place. But there is a bias within scholarship to imagine that good ideas make it in the world on their own merits. Yet even Newton's theory of gravitation—which could amazingly explain simultaneously how the planets move and why humans do not fly off the earth—needed to be carefully explained to others. As noted above no scientific discovery is perfect, and thus persuasion is an essential component of scientific creativity. This challenge, at least at the present time, is especially great for interdisciplinary insights which must overcome disciplinary resistance.

If the first lesson is that we should pay more heed to persuasion in the IRP, the second is that this is also a creative act. Again we must battle against the naïve presumption that logical argument and detailed evidence will inevitably win the day. Since no argument or evidence is perfect, rhetorical strategies become of crucial importance. Analogies, arguments from examples, appeals to emotion or authority, and carefully crafted prose are among the rhetorical strategies that may mean the difference between an idea being accepted or rejected. Since these are creative acts, we thus have to bring the subconscious back in at this final step in the IRP.

And then emotions matter again. Many scholars are much more comfortable with the development part of academia than with the persuasion part. Such scholars may hold most tightly to the belief that ideas win on their own merits—it would be a wonderful world if this were true. They may tell themselves that it was fate, or just those nasty disciplines, that did not give their ideas their due. The lesson here is that persuasion is not an optional part of the creative process. Sternberg (2006) notes that creative people often thrive on constructive conflict. While thriving may not be essential, the creative academic needs to not avoid or downplay the importance of persuasion—or allow their subconscious to do so. If they do then academic discourse will be dominated by those who are better at persuasion than at developing good ideas in the first place.

Researchers may hope that their ideas will be greeted with immediate applause. But the fact is that the most creative ideas are often greeted with skepticism. Scholars can take guidance from those many insights that were viewed skeptically at first but came to be judged transformative over time. Moreover, one never has a better opportunity to persuade than when one's ideas are critiqued, for then one faces the simpler task of pointing out weaknesses in counter-arguments. More prosaically, while it may be harder to get creative ideas published, these have a much greater chance of one day being widely cited. Conscious appreciation of these facts of life may help subdue subconscious fears of scholarly objection to creative ideas.

Evaluation

How should editors or referees judge the creativity of a piece of research? They can look at the outcome and evaluate its novelty and usefulness. The last part will be especially tricky, for the utility of truly novel ideas is often not immediately obvious. They can also look at the process to see whether creativity-enhancing strategies were pursued. In judging student work this should perhaps introduce an element of fairness into the evaluation for creativity is a risky project and sometimes one does all the right things and does not have a creative breakthrough. Note also that a research paper that is not itself terribly creative may spark creativity in others—perhaps because the first paper missed one key element that another can add.

Institutions

We have mentioned the institutional environment above more than once. Hemlin, Olsson, and Denti (2013) summarize the empirical research on creativity, noting that this has identified valuable individual and team characteristics but also supportive institutional elements: A supportive environment, including encouragement for innovation, sufficient resources, access to expertise and information, autonomy, and an empowering leadership style. Our universities, granting agencies, and journals can encourage creativity by being more supportive of it: Universities and granting agencies can appreciate that creativity is risky and time-consuming; journals can see value in controversial ideas. Perhaps most importantly, journals could recognize that no argument is perfect, and that pretending otherwise encourages a scholarly focus on minutiae.

We noted above that it would be feasible to change the way we organize information in a way that would facilitate interdisciplinarity and creativity. We can note here that these changes would make it easier to find insights that received little attention when first published. Such an institutional change might thus tip the balance away from ideas that are sold well toward ideas that are useful. All of these institutional enhancements could encourage researchers to employ the various creativity-enhancing strategies outlined above.

Conclusion

The IRP is a creative design process: It follows a similar set of steps and can/should employ many of the same strategies. Various strategies can be pursued in the early steps of the process which increase the likelihood and degree of creativity—but these strategies are inherently risky and time-consuming. Just as it is useful for creative design students to be acquainted with the creative design process, the IRP can encourage rather than detract from scholarly creativity. But this will be the case only if researchers are acquainted with the many trade-offs along the way. The creative act itself can be encouraged by a range of practices quite distinct from those pursued in earlier steps. We then need to carefully evaluate the necessarily imperfect ideas that our subconscious generates. Perhaps most importantly of all, we then need to engage in the essentially creative act of persuasion. This paper has urged a variety of creative strategies that are entirely compatible with the IRP: Collectively these show that the IRP can and should encourage creativity.

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Chapter 3
Large-Scale Interdisciplinary Design Thinking for Dealing with Twenty-First Century Problems and Opportunities

Don Ambrose

Abstract This analysis extends creative design thinking to the macro-level, applying it to the enormous problems and opportunities generated by twenty-first century globalization. Today's macroproblems and macro-opportunities require creative, interdisciplinary thinking, and collaboration to enable individuals and teams to address the dogmatism that hinders perception of the complexity embedded in complex issues. Suggestions are made for grappling with dogmatism. Examples of interdisciplinary projects aimed at large-scale creative design thinking are provided. Some barriers to creative interdisciplinary work are examined. Finally, the use of visual–metaphorical artistic design is explored as a strategy for simplifying and synthesizing complex ideas and strengthening interdisciplinary creative design thinking.

Keywords Interdisciplinary · Creative thinking · Critical thinking
Dogmatism · Globalization

Introduction

Twenty-first century globalization presents us with enormous macroproblems and macro-opportunities (see Ambrose & Sternberg, 2016a, b). A macroproblem is very difficult to address because it is (a) international so it cannot be solved from within the borders of a single nation no matter how powerful; (b) interdisciplinary because it cannot be solved by marshaling the knowledge base and expertise of a single academic discipline or professional field; and (c) long term because it took decades or even centuries to create. Just a few examples of macroproblems include climate change (see Archer, 2009; Friedrichs, 2013; Nordhaus, 2013; Sherwood & Huber, 2010; Verchick, 2010), natural resource shortages (see Klare, 2012), the erosion of democratic governance in developed nations (see Hacker & Pierson, 2005, 2010;

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Wolin, 2004, 2008), and severe socioeconomic inequality (see Piketty, 2014; Stiglitz, 2010; Wilkinson & Pickett, 2009). A macro-opportunity is a set of conditions that could lead to unprecedented, widespread prosperity, and self-fulfillment. Examples include the enormous potential in the global networking of scientific minds (see Nielsen, 2011), and growing recognition of the benefits deriving from cognitive diversity in organizational teams (see Page, 2007, 2010). When it comes to complex problem solving in organizations, cognitively diverse teams consistently outperform homogenous teams. A cognitively diverse team encompasses diverse philosophical and theoretical perspectives, problem solving heuristics, belief systems, and knowledge bases.

As pointed out by the editors of this volume, design thinking has expanded beyond emphases on specific processes and products. Now, it is being applied to broader problem solving. In this chapter, I propose that interdisciplinary exploration and collaboration can expand creative design thinking to the macro level, thereby giving us some of the conceptual tools necessary for handling twenty-first century macroproblems and macro-opportunities. First, I discuss some daunting barriers to macro-level creative design thinking. These barriers tend to arise from various forms of dogmatism. Second, I describe the ways in which interdisciplinary exploration and collaboration can help us understand and deal with the complexities of macroproblems and macro-opportunities. Examples of some recent interdisciplinary projects flesh out this description. Third, I recommend some next steps for the development and support of the interdisciplinary expertise we will need for dealing with the complexities of our rapidly evolving socioeconomic, technological, and cultural systems.

Dogmatism Preventing Perception of Twenty-First Century Macroproblems and Macro-opportunities

Why is it so difficult to deal with big problems and opportunities? Arguably, we need an evolutionary leap forward in our capacities to think big picture, but we seem to be remarkably resistant to such a leap. This arises from the problem of dogmatism. Suggest to anyone that he or she is dogmatic and you will raise hackles and evoke indignant argumentation. None of us like to believe that we are dogmatic in any way; however, all of us likely are dogmatic to some extent about some concepts and issues. Dogmatic inclinations have caused enormous problems and catastrophes throughout human history, and the situation doesn't seem to be improving, at least not markedly so. The narrow-minded, rigid, superficial thinking caused by dogmatism is responsible for inflexible adherence to inadequate, worn-out theories such as the excessive entrapment within behaviorism in psychology during the mid-twentieth century (see Ambrose, 2009; Cross, 2003; Gardner, 2008) and the rational actor model that dominates neoclassical economic theory making human behavior seem like it derives from hyper-rational, Spock-like creatures that have been sanitized of altruism (see Ambrose, 2012b; Piketty, 2014; Sen, 2010; Stiglitz, 2010). Various forms of dogmatism have confined populations within competing, other-hating identity groups that have precipitated ethnocentrism, racism, slavery, minor and major wars, terrorism, and genocide (Ambrose & Cross, 2009; Ambrose & Sternberg, 2012; Ambrose, Sternberg, & Sriraman, 2012; Granik, 2013). So it seems that much of the misery experienced throughout human history has been caused by this serious flaw in human cognition.

While the most spectacularly damaging macroproblems seem to come from dogmatism that is widely shared throughout a population, academia and the professions certainly are not immune. There is accumulating evidence that deepening expertise can produce dogmatism, and that intelligence and giftedness can be accompanied by dogmatic idea frameworks (Elder & Paul, 2012; Ottati, Price, Wilson & Sumaktoyo, 2015). A particular form of dogmatism involving a craving for certainty, clarity, and specialization exerts considerable pressure on academic disciplines and professional fields. For example, three leading thinkers in three different disciplines discussed the ways in which a craving for certainty limits progress in their fields. The prominent mathematician Byers (2007, 2011) coined the term *sterile certainty* to illustrate the ways in which researchers and theorists in mathematics and the natural sciences tend to impose unwarranted conceptual order on the phenomena they are studying. The result is somewhat artificial certainty and precision while, in actuality, inquiry in mathematics and the natural sciences is much less precise, certain, and bound to logic than is commonly assumed.

Along similar lines, the prominent political scientist Shapiro (2005) critiqued scholarship in the social sciences and humanities, paying particular attention to the law and economics paradigm and the rational choice model that dominates this thought framework. He showed that many researchers in these fields tend to be captured by the intricacies of their dominant theories and methodological tools and lose focus on the complexity of the phenomena they are studying. This results in overzealous statistical modeling and excessive reductionism, which oversimplifies and sanitizes the phenomena. Shapiro described this problem as the *Flight from reality in the human sciences.*

Also, in his groundbreaking book on the flaws in the global economic system the leading economist Piketty (2014) argued that his discipline is caught up in a dogmatic *scientific illusion* because the scholars in his field crave recognition of their work as scientific. Consequently, they ignore the contextual influences on economic behavior that comes from political and cultural dynamics. His description of what is behind the scientific illusion is revelatory:

> I dislike the expression "economic science," which strikes me as terribly arrogant because it suggests that economics has attained a higher scientific status than the other social sciences. […]. For far too long economists have sought to define themselves in terms of their supposedly scientific methods. In fact, those methods rely on an immoderate use of mathematical models, which are frequently no more than an excuse for occupying the terrain and masking the vacuity of the content. (Piketty, 2014, pp. 573–575)

In short, it seems to be the groundbreaking scholars in various fields who escape the dogmatism of sterile certainty in order to embrace ambiguity, aesthetics, subtle contextual influences, and complexity, while the more pedestrian thinkers in those fields crave certainty and impose it on the knowledge bases within their fields. One way to escape sterile certainty is to engage in interdisciplinary explorations and connect concepts across the conceptual border fences that keep knowledge bases separate.

Some Examples of Interdisciplinary Explorations Aimed at Combating Dogmatism and Illuminating the Big Picture

While much can be gained from research and theory within the borders of single academic disciplines and professional fields, the big problems and opportunities of the twenty-first century require macro-level creative design thinking that includes interdisciplinary synthesizing and collaboration. For example, solution of climate change certainly will require the domain-specific expertise of climate scientists; however, we will need to combine this expertise with the work of (a) philosophers and psychologists who can reveal the dynamics of the dogmatism that prevents much of the population from perceiving and addressing this macroproblem, (b) economists who can recommend modifications to our economic systems that will favor innovation in the green energy sector, and (c) political scientists who can point out where corruption in democratic governance systems prevents the implementation of regulatory frameworks that can diminish the spewing of greenhouse gases. Experts from other fields also will be needed.

Some examples can provide additional clarification about the need for this interdisciplinary work. The following are brief descriptions of projects that bring into play diverse perspectives on phenomena often confined within single disciplines or professional fields. They represent attempts to engage in creative design thinking applied to big, complex issues. I begin with some of my own interdisciplinary projects pertaining to the strengthening of creative intelligence, which is a twenty-first century macro-opportunity (Ambrose & Sternberg, 2016a, b) and then discuss a few other interdisciplinary initiatives that can be considered examples of macro-level creative design thinking.

Broader Visions of Creative Intelligence

Much of my interdisciplinary work comes from traveling far and wide through the terrain of multiple disciplines to extract insights that can clarify and strengthen our conceptions of creative intelligence. A few of these projects, described here, involved the translation of academic concepts across disciplinary borders, making creative associations about creative intelligence by smacking together theories and research findings from many disciplines and professional fields; bringing diverse disciplinary insights into play while focusing on the moral–ethical dimensions of creative intelligence; combating dogmatism by viewing its nuances through interdisciplinary analyses; bringing together ideas from diverse fields to look at creative intelligence through the conceptual lenses created by complexity theory; analyzing the ways in which twenty-first century globalization will require us to accelerate the evolution of our conceptual abilities; and importing findings from neuroscience into gifted education.

One project involved a very broad exploration of 89 theories and research findings from 29 academic disciplines and professional fields (Ambrose, 2009). In this undertaking, I looked for constructs that could contribute to our understanding of creativity, intelligence, giftedness and talent development. Most research and theory pertaining to these concepts come from psychology and educational research with a little coming from other fields such as business and cognitive science, so I deliberately went far afield to discover connections that had received little or no previous treatment. Each extracted insight was summarized in some detail and then cross referenced with one or more other constructs from different disciplines to generate creative association mind sparks. For example, the problem of anti-intellectualism has plagued American society for some time (Bender & Schorske, 1997; Hofstadter, 1963). This erodes public faith in academic research findings and leads to unwise federal, state, and local policies, including the corporatization of the university which, in turn, robs young people of their capacities for higher-order thinking. After describing the details of anti-intellectualism, which derive from political science, history, and philosophy, I connected the phenomenon with a construct from the history and philosophy of science—the aesthetic beauty that drives scientific inquiry (see Dyson, 1995; Holton, 1996, 1998; Miller, 1996; Weschler, 1988). Based on this interdisciplinary connection, I hypothesized that at least some manifestations of anti-intellectualism arise from the remoteness of academic constructs from the minds of most in the lay public. While the beauty of experimental phenomena and intricate mathematical calculations can be aesthetically appealing to the scientific and mathematical experts who are doing the research, these phenomena and inquiry tools are so remote from the experiences of ordinary citizens that they cannot appreciate the aesthetics. Further, I also hypothesized that a form of anti-intellectualism might arise between accomplished scholars in different disciplines because the phenomena and inquiry tools in one discipline might differ substantially from those in another discipline.

For example, a biologist may perceive the aesthetic power of new genetic findings but not the beauty of Gödel's incompleteness theorem, which tends to captivate mathematicians and theoretical physicists. When members of interdisciplinary teams are unable to appreciate the value in each other's work, they tend to talk past each other, or they engage in excessive conflict (Ambrose, 1992). Some of this underappreciation of foreign concepts may derive from the inaccessibility of the aesthetics of the constructs under consideration. When it comes to profound scholarly and scientific concepts, beauty may indeed be much more than skin deep. It is possible that only those who have spent their lives developing impressive expertise with the knowledge, skills, and dispositions of a particular discipline can get well under the skin of discipline-specific concepts. (Ambrose, 2009, pp. 77–78)

So if this hypothesis has some potential, it could be that a modified form of anti-intellectualism contributes to the difficulty of interdisciplinary work, thereby making it more difficult to discover and synthesize theories and research findings that could flesh out our currently incomplete understandings of creative intelligence. If we can find ways to overcome this problem, we might be able to accelerate the creative design thinking needed to produce the stronger human minds needed for tackling twenty-first century macroproblems.

Several other book projects brought together researchers and theorists from diverse disciplines to deal with various dimensions of creative intelligence. One of these projects represented an attempt to expand our thinking about the moral–ethical aspects of creativity and giftedness (Ambrose & Cross, 2009). While many of the contributing authors were leading psychologists and educational researchers, other collaborators came from philosophy, law, critical thinking, theoretical physics, political science, political philosophy, neuroscience, and economics. These "outside" contributors enabled us to consider the ways in which: (a) resource exploitation and environmental abuse come from distortions of creative intelligence (economics); (b) Aristotle's golden mean, a philosophical injunction favoring moderate positions between extremes, might apply to decisions made through creative thinking (philosophy); (c) neuroplasticity (neuroscience) can connect with both free will and self-transcendence (political philosophy); and (d) we construct ourselves through identity formation strongly influenced by the values and legal frameworks that dominate the society into which we are born (law); among other connections.

As previewed in an earlier section of this chapter, two other book projects brought together leading thinkers who analyzed the distortion and suppression of creative intelligence by the common plague of dogmatism (Ambrose & Sternberg, 2012; Ambrose et al., 2012). The majority of the contributors were prominent psychologists but some "outsiders," were involved. For example, leading military historian Bacevich (2012) showed how otherwise intelligent leaders repeat the mistake of plunging their societies into devastating wars on the mistaken assumption that they can avoid the mistakes of leaders from the past. Sociologist Chirot (2012) described ways in which creative, intelligent, but unethical leaders fire up their followers to the point where they willingly engage in genocide for the purposes of expedience, exacting revenge, preempting imagined attacks, and fear of pollution by impure outsiders. Other topics dealt within these volumes included the nature of creative but unethical leaders who manipulate thoughtless, authoritarian followers; the distortions of creative intelligence that can come from utopian ideological and political belief systems; the devastating socioeconomic circumstances that can emerge from narrow-minded, dogmatic economic theory; and the ways in which dogmatic educational reformers are leeching creativity from the American education system. All of these illuminations of dogmatism can help us design stronger creative intelligence by recognizing and possibly counteracting some of the most pernicious influences on the mind.

Several other collaborative projects continued these interdisciplinary explorations of creative intelligence. Yet another anthology brought together theorists, researchers, and professionals from psychology, education, business, urban planning, mathematics, philosophy, and organizational leadership (Ambrose, Sriraman & Pierce, 2014). These scholars synthesized their expertise with discoveries in complexity theory to shed light on the ways in which human minds, which are complex adaptive systems, can be strengthened in order to grapple more effectively with the complexity we face in today's world. Two more projects brought together many of the world's leading scholars of creativity and giftedness, so they could react to a wide-ranging, in-depth, interdisciplinary analysis of the structure and dynamics of twenty-first century globalization (Ambrose & Sternberg, 2016a, b). Their purpose was to respond to the demands of globalization through the lenses of their expertise. More discussion of the creative design thinking embedded in these twenty-first century projects appears elsewhere in this chapter. In addition, two special issues of the *Roeper Review* brought important findings from neuroscience into the field of gifted education to clarify some of the inner workings of the brain–mind system as well as the dynamics of visual–spatial thinking (Kalbfleisch, 2008, 2013). The results were new insights about cognitive development and differences.

These are brief descriptions of some of my efforts to expand creative intelligence inquiry into the terrain of foreign disciplines. There has been other work on generating interdisciplinary syntheses of research and theory pertinent to conceptions of creativity and intelligence. For example, Malone and Bernstein (2015) pulled together insights from economics, biology, artificial intelligence, cognitive psychology, social psychology, organizational theory, communications, and legal studies to produce new perspectives on the nature and dynamics of collective intelligence. This synthesis revealed some ways in which the integration of people through technology is generating intelligent ideas and behavior. This aligns with the strengths of networked science, which enables syntheses of "modularized micro-expertise" from contributors around the world who work on very difficult problems in mathematics, architecture, and biology (Nielsen, 2011). The syntheses of small pieces of complex intellectual puzzles through online systems tend to produce better results than can arise from the work of isolated geniuses or even insular teams comprised of geniuses.

Digging into the Complexities of Socioeconomic Inequality

The globalization of the economy is making it easier for corporations to hide profits from taxation while outsourcing employment to third world sweatshops and shedding well compensated workers in developed nations (Stiglitz, 2003, 2010; Piketty, 2014; Madrick, 2011, 2014). The result is growing socioeconomic inequality within developed nations. This is an enormous twenty-first century macroproblem that requires syntheses of insights from relevant disciplines. Most academic work on inequality takes place within the fields of economics and sociology; however, some interdisciplinary projects have arisen to expand our thinking about this problem. For example, Hardi, Heywood, and Torsello (2015) brought together experts from political science, law, business, philosophy, anthropology, and behavioral science to shed light on the ways in which inequality and corruption mutually reinforce, pushing massive amounts of resources upward from the majority of the population to the elites while damaging societal processes and institutions by generating a sense of pessimism throughout the population.

Making Medicine More Innovative

Goldman (2016) described some momentum toward breaking down the barriers of specialization between physicians, scientists, regulators, and policymakers to enable more holistic visions of healthcare issues. The integration of knowledge from diverse fields promises to enable more patient-centered care that recognizes the genetic, environmental, and lifestyle influences on the well-being of individuals. In the long run, healthcare education might become more interdisciplinary to enable physicians to employ precise, mechanistic interventions that simultaneously recognize contextual, environmental influences on health. This could represent creative design thinking aimed at solving healthcare problems around the world, which can be construed as aspects of yet another macroproblem.

Other Examples of Promising Interdisciplinary Work

Suresh (2013), former director of the National Science Foundation and chair of the Global Research Council, argued that the new norm in scientific work entails international, interdisciplinary collaboration. If Suresh is right, domain-specific expertise and interdisciplinary collaboration must work together to enable us to solve twenty-first century macroproblems and capitalize on macro-opportunities. The examples provided in prior sections of this chapter establish some support for Suresh's claim. Here are a few other examples of productive interdisciplinary synthesizing and collaboration.

- Le Bihan (2015) described some ways in which experts in neuroscience, medicine, and physics are refining and strengthening neuroimaging techniques that can expand our knowledge of cognition.
- Investigators continue to reveal connections between the arts and productivity in STEM fields (See Ambrose, 2015; Edwards, 2010; Fisher, Green & Arias-Hernández, 2011; Gamwell, 2015; Root-Bernstein et al., 2008; Winner, 2007). Expanding knowledge of these art–science connections is particularly important given the marginalization of the arts in the dogmatic school reform initiatives that have done so much to damage education, especially in the USA (see Berliner, 2011, 2012; Ravitch, 2010, 2013).

- Larson (2014) explored the impact of metaphorical conceptions on environmental science. He brought into play an array of ideas and findings from ecology, biology, sociology, psychology, and linguistics, among other fields. This work aligns with research showing the powerful impact of metaphor on thought, and the ways in which metaphorical constructs can trap us within dogmatism or free us from it (e.g., Ambrose, 1996, 1998, 2000, 2009, 2012a; Lakoff & Johnson, 1980, 1999; Sternberg, 1990).
- Other projects addressing environmental issues get right to the heart of interdisciplinary work. Rice (2013) showed how environmental scientists increasingly recognize the interconnections among systems within systems and the concomitant need for crossing the borders at the edges of scientific disciplines and professional fields. He identified barriers hindering interdisciplinary collaboration and international cooperation aimed at the improvement of environmental awareness and protection. Along similar lines, Weart (2012) described how climatology was ineffective until it became more interdisciplinary. This occurred near the beginning of the twenty-first century when the Intergovernmental Panel on Climate Change triggered interdisciplinary collaboration facilitated primarily by advances in computer modeling. Climate change is a global macroproblem, so this kind of work is an especially promising example of interdisciplinary creative design thinking.
- Strong efforts have been made to generate interdisciplinary syntheses of work in psychiatry, clinical psychology, and cognitive/affective neuroscience to shed light on the nature of empathy (see Decety, 2011; Decety & Ickes, 2009). This work emerges from the recognition that domain-specific insularity will prevent us from perceiving the connections between biological, cognitive, and social phenomena that contribute to manifestations of empathy, or its lack, in human interactions. The presence or lack of empathy strongly shapes the socioeconomic and cultural products of creative minds, so work along these lines should make significant contributions to creative design thinking about innovative products and processes.

These are some examples of interdisciplinary work that can be considered as creative design thinking for the solution of macroproblems and the recognition of macro-opportunities. With the increase in interdisciplinary work, we can expect more examples like these to emerge in the years to come. But to facilitate the emergence of those examples, we must find ways to make interdisciplinary work more rewarding and efficient.

Strategies for Strengthening Large-Scale Interdisciplinary Creative Design Thinking

Engaging in interdisciplinary work is not easy, and it is made far more difficult if its purpose is to help us grapple with the immensely complex macroproblems and macro-opportunities of the twenty-first century. A comprehensive treatment of strategies for strengthening interdisciplinary thought and action would require a treatise much longer than this chapter; however, two examples are provided here. They have to do with strengthening the reward systems for interdisciplinary work and overcoming the difficult communication problems that arise from epistemological differences between disciplines.

Addressing the Lack of Professional Reward for Interdisciplinary Work

Academic and professional success usually requires deep immersion within the knowledge base of a chosen field. For example, the promotion and tenure process in an academic discipline forces faculty members to accumulate extensive knowledge about a particular niche within the discipline, and master a set of inquiry tools appropriate for impressive empirical or theoretical work. In the publish or perish environment established by the requirements of the institution and the profession, those faculty members have to know the research terrain so they can discover high-potential pieces of territory for drilling empirical holes in search of knowledge gemstones. All of this requires a tremendous commitment of time and effort. Anyone who deviates from this pattern to climb over the fences between disciplines and explore the conceptual terrain in foreign fields is jeopardizing her or his prospects for promotion and tenure. Those who do take this risk jeopardize their chances for achieving anything near eminence in their discipline. Consequently, there is strong disincentive for those who might be inclined to think in big picture ways and engage in interdisciplinary inquiry.

I certainly felt these pressures in the early years of my transition to higher education; however, the interdisciplinary work I did in graduate school was so compelling and intrinsically motivating that I did not care much about the long-term consequences. Pursuing interdisciplinary exploration likely hurt me in some ways, but the fascinating journey into the terrain of so many diverse fields was more than enough reward to compensate.

That said, if we are to develop sufficient interdisciplinary expertise to understand and grapple with twenty-first century macroproblems and macro-opportunities, we must find ways to incentivize this kind of work. Returning to Suresh's (2013) observation that the new way of doing science is international, interdisciplinary collaboration could help with that. The growing emphasis on interdisciplinary work (see Frodeman, Klein, Mitchum & Holbrook, 2010) along with a growing recognition that such work is necessary for tomorrow's scientific progress could motivate more young scholars to pursue this kind of research and theory development.

Academia and the professions must recognize the need for support along these lines. For example, highlighting the methodological, empirical dogmatism embedded in the *flight from reality in the human sciences* (Shapiro, 2005), the *scientific illusion* (Piketty, 2014), and the *sterile certainty* of excessively mechanistic models and methods (Byers, 2007, 2011) throughout the academic world could prevent at least some new academics from non-reflectively pursuing the path of least resistance and investigating only a tiny patch of conceptual terrain in great depth and detail when they may be inclined to elevate their vision and gain glimpses of intriguing patterns in foreign disciplines. A combined message along these lines from a leading political scientist (Shapiro), a prominent economist (Piketty), and a renowned mathematician (Byers) provide some weighty perspectival triangulation that warrants attention from young scholars as well as their older mentors.

However, this bumps up against the accumulating work on domain-specific expertise in both creativity studies (see Baer, 2012, 2015, 2016) and gifted education (Olszewski-Kubilius, Subotnik & Worrell, 2016; Subotnik, Olszewski-Kubilius & Worrell, 2011). This research increasingly portrays creativity and giftedness as aligned with the development of deep expertise, which leads toward eminence in a specific academic discipline or professional field. Metaphorically speaking, scholars or professionals building excellence along these lines would stay focused on a particular patch of territory within the fence separating their field from foreign disciplines. They would become intimately familiar with most of the detail within that patch; however, they would be disincentivized from engaging in interdisciplinary work. It simply would seem counterproductive because it would distract attention from the primary purpose of mastering the selected patch of terrain and possibly becoming eminent within it.

Those highlighting the importance of domain-specific expertise certainly have an important message and we must not ignore it. However, higher-order thinking entails nuanced judgment, which brings with it the ability to embrace conflicting ideas simultaneously and to possibly generate creative syntheses of opposing constructs (Elder & Paul, 2012; Paul & Elder, 2002; Resnick, 1987). If academic disciplines and professional fields are to achieve the kind of higher-order thinking necessary for success in the complexity of twenty-first century globalization, they must develop sufficient nuanced judgment to embrace and synthesize *both* the research on domain-specific expertise *and* the research on interdisciplinary exploration. This cannot become an either or battle between proponents of opposing sides. In order to solve today's macroproblems and capitalize on macro-opportunities, our finest minds must seek out insights from those who develop impressive expertise within specific domains and find ways to combine those insights across the border fences that separate diverse domains.

This suggests that a particular form of cognitive diversity must become more prominent in the years ahead. Recall that cognitively diverse teams in organizations encompass diverse theories and philosophical perspectives, diverse problem-solving heuristics, and diverse belief systems and backgrounds (Page, 2007, 2010). If we can prevent excessive argumentation between those who favor domain-specific expertise and those who prefer big picture, interdisciplinary pattern finding, we might be able to bring them together to capitalize on their diverse minds. Bringing together gifted, creative, domain-specific specialists and highly intelligent interdisciplinary explorers could generate the cognitive diversity necessary for digging up brilliant conceptual gemstones from various domain-specific patches of academic territory and then synthesizing them into impressive transdisciplinary chandeliers that can shed sufficient light on the complexity of macroproblems and macro-opportunities.

Artistic "Pidginization" of Foreign Concepts

The historian of science Galison (2001) discussed major barriers to interdisciplinary collaboration posed by epistemological differences that make communication between experts in different fields difficult. When they attempt cross-disciplinary communication even highly accomplished scholars have difficulty understanding the concepts coming from a foreign discipline almost as if those concepts represent terminology from a foreign language. Consequently, Galison said that cross-disciplinary communication takes the form of a pidginization, which is analogous to the simplification of language as it moves from one culture to another. In Galison's words, such pidginization "facilitates common border interactions so coordination around specific problems and sites becomes possible even where globally shared meanings are not. The history of physics can be seen profitably as a myriad of such productive, heterogeneous confrontations" (p. 189). For this reason, I've been exploring ways in which visual–metaphorical renderings can facilitate interdisciplinary communication by synthesizing and simplifying enormous amounts of diverse research findings and theoretical constructs.

Cohen (1994) jump-started this visual metaphorical process by recognizing the interdisciplinary pidginization problem when she organized several week-long conferences involving leading theorists and researchers who were studying creative intelligence from various disciplinary perspectives. She brought together over 20 prominent scholars to meet at theory summit sessions in an idyllic setting on the West Coast of the USA. Their purpose was to "unify theories of creative intelligence," which turned out to be an unreachable goal with a complexity making it nearly analogous to discovering the meaning of the universe (see Ambrose, Cohen & Tannenbaum, 2003). Nevertheless, the participants made strong efforts to share important ideas and strive for conceptual syntheses. Many of them were psychologists and scholars of giftedness and talent. But others came from philosophy, economics, neuroscience, and theoretical physics. As a graduate student facilitator during these conferences, my job was to translate the participants' theoretical and research position papers into the form of visual metaphors with accompanying labels and legends, so other participants from other disciplines could simply look at a picture and read the brief accompanying text to understand the work of someone else. This attempt at translation worked exceptionally well for some participants but did not do much for the majority (Ambrose, 1992). Figure 3.1 is an example of a visual metaphor with the accompanying explanation of the symbolism.

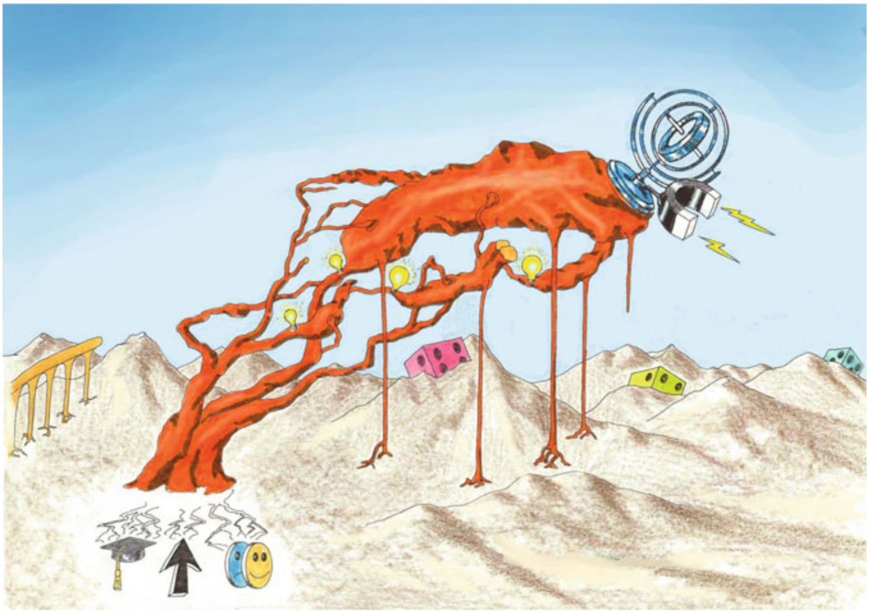

Fig. 3.1 Visual–metaphorical synthesis of Howard Gruber's (1989, 1999; Gruber & Bödeker, 2005) scholarship on the evolving systems approach to creative work (Ambrose, 2017)

Explanatory notes of Fig. 3.1

Explanation of the symbolism in the visual metaphor representing the long-term work of a highly creative individual:

- Body of the "plant" = the network of enterprises comprised of multiple, intertwining creative projects.
- Mortarboard (impressive knowledge base), arrow (powerful, motivational sense of purpose), and faces of the emotion (strong affect and aesthetic appreciation) in the root system = the subterranean sustenance (intertwining seed and root system) for the entire network of enterprises.
- Lightbulb of insight = a creative insight that diverts personal resources and motivation into a particular branch (enterprise) making it grow vibrantly. The bulbs do not just switch on; instead, they glimmer and light up over time, so an insight is preceded by an affectively laden, growing awareness of something important.
- Gyrocompass of purpose at the front of the network = keeps the network heading in a general direction toward creative, long-term purposeful achievement; derives signals from the system of purpose in the root complex.

- Magnet of innovation = a deviation-amplifying influence pulling the network toward the metallic dice of opportunity (representing chance) that emerges from the shifting sands of the socioeconomic and cultural environment. The gyrocompass and magnet often are in dynamic tension with the former attempting to keep the network on course and the latter attempting to pull it off course.
- Rootstocks of felicity = “ground” the network into the environmental milieu by clarifying the compatibility of the creative endeavor with human needs, purposes, and values. Without the rootstocks the system would collapse regardless of its elegance.

While visual–metaphorical rendering of complex academic content seems rather arcane, and it did not work for many of the theory summit participants, it is worthy of exploration because it represents a powerful way to condense vast amounts of material and makes it understandable to others. More research on visual–metaphorical translation, which Cohen (1994) termed “mode switching” because it involved switching from verbal to visual thought modality, could help turn this into a strong tool for scaffolding interdisciplinary work.

Conclusion

These examples of strategies for strengthening interdisciplinary thought and communication certainly are not comprehensive. They do, however, suggest some ways that researchers and theorists can push toward the idea of expanding interdisciplinary work. In view of Suresh’s (2013) observation that the new way of doing science entails international, interdisciplinary collaboration, we must strive to move interdisciplinary research and theory development to the front-center stage of academia and the professions. We can take some steps toward that by magnifying its importance as a method for creative design thinking aimed at solving the macroproblems and capitalizing on the macro-opportunities of twenty-first century globalization.

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Chapter 4
Creativity, Design, and Transdisciplinarity

Julie Thompson Klein

Abstract This chapter explores the relationship of creativity, design, and transdisciplinarity, with emphasis on collaborative research. It sorts through definitions of the core terms in order to identify their intersections across discourses of transdisciplinarity. Outcomes differ from extending an existing approach to redirecting or reformulating it. Contexts likewise differ from product innovation to environmental problem solving. However, shared characteristics of novelty, boundary crossing, and generativity appear widely as well as synthesis, critique, and reflexivity. In the first of three examples—architecture and urban planning—transdisciplinary approaches are generating new hybrid modes of inquiry and action that are bridging gaps between critical theory and projective design and between practice and social, political, and normative concerns. Designerly ways of thinking are also leveraging creative dimensions of practice, fostering relational knowledge while being open to subjectivity and the unexpected. The second example—environmental sustainability—highlights heuristic thinking in an "ecological rationality" or "pragmatism" that fits a particular problem, rather than deriving from a generic method. Transdisciplinary problem solving is reimagined as a creative art of invention, accentuating discovery and learning. The third example—integrations of physical sciences and engineering with life sciences and medicine—is fostering creative development of alternative methods and protocols. A process of divergence–convergence is spinning off new uses through "combinatorial innovation." The chapter closes by reflecting on an overriding topic that emerges from intersections of the core concepts—situated learning—then concludes by reflecting on the phenomenon of increased boundary crossing.

Keywords Transdisciplinarity · Creativity · Design · Interdisciplinarity
Boundary crossing

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Introduction

The concepts of creativity, design, and transdisciplinarity have rich histories.[1] Their intersections, though, have never been examined at length. This chapter tracks junctures of meaning in order to identify elements of creativity and design thinking in transdisciplinarity, with emphasis on collaborative research. It establishes a foundational link between characteristics of creativity and interdisciplinarity then extends those characteristics to designerly ways of thinking in three examples of transdisciplinary research: architecture and urban planning, sustainability, and integrations of life sciences with physical sciences and engineering. The pivotal term—transdisciplinarity (TD)—is dated conventionally to the first international conference on interdisciplinary research and teaching in 1970. The definition of "interdisciplinarity" was wide, encompassing interactions among two or more disciplines from simple communication of ideas to mutual integration of concepts, methodologies, procedures, epistemology, terminology, and data. In comparison the definition of "transdisciplinarity" was narrower, connoting a higher level of synthesis in "a common system of axioms" that transcends the narrow scope of disciplinary worldviews. The exemplar was anthropology conceived as a comprehensive science of humans, though conference participants elaborated the concept differently. Piaget (1972) defined TD as a superior stage in the epistemology of interdisciplinary relationships based on reciprocal assimilations and the prospect of a general theory of systems or structures. Lichnerowicz (1972) advocated "the mathematic" as a universal interlanguage and structure, and Jantsch (1972) imbued TD with social purpose in a hierarchical model of science, education, and innovation grounded in general systems theory and organization theory.

By the end of the twentieth century transdisciplinarity had gained visibility and new connotations across three major discourses. The first discourse of transdisciplinarity—transcendence—is linked with the historical quest for unity of knowledge and culture. As belief in a pregiven unity eroded, however, new overarching frameworks emerged including general systems theory, feminist theory, and sustainability. The second discourse—transgression—was forged in critique of the existing structure of knowledge and education shaped by critical theory, social and political movements, and interrogation of dominant systems of disciplinarity and the technical-rational model of science. The third discourse—problem solving—was fundamental to early conceptions of interdisciplinarity, including problem-focused social science research in the 1920s and defense-related research during the World War II era. A new transdisciplinary momentum evolved in the late twentieth century, though, driven by the need to solve complex "real-world" problems of society and inclusion of wider range of stakeholders in research (Klein, 2015, 2017). Elements of the three discourses appear across the three examples

[1] I thank Dena Fam, Tanzi Smith, and Dana Cordell for permission to use Fig. 4.1, from the chapter cited below. I also thank Rick Szostak and Frédéric Darbellay for comments on earlier versions of this chapter.

highlighted in this chapter, along with characteristics of creativity and designerly ways of thinking. Their intersections are situated in a broad historical shift from linear process and rote application to user-oriented and heuristic approaches that are also responsive to contingencies of context. Together they are fostering new relational forms of knowledge production and practice. The chapter closes by reflecting on an overriding topic that emerges from the intersections—situated learning—then concludes by reflecting on the phenomenon of increased boundary crossing across the divides of disciplines, occupational professions, government, industry, and the public sphere.

Creativity and Interdisciplinarity

Etymology is a good starting point for any investigation of meaning. The English noun "creativity" derives from the Latin *creativitus*, connoting a capacity or faculty for bringing something new into being.[2] The concept appears across multiple fields, including art, philosophy, sociology, psychology, and cognitive science. Case studies also appear across domains of professional practice, such as education, business, architecture, and engineering. Comparably, the source is attributed to a wide range of explanations, ranging from divine inspiration and individual genius or personality to team dynamics and organizational cultures. And, the weight of definition varies from open-ended exercise of the imagination to managed applications. Nonetheless, common characteristics appear across contexts. In defining the nature of creativity Sternberg (2006) identified eight major types grouped into three categories. The first category—acceptance of current paradigms and attempts to extend them—results in replication, incrementation, and further advancement. In contrast, the second and third categories exhibit a more transgressive imperative by challenging the status quo. The second—rejection of current paradigms and attempts to replace them—leads to redirection, reconstruction/redirection, and reinitiation. The third—higher-level synthesis of current paradigms—is associated with integration and combinations of mental models to generate holistic solutions and in rarer cases a new paradigm or field.

Looking more specifically at the relationship of creativity and interdisciplinary studies, Sill (1996) highlighted three primary aspects of creativity that Getzels and Csikzentmihalyi (1964) identified in their classic definition:

1. original production
2. cognitive problem solving
3. subjective experience.

[2]Creativity. (2016). In Oxford English Dictionary. Retrieved from http://www.oed.com/view/Entry/44075?redirectedFrom=creativity#eid [Accessed 25 May 2016].

In addition to these core traits, Sill (1996) highlighted four concepts relevant to this investigation. In his book *The Act of Creation* (1964), Koestler argued that creativity derives from "bisociative thinking," which is derived in turn from "synthesis of independent matrices of thought" Sill likened to disciplines (p. 136). Koestler also called "creative tension" the driving engine of creativity, requiring resolution when two or more matrices contradict or conflict. Finke, Ward, and Smith (1992) further called "preinventive structures" within the subconscious raw material for creativity in the form of ideas, images, and untested concepts residing in memory or emerging in the imagination. Several parallels between creativity and interdisciplinarity emerge from combining the seven defining traits and concepts Sill identified. Both entail moving beyond existing approaches. In both cases, generativity is a common trait, along with cognitive flexibility. Both also acknowledge the subjectivity of personal experience and feelings, generating alternative modes beyond technical rationality while acknowledging contingencies of context. Both require bridging separate matrices of thought, in a form of problem solving that leverages preinventive structures as resources for new insights and synthesis. And, both have a temporal dynamic of iteration, which Szostak in this volume (Chap. 2) also identifies as a shared dynamic of creativity and integration.

In defining the relationship of creativity and "integrativism," a composite term for cross-disciplinary and integrative modes of work, Dillon (2006, 2008) argued that working across and between disciplines is "inherently creative." When individuals interact and combine modes of thinking, they generate new outcomes. Dillon aligned "transdisciplinarity" with a quest for unified knowledge in the discourse of transcendence, and "interdisciplinarity" with resolving tensions and contradictions between differing forms of knowledge. However, tensions and contradictions also appear in transdisciplinary research. "Unity" is a relative term. It is not embodied in a single transcendent theory of everything, despite some continuing efforts to assert it. Unifying approaches emerge on different levels based on the context of a particular project, program, or field. Moreover, in transdisciplinary research on complex challenges such as climate change and health disparities problems are typically ill-defined, requiring creative approaches that are not prescribed in existing methods.

Design and Creativity in Transdisciplinary Architecture and Urban Planning

Once again, etymology furnishes a starting point. The English noun "design" is borrowed from the French word *deseign* meaning a plan or a scheme executed through action, derived in turn from the Latin word *designare* meaning to mark and to devise.[3] Like creativity, design is not the province of a single discipline. It appears, Boradkar (2010) found, in a variety of domains including architecture, urban planning, engineering, automotive and industrial design, graphic and interior design, along with newer design experiences and services. Most definitions, Boradkar added, refer primarily to practice in professional occupations that have historically had an instrumental focus, although the new field of design studies and theories of practice incorporating critique extend conception of design. Fischer (2015) has described design thinking as a tool for fostering creativity while also providing a structure for systematizing ideas without sacrificing free flow of ideas. Taking a step further Yajima (2015) proposed interdisciplinary research could be enhanced by design thinking in the context of grand challenges that have no disciplinary boundaries and require teams to combine deep expertise for a common goal. Both designers and scientists want to discover something new and both interrogate existing assumptions. Designers also like to look at a problem in different ways, and scientists confront the status quo while pushing knowledge forward in the transgressive connotation of Sternberg's (2006) second category of creativity.

Architecture and urban planning provide an insightful example of the intersection of design, creativity, and transdisciplinarity. Doucet and Janssens (2011) sketched several dimensions of their relationship in the 2011 collection *Transdisciplinary Knowledge Production in Architecture and Urbanism*. The transdisciplinary character of new hybrid modes of inquiry, practice, and learning lies in experimental approaches that have the capacity to overcome past schisms of theory, history, and practice through integration. Architectural practice is reconceptualized from rote application or instrumental service to a form of relational knowledge situated in particular contexts, responsive to their stakeholders, and open to change. The gap between critical theory and projective design is also bridged. Whether refitting metropolitan areas because of growth or moving cities because of climate change, questions of design are not separate from social, political, and normative concerns. Ethics are also placed inside of disciplinary and professional work rather than outside their borders as a peripheral concern or afterthought. And, new objects come into view while situating practices in new configurations and incorporating once excluded forms of knowledge including the experience of lay people.

Four related concepts may be combined for a fuller picture of the link between creativity and design. First, Rendell (2004) distinguished research "for" and "into" design, connoting theory in the form of historical and theoretical perspectives within existing disciplinary modes, from research "through" design, connoting practice oriented to application. Second, in a parallel distinction Biggs and Büchler (2011) differentiated studies "on" architecture, which adopt established models, from studies "in" architecture, which often contain an element of creative practice

[3]Design. (2016). In Oxford English Dictionary. Retrieved from http://www.oed.com/view/Entry/50840?rskey=v6MxwG&result=1&isAdvanced=false#eid [Accessed 25 May 2016].

not encompassed in generic approaches. Third, in another parallel concept Cross (1982, 2001) contrasted "design science," grounded in the objectivity and rationality of formal protocols, and new "designerly ways of knowing," developed in alternatives that acknowledge subjectivity, unpredictability, and an epistemology of design accountable for creativity and innovation. Like Biggs and Büchler, Cross also highlighted the fourth concept, "reflection-in-action." Schön's (1983) concept, Yaneva (2011) recalled, prompted a "revolution" in design anthropology during the 1980s. He sought a reflexive epistemology of practice implicit in artistic, intuitive processes within contexts of uncertainty, instability, uniqueness, and value conflicts (p. 117). The competence and artistry embedded in skillful practice is a starting point, rather than a prescribed linear way of knowing. A pragmatist form of inquiry and innovative approach to professional education, reflection-in-action is also situation-based and recognizes tacit knowledge.

New approaches to design education are further bridging the gap between engineering principles of efficiency coupled with performance specifications and artistic principles of beauty and form. In the context of a Transdisciplinary Design Studio, Guyotte, Sochacka, Costantino, Walter, and Kellam (2014) conceived of engineering problems as creative challenges in which different forms of knowledge are manipulated. Engineering, art, and landscape architecture were integrated in a case of STEAM education, which extends STEM's focus on science, technology, engineering, and mathematics by including art. The authors further conceptualized STEAM as a transdisciplinary social practice of community engagement and ecological sustainability. Two faculty from engineering and from art collaborated on the course, with 11 students from art education, landscape architecture, and civil and environmental engineering. The first of two design challenges asked students to conceptualize a community initiative on solid waste reduction if landfill diversion goals were extended to zero waste by 2030. The instructors felt, though, students would have gained deeper conceptual and experiential understanding if they actually undertook community initiatives. So, the second challenge combined organizing and implementing an initiative. By exhibiting art in a public gallery, students also engaged with and learned from community stakeholders outside the boundary of academic walls.

Chou and Wong (2015) also linked integrative design to reflection-in-action in a student project called "Public Art" that brought together art and technology in order to establish an interactive environment for citizen awareness and participation. The students also came from varied backgrounds, in this case including design, information technology, management, art, engineering, and education. Several lessons emerged that echo earlier parallels between creativity and interdisciplinarity. To begin with, inter- and trans-disciplinarity constitute "a heterogeneous conglomeration of different research activities" (p. 219). Knowing-in-action and reflection-in-practice are also essential when cooperation is more unpredictable and team members need to be more flexible. Moreover, an integrated working process requires removing hierarchies among disciplines to generate more options and potential solutions. And, finally, characteristics of creative design in transdisciplinary contexts are situated within a broader historical shift in design research from production of artifacts to a user-centered approach focused on integration of knowledge and fields. In calling design “antidisciplinary,” Ito (2016), Director of MIT’s Media Lab, cites a transgressive imperative as well. He deems design in the laboratory “antidisciplinary” because work occurs in spaces that do not fit into existing academic disciplines and may even constitute a new field, such as cybernetics.

The second example further illustrates the transgressive role of design thinking in alternative modes of thought and action responsive to context, this time in the realm of sustainability. Comparable to architecture and urban planning, complex challenges of environmental sustainability cannot be adequately tackled using established methods alone.

Creative Design in Transdisciplinary Sustainability

Complex problems associated with transdisciplinary collaborative research are often likened to “wicked problems” characterized by uncertainty, indeterminacy, value conflicts, unexpected outcomes, and lack of ready-made criteria, answers, and solutions. In describing the stages of a transdisciplinary sustainability science project, Hall and O’Rourke (2014) identified five phases that often appear in descriptions of research process: *Framing*, *Launching*, *Integrating*, *Generating*, and *Deciding*. Pressure can result in settling too quickly on a “right” answer due to time, money, and defaulting to an established approach or past experience. Doing so, though, can slow or scuttle the process of generating ideas and identifying options. In the fourth stage of *Generating*, diversity can improve both the quality and creativity of solutions, allowing individuals to voice views not normally expected in their prescribed roles. Some descriptions of creative process accentuate freedom from structures, though Hall and O’Rourke found that structured dialogue can boost creativity even if the balance of structure and freedom differs by the activity in question. Constructive criticism of alternatives is a form of priming that can lead to innovative possibilities.

Hall and O’Rourke (2014) also emphasized the centrality of communication. It is one of six core qualities of transdisciplinary research that Fam, Smith, and Cordell (2017) identified in interviews with 14 leading transdisciplinary researchers. The others are creativity, curiosity, commitment, critical awareness, and connectedness. Their informants associated creativity in particular with five traits depicted in Fig. 4.1, while further describing the process as “thinking out of the box,” “thinking laterally through a puzzling challenge,” and being willing to “push the boundaries.” Like Huutoniemi and Willamo (2014), they also likened the process to de Bono’s (1970) concept of lateral thinking. The six areas are not separate. Curiosity entails a flexible willingness to explore new insights beyond one’s own expertise. Commitment often involves “challenging the status quo.” Critical awareness, in turn, is a form of reflexive thinking and openness to others’ suggestions. And, communication is essential both to clarify one’s own perspective and to work

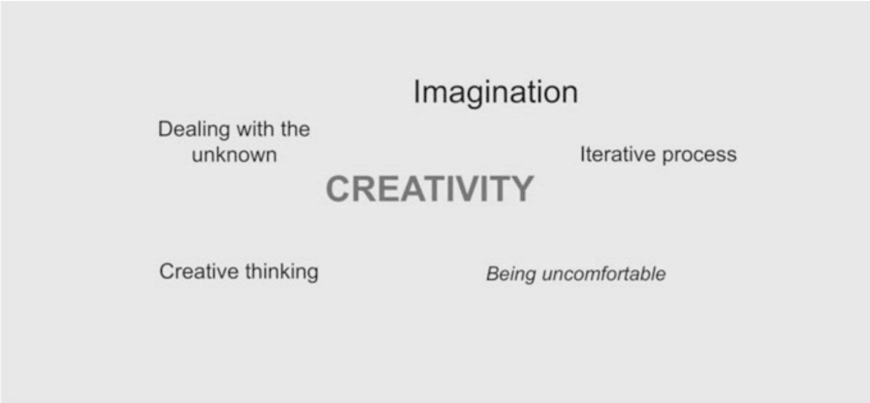

Fig. 4.1 Attributes of creativity in transdisciplinary research (from Fam, Smith, and Cordell 2017, p. 83)

successfully together with others. Finally, connectedness is key to synthesizing different matrices of thought.

When focusing on novelty as a defining trait of creativity, Sill further (1996) emphasized heuristic thinking. The English word "heuristics" derives from a Greek word meaning "to find."[4] Over the centuries the concept became associated with an art or form of logic that is more fluid and ad hoc than linearity and the mechanical rule of algorithmic thinking, relying instead on rules of thumb or incomplete guidelines to drive discovery. Introducing the book *Transdisciplinary Sustainability Studies,* Huutoniemi (2014) framed heuristics as a cognitive concept in an "ecological rationality" or "pragmatism" (pp. 10–11) that fits a particular problem, rather than a generic method. Existing methods still have value for generating new ideas though, including scenario building, expert deliberation, "what-if" modeling, and the Delphi technique of controlled iterations. Willamo joined Huutoniemi (2014) in adding "outward thinking" (p. 27) as a search tool for systemic understanding, achieved by looking outward from an object of interest and thereby opening up the possibility of inventing new categories or rearranging established ones. They likened outward thinking to de Bono's (1970) concept of "lateral thinking," which redirects thinking away from the "vertical logic" of Western reasoning and may lead in surprising new directions. It also parallels a "design turn" (p. 26) within systems thinking that shifts attention from the ontological status of a system to its heuristic functions and technologies.

Ultimately, heuristics constitute a form of invention that lies at the heart of heuristics, a branch of logic associated with the art of discovery or invention. The rhetorician Ulmer (1994) extended this concept in his book *Heuristics*. In seeking

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[4]Heuristics. (2016). In Oxford English Dictionary. Retrieved from http://www.oed.com/view/Entry/367823?redirectedFrom=heuristics#eid [Accessed 25 May 2016].

forms for cultural studies research and teaching writing in the digital age, Ulmer contrasted traditional methods of interpreting print-based texts to the "generative productivity" that occurs in avant-garde expression and in composition of digital works that mix word, image, and sound. Transdisciplinary sustainability is not focused on hypermedia, but it too requires creating solutions that do not derive from applying traditional methods. Like Ulmer, Huutoniemi (2014) noted poststructuralist and postmodern theories have been influential in critique of the modern techno-scientific paradigm along with pragmatist philosophies, literacy criticism, feminist and standpoint epistemology, and science and technology studies.

The triangulation of creative process, a designerly way of thinking about a complex problem, and transdisciplinarity is further apparent in the third example. Szostak, in this volume, observes that "Creativity is generally defined in terms of both novelty and utility" (p. 18). Likewise, Sternberg and Lubart (1999) contended that creativity is characterized by not only *novelty* but something *useful*. This quality is central to new integrations of life sciences and medicine with physical sciences and engineering.

Utility and the Generativity of Divergence–Convergence

Creativity is often deemed an "engine" of innovation and invention in the economic sphere. A recent survey by the American Management Association, for instance, identified creativity as one of the "4Cs" of twenty-first century skills, along with communication, collaboration, and critical thinking (Reilly, 2010). Fillis and Rentschler (2010) located the heightened role of creativity in a historical shift from knowledge-based activities in the economy to creativity, innovation, entrepreneurship, and imagination. The criterion of success does not lie in novelty alone. It is forged in the marketplace of ideas. The full title of a 2013 report issued by the American Academy of Arts and Sciences reinforces the connection between innovation and utility. *Arise 2, Advancing Research in Science and Engineering* is subtitled *Unleashing America's Research and Innovation Enterprise*. Citing "Transdisciplinary Opportunities" as a common theme in current discussions of the research enterprise, the report calls for "deep integration" across disciplines for both basic discovery and development and application. In contrast to interdisciplinary collaborations between disciplines, the authors contend, deep integration is a "true conceptual leap" of transdisciplinary scope across physical sciences and engineering (PSE) and life sciences and medicine (LSM). The report claims interdisciplinarity borrows techniques from different fields without integrating them, ignoring a sizable literature on the centrality of integration in interdisciplinary research and education. Yet, it captures the power of transdisciplinarity to transgress disciplinary boundaries while fostering emergence of new disciplines (American Acadey, 2013).

The report also cites numerous examples of what a refigured research ecosystem looks like. Life sciences and medicine rely increasingly on sophisticated instrumentation, intensive computational resources, and systems approaches in collaboration with physical sciences and engineering, including nanotechnologies and supercomputing. The aggregation of elements provides “nucleation points” for further integration and collaboration in a “massive ‘knowledge network’.” A transdisciplinary systems-level approach to the cell, for instance, is leading to a new level of understanding that merges expertise in molecular and evolutionary biology with the chemistry of small molecules and macromolecules plus the physics of energy storage and transfer, network and chaos theories, mechanical and systems engineering. Likewise, efforts to develop economically and ecologically viable replacements for fossil fuels bring together expertise from chemical, systems, and environmental engineering as well as microbiology, plant science, ecology, computational science, and economics. Moreover, in both cases multiple boundaries are being crossed, not only between disciplines but also basic and applied research as well as the academy, industry, and government.

Many of the drivers of change in *Arise 2* also shape the underlying concept of *Convergence*, a report issued the following year by the National Research Council in the USA (2014). Subtitled *Facilitating Integration of Life Sciences, Physical Sciences, Engineering, and Beyond*, the report defines convergence as “an expanded form of interdisciplinary research” (p. 20) that integrates knowledge, tools, and ways of thinking from different domains. Aligned explicitly with the concept of transdisciplinarity, it aims to create a transcending synthetic framework for dealing with current scientific and societal challenges, including understanding complex biological systems, improving patient outcomes, revolutionizing manufacturing, improving energy storage systems, and meeting the need for secure food supplies in the midst of climate change. Here too, multiple boundaries are being crossed in interactions and partnerships across the academy, national laboratories, industry, clinical settings, and funding bodies.

The underlying dynamic of transdisciplinarity in the report is a process of divergence and convergence that fosters creative development of products or practices that are both novel and tailored to context. Routine problem solving, Steiner (2009) explained, does not need divergent thinking since neither novel procedures nor outcomes are needed. In contrast, creative problem solving requires both divergent and convergent thinking modes, leveraging critical analysis and connections between disparate ideas. Problem solving and creative approaches also combine to yield a mixed form of *creative problem solving* oriented toward discovery and innovation. In a 2013 report on *Convergence of Knowledge, Technology, and Society*, Roco, Bainbridge, Toon and Whitesides depicted the convergence-divergence process as an escalating and potentially transformative development linked with combinatorial innovation. It occurs when a new technology or set of technologies yields components that may be combined and recombined, spinning off applications and elements that might continue to be recombined and integrated. In a subsequent phase of divergence, new convergences are then applied in new areas, discoveries, and outcomes.

Roco, Bainbridge, Toon, and Whitesides (2013) depicted the historical evolution of combinatorial innovation in three stages. The first stage, dating from the late 1990s into the 2000s, occurred in efforts to develop nanotechnology through

Table 4.1 Three phases of CKTS convergence (Roco, et al., 2013, p. 17)

Time frame	Phase	Characteristics
2001–2010	Reactive convergence	Coincidental, based on ad hoc collaborations of partners or individual fields for a predetermined goal
2011–2020	Proactive convergence	More principled and inclusive, approaching convergence through more explicit decision analysis; the immediate future of CKTS
After 2020	Systemic convergence	Holistic, with higher-level (multidomain) purpose, with input from convergence/governance organizations

convergence of separate scientific and engineering disciplines. The second stage, moving into the 2000s, catalyzed the convergence of nanotechnology with biotechnology, information, and cognitive technologies (abbreviated as NBIC). It connected emerging technologies based on shared elemental components such as atoms, DNA, bits, and synapses that were integrated across scales. The third stage, unfolding in the 2010s, is connecting emerging NBIC technologies with platforms of human activity on multiple scales. Table 4.1 depicts the trajectory of Converging Knowledge and Technologies for Society (CKTS).

The significance of this timeline lies in degrees of intentionality and formality, moving from the coincidence of ad hoc collaborations to more principled and inclusive efforts to ultimately a holistic level across domains. The development of new languages, it should also be said, is essential to CKTS, generating higher-level languages for constructing shared technology and concepts common to multiple domains.

The Cross-Secting Role of Situated Learning

Several implications follow from the intersections of creativity, design, and transdisciplinary research though situated learning stands out. The "Ah-ha" moment or *Eureka* flash of insight is often associated with creativity. Yet, Lozano (2014) emphasized, change in mental models and behavior requires constant learning that is not simply additive but transformative. Argyris' (1977) theory of learning loops accounts for the difference. In single-loop learning, organizations compare their performance against pre-established standards, detecting and correcting errors in order to carry on present policies or to make adjustments. In double-loop learning underlying assumptions, norms, objectives, policies, goals and programs are questioned. Delving deeper into the structure of a system facilitates interrogation of established models. Others have extended Argyris' theory to include triple-loop learning: new processes or methodologies are developed that take the further step of reframing thinking.

Mitchell, Cordell, and Fam (2015) brought together the concepts of triple-loop, deep, generative, and transformative learning in describing transdisciplinary sustainability research. It entails a social process of reflection throughout interactions, communications, and relations among actors in a particular project. As a result, it is constructivist in nature. Problems are never simply received, Fry (2011) emphasized. They are always interrogated and redefined. Put another way, practice never "prefigures the form of the solution" or more specifically "architecture never just begets architecture" (p. 21). Transdisciplinary process entails continually learning what the problem is through critical reflection. The form of "relational thinking" that emerges from situated learning not only dissolves disciplinary differences. It has a capacity for "redirective practice" that stems from transgressive rupture of current practice, not pragmatic problem solving alone.

The element of surprise can also foster learning. Darbellay, Moody, Sedooka, and Steffen (2014) acknowledged Repko's 10-stage model of interdisciplinary research process (2006) in a textbook for students doing individual projects. Repko himself also recognized the role of potential feedback, iterativity, and negotiation mechanisms capable of introducing flexibility. Yet, Darbellay et al. contended Repko's model follows a standard procedure: moving from formulating a problem and questions and hypotheses to methodological choices and analyzing and interpreting results. While valuable, Darbellay et al. acknowledged, this approach does not account for the unexpected, which could intervene at any stage and even reconfigure the research process through digression and diversion. They likened serendipity to Peirce's concept of *abduction* (1965), an intuitive and exploratory way of reasoning that allows the possibility of a surprising fact paving the way for new avenues of thought, theories, and innovation. The research process may even be radically reconfigured.

Both creativity and learning, Lozano (2014) further observed, occur in units ranging from individuals and groups to organizations and society. Individual learning entails examining assumptions underlying mental models and considering how different models can be brought together. The combined intelligence of collaboration fosters development of new or revised models and capacities for collaborative action. Collaborative creativity, Steiner (2009) emphasized, is not the simple sum of individual performances. Creative solutions emerge as a result of associative thinking and communication among people with different backgrounds, experiences, value systems, and expectations. Steiner also acknowledged the value of stage models. All problem solving processes share common fundamental steps, moving from finding and defining a goal to scanning and generating information then deriving viable solutions. Yet, he admonished, routine and creative problem solving differ with respect to their initial events, process characteristics, and novelty of outcomes.

Conclusion

The intersections of creativity, design, and transdisciplinarity identified in this chapter underscore the increasing ambiguity of boundaries: not only divides of disciplines but also occupational professions, sectors of society, and domains of science and technology, social sciences, humanities, and arts. Reflecting on changes in architecture and urban planning, Doucet and Janssens (2011) called attention to the hybridization and relationality of knowledge today. Tasks lie at the boundaries of and spaces between systems and subsystems. The widening shift from prescriptive linear and generic models to relational knowledge has also expanded the heterogeneity of approaches that are available, while bringing new objects into view beyond conventional taxonomies of disciplines and placing practices in new configurations. As a result, the ability to cross boundaries has become an essential skill, not only individual capacity for Koestler's (1964) notion of "bisociative thinking" that bridges "independent matrices of thought" but also group capacity for negotiating difference and generating collective intelligence.

Ultimately, transdisciplinarity may be understood as a creative process that is itself a form of design. In the absence of an a priori unity of knowledge or universal paradigm of practice, synthesis must be constructed. Several other concepts from this investigation also have general import. Huutoniemi's (2014) notion of heuristics as a cognitive concept in an ecological rationality or pragmatism highlights the need to test both existing and new models and methods in the forge of context and contingency. The concept of deep integration reinforces the idea of transdisciplinarity as a conceptual leap of greater scope and power. The notion of aggregated elements providing nucleation points for further integration and collaboration also situates individual activities within a massive knowledge network. Degrees of change, though, will still vary, echoing Sternberg's (2006) spectrum across modifications and extensions of current paradigms to transgressive redirections and reformulations to higher level of synthesis in new transcending frameworks.

Several closing caveats, however, check the unbridled rhetoric of transformation. To begin with, priorities conflict when resources are limited. Inventing new goods and services for the marketplace has greater economic and social capital than a democratic solution to an environmental problem. Echoing Chou and Wong (2015), connections among disciplines are not always clear either, requiring greater attention to teamwork for integrated solutions to multidimensional problems. Roco et al. (2013) also concluded the research and development focus for converging technologies has been more reactive and coincidental, not the holistic systematic approach a theory of transdisciplinary convergence beckons. Comparably, reports on inter- and trans-disciplinarity, as well as team science, tend to repeat the same recommendations for removing barriers to integration and collaboration, including devising new administrative policies, training programs, and mechanisms for funding and communication. Moreover, the agora of public space championed in the discourse of problem solving is not without limits. Russel, Wickson, and Carew (2008) caution the agora is heterogeneous and complex, with its own imbalances of power. Even strategic targeting of environment and climate runs the risk of creating "mega-silos" that consolidate interest and resources into institutional blocks stifling further connections while limiting creativity and innovation.

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Chapter 5
Cross-Disciplinary Creativity and Design Thinking

Ai-Girl Tan

Abstract Cross-disciplinarity is a converging process of reinstating the human as the core focus of all scientific endeavour and cultural practices, and humanness. Creativity is a renewal of human experience for good life. Design thinking is a skill of the twenty-first century towards generating immediate solution for complex and practical problems. Our chapter presents three assumptions of cross-disciplinary creativity for nurturing design thinking. One assumption is related to mechanisms of creativity: convergence, divergence, and emergence, which embrace the assumption of humanistic values of design thinking: harmony, authoritative conversation, and respect. Another assumption concerns principles of creativity experiences: interaction, continuity, and complementarity. In experiencing learning the principle of interaction unites (converges) with the principle of continuity. The principle of complementarity embraces the unified interaction and continuity in experience for creative synthesis (convergence in divergence) or emergence. Design thinking searches for emergence of novelty within the designer(s) or within the community of designer(s) in the presence of harmonious and respectful conversations. Value-oriented boundary crossing creativity nurtures design thinking for ethical solutions for complex problems. To elaborate, we present our experiences with the community of practice in an action research project on cross-disciplinary creative design teaching. We conclude by presenting an account on Singapore's narratives of its creative design development and transformation.

Keywords Creativity · Cross-disciplinarity · Design thinking · Respect
Harmony · Conversation

The writing of this project has been a creative synthesis of the author in her continuous and regular dialogues with Angeline Yam, Shirley Lim, and Ranae Lee (June 2014–the present). It has been a reflective piece of invaluable contributions of the late Jerome Bruner's (1 October 1916–5 June 2016). The author would like to record her words of appreciation to Angeline, Shirley, and Ranae and would like to dedicate this chapter to J. Bruner in memory of his forward-looking narratives in the fields of psychology, instruction, and creativity.

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Introduction

This chapter comprises three parts. In the first part, the interrelation of cross-disciplinarity, creativity, and design thinking is presented. Mechanisms (convergence, divergence, and emergence) of the theory of convergent creativity are outlined. Systematic, structural, and functional integrations are elaborated as diverse forms of convergence *in* divergence in "getting ready" *for* emergence. Creativity values (harmony, conversation, and respect) are paramount in designing something for immediate and practical solutions. Harmonious relationships facilitate multidisciplinary, interdisciplinary, and transdisciplinary cooperation. In the second part, principles of creativity experiences (continuity, interaction, and complementarity) are discussed in the context of design thinking, a process to construct immediate and practical solutions to complex social problems in collaboration. Tools of interaction (narratives) and thinking in action (plans) are highlighted with reference to designing and implementing plans for nurturing design thinking. The chapter concludes with narratives of creativity development of a city of design, Singapore, that has valued over-generational collaborative effort, authoritative conversation for a good future, and respect for diversity and harmonious relationships.

Cross-Disciplinary Creativity

Cross-disciplinarity is a converging process of reinstating the human as the core focus of all scientific endeavours and cultural practices, and humanness (*renwen*, 人文) as the mean and outcome of these activities (Tan, 2014). The humanistic endeavour is converging and is meant for a new understanding of an inclusive community and ethical practices. In an inclusive society, humanness permeates knowledge innovation and cultural practices (Vygotsky, 1993). Cross-disciplinary inquiry is about collectively making efforts to address complex systems or to design ways to embrace social issues, not bounded by a single disciplinary knowledge and expertise. Professionals, researchers, and educators co-construct systems of communication, structures of interaction, and plans of implementation to address immediate practical problems (Klein, 1990). They engage in open dialogues and genuine conversations (Gadamer, 2004). They are aware of the purpose of their dialogues and interactions that mediate development of plans for positive growth (Ponomarev, 2008). They co-construct realities mindfully and with their audience. The researchers determine their roles as theorists, practitioners, researchers, or a combination of some or all. They must know if their inquiry serves the public good and if it is relevant to the policy and practice of their communities (Ball, 2012). Plans of actions of cross-disciplinary research integrate knowledge, methods, research collaboration, culture of knowledge, and culture of settings of knowledge (Aagaard-Hansen, 2007).

Mechanism

Creativity is life (Kaufman, 2015), a renewal of human experiences (Dewey, 1884). The theory of convergent creativity in the context of cross-disciplinarity for positive growth (Tan, 2014, 2015a, b; Tan & Sriraman, 2016) adheres to three assumptions of creativity mechanisms, experiences, and values. The assumption of creativity mechanisms (convergence, divergence, and emergence) concerns effortful practices (Cropley, 2006) for constructing knowledge or values. A positional change of a set of elements is observed in *convergence* (*integration*) and *divergence* (*variation*), and a change of the very set of a system of elements is seen in *emergence* (*transformation*) (Kastenhofer, 2007). Tan (2016) uses the prepositions "*in*" and "*for*" to indicate the interrelation of these mechanisms in a loop and a cycle of dynamics of creativity experiences. Convergence and divergence are at the state or phase of "disequilibrium" when the elements of the set rapture in the desirable direction or orientation. Convergence *in* divergence is a state or a phase of congruence, coherence, or "getting ready" to the next state or phase of change, i.e. emergence. Inclusion exemplifies emergence of social practice that embraces all including the vulnerable people (Vygotsky, 1993). It involves a change in the very set of a value system that respects multiple voices regardless of their backgrounds and that embraces voices of people with special needs (with gifts, talents, or disabilities).

Integration

Creativity in cross-disciplinary inquiry begins with negotiating and boundary crossing and continues with applying a combination of modes of thinking in generating new outcomes (Dillon, 2008). Creative synthesis is oriented by the search for similarities in the language of communication, structures of interaction, directions of plans, and so forth (Harvey, 2014). Boundary crossing is creative combining modes of thinking for a new outcome. Cross-disciplinary inquiry takes convergence *in* divergence effort or integration as a process and an outcome of creative synthesis: *systematic, structural*, and *functional* (Wechsler & Hurst, 2011).

Briefly, *systematic integration* is about constructing a new language of communication within and across disciplines that can facilitate dialogue, conversation, and narratives among the members of the community of practice. It involves contents, methods, expertise, and innovation inducement processes. *Systematic integration* or *cooperation* focuses on developing a new language that represents the shared theoretical, methodological, conceptual, and practical understanding of the issue of concern. Within the new language, the actual life and becoming are created with a multitude of concrete worlds and social belief systems (Bakhtin, 1981). Furthermore, within the social belief systems are elements of language filled with various semantic and axiological contents and each with its own different sound (Bakhtin, 1981). In the dialogical imagination, the intentional possibilities are realized in "specific directions, filled with specific content, they are made concrete, particular, and are permeated with concrete value judgments" (Bakhtin, 1981, p. 289).

Another type of cooperation, *structural integration,* focuses on constructing spaces, settings, and affordances that enable interacting, designing, and experiencing. The environment of learning is in reciprocity with maturation and capacities of the person (Gibson & Gibson, 1955). The learners in interdependent relationships with the environment encounter, discriminate, and select objects, events, and activities that fit their bodily maturation and developmental capacities (Gibson, 1979). Social-cultural or proximal spaces in the forms of networks of communication support idea generation, sharing, and combination. Affordances refer to the available things, objects, materials, spaces, environments, and intelligent systems (Buber, 1937; Gibson, 1979). *Structural integration* constructs spaces of dialogue, conversation, and interaction among the professionals of interdisciplinary departments, graduate programs, and research projects. Some conditions for emergence of constructive creativity include empathetic interpersonal relationships among the team members, open spaces of interaction, and readiness of the minds to combine ideas freely and to design something practical (Rogers, 1961).

Systematic and structural integrations exemplify the "getting ready" state of mind in *convergence in divergence* (Tan, 2015a, b) that engages the positional change of elements within a set of system (Kastenhofer, 2007). Another type of cooperation is termed *functional integration* which builds on the two types of integration (*systematic, structural*) and which concerns planning and implementing plans for nurturing design thinking. *Functional integration* exemplifies *emergence.* The three types of integration and cooperation complement each other.

Values

Cross-disciplinary creativity assumes that humanistic values guide boundary crossing narratives towards positive growth. Values are beliefs that refer to special goals or that motivate actions and that serve as criteria of change (Schwartz, 2012). Positive values of cross-disciplinary creativity include interdependence, excitement, contemplation, harmony, respect/acceptance of the tradition, enhancing welfare, and the like.

Values that orientate cross-disciplinary cooperation include: *harmony, conversation,* and *respect*. *Harmony* (*he*) emerges when shared goals and common grounds include all and acknowledge different voices. Self-care and care for the other people are paramount in cross-disciplinary cooperation. Active listening to autobiographic and social-cultural narratives is essential for fostering harmonious interpersonal relationships. There are different levels of cooperation. *Multi-disciplinarity* refers to the state of a low-level cooperation when parallel tasks are coordinated towards a common goal. *Inter-disciplinarity* refers to the state of the second level of collaboration or cooperation to achieve a common goal by a transfer of method, or by integrating contents of two or more disciplines (Klein, 1990; Moran, 2002). To solve real-life problems, *transdisciplinary* experts take humanity as the foremost (Rue, 2007). The experts share a conceptual framework, make inquiry with a shared goal, and draw on their expertise to address common problems.

In *conversation,* morality emerges (Gadamer, 2004). The persons in conversation observe the feelings of the other people and notify the intention behind any creation (Nishitani, 1991). The value of *respect* embraces and permeates harmonious human relationships, creative dialogues, and ethical conversations. *Respect* ensures the imbalanced power relations remain harmonious in any productive dialogue for social growth, esteem, interest, human progress, goodness, and wellness. Value-based teaching regulates learning with a set of instructions and with individualized curricula that spiral up and down specific levels of understanding of the individual learners (Bruner, 1982).

Design Thinking

We pose some questions to consolidate our theory of convergent creativity in cross-disciplinary designing (Love, 2002): What is design for? How does designing relate to creativity? How does designing emerge within the person in his(her) world of possibilities? Parsons (2016) defines design as, "an intentional solution of a problem, by the creation of plans for a new sort of thing, where the plans would not be immediately seen, by a reasonable person, as an inadequate solution" (p. 11).

The intentional solution in the context of convergent creativity for inclusivity demands reflective practice in action (Schon, 1983) to lead life and to enhance positive growth (Dewey, 1997), personhood (Rogers, 1961), and humanism (Taixu, 1989). Creation of plans for a new sort of thing is understood with reference to constructing social worlds of goodness, harmony, and peace. In designing and creating, the unperceived is more important than the perceived (Ponomarev, 2008). An example is a lesson plan that aims to nurturing creativity in design learning (Guilford, 1950) oriented by deliberate goals and/or induced by intuitive feelings. Another example of a design plan is a series of steps to construct an attractive poster for a public campaign such as a healthy diet for the elderly with special needs by taking moderate amount of long grains brown rice daily. Design education is an effortful commitment to construct plans and to engage all in the process of becoming (e.g. personhood), in transforming the collective (e.g. *conversation* and *respect*), and in implementing plans of a good life (e.g. *harmony*). The plans in designing are likely to be seen as inadequate and less likely to be seen as an immediate solution (Parson, 2016). Design education for goodness converges knowing and seeing, that are immediate and here and now, as well as integrates knowledge and skills, that are cultural-historical and interdisciplinary relevant. The designers construct meanings, signs, and symbols to represent their knowing and seeing of a personal encounter or a social issue.

Principles

Cross-disciplinary creativity for designing adheres to the principles of creativity experiences in the context of growth. Human experiences are in *continuity*, that is, to say that experiences are over-generational, from the knowledgeable others to the learners, and accumulative, from the past to the present and future (Dewey, 1997). Development of emerging properties of the mind or capacities is mediated by *interaction* (Ponomarev, 2008; Vygotsky, 2004). Furthermore, the emerging properties of the mind can be at a state and in a phase of *complementarity* (Bohr, 1950). For instance, the compassionate mind emerges with properties of the accumulative (e.g. memorization), ethical (e.g. for the good), and courageous (e.g. risk taking) capacities (Yin, 2014).

Designing is a process of suggesting immediate and practical solutions to address the complex needs of the audience. On the continuum of experiences, the designer-actor adopts complementary roles including that of the audience or the public (Bohr, 1950; Dewey, 1997). In his(her) space of experiencing (*Erlebnisraum*, Stern, 2010), the designer contemplates introspectively. In creating the individuals adopt multiple roles and appreciate multiple voices. The voice of designer-actor intercepts with that of the designer-audience (*convergence*). The designer-actor's narratives align with and complement those of the audience (*convergence*). Ideation in the experiencing space is intuitive (Bruner, 1969) and value-laden. During introspection, the person resolves any conflicting values and accommodates them in constructing meanings. She/he relates knowing to affordances and his(her) intent of becoming. In the proximal space (*Erfahrungsraum*, Stern, 2010), the designer interacts with the knowledgeable others and/or with members of the community of practice. The person in collaboration sees any possible emergence of the good by making reference to ideas of the others in the groups, and/or by making sense of the appealing affordances. Getting feedback and comments is relational during any authoritative conversation (Yam, Tan & Lim, 2015). Design thinking is a process of constructing realities and possibilities when the designer and the audience work in collaboration towards searching for a shared solution. Positive growth emerges "from within" the person in the world of possibilities. The designer knows the affordances and sees the emergence of the good as possibilities in life. His(her) designs are realistic and ethical as they emerge from his(her) continuous effort to solve practical problems and/or to address social issues.

An Action Research Context

In an action research project, researchers from the disciplines of psychology, visual communication, and education investigated classroom practices of a design course (typography) with reference to culturally appropriate pedagogies and creative design thinking (see Yam, Tan, & Lim, 2015; Tan, Yam & Lim, 2015). The participants and the researchers of the project were members of an emerging university with less than 40 years of history and in a young country with only half a century of history. The researchers were aware of values of collaborative creativity and Confucius heritage culture in the contexts of an emerging city of design and of the digital and information-technological era. The action research project outlined three goals: identifying gaps and designing creative pedagogies to foster design thinking, enhancing design thinking in collaboration, and developing design thinking competencies. The research team adopted theoretical orientations of Jerome Bruner (1915–2016), Lev Vygotsky (1896–1934), and Confucian heritage communities (CHC). Specifically, the project referred to Bruner's (1982) theory of education, Vygotsky's (1993, 2004) social-historical and creative imagination theories, Bakhtin's (1981) dialogical imagination, CHC values of harmony within groups and respecting the authoritative conversation, and twenty-first century values and skills of education in a modernized multicultural and inclusive society.

The initial cooperation of the team members was at the level of multi-disciplinarity. The psychologist-educator referred her theory of convergent creativity (Tan, 2014) and her position with respect to the relations of critical and creative thinking relevant to design thinking. The visual communication instructor and the principal investigator, who designed the course, shared her practices of culturally appropriate pedagogies and design thinking. The other visual communication instructor, who was a part-time faculty and a collaborator, had a strong interest in understanding the role of critical thinking from the doing and making perspectives. The shared goals of the study guided their regular dialogues. The research project's community of practice respected the instructor's intention to create spaces of dialogue that valued efforts to initiate and to participate in authoritative conversations, peer critique sessions, and creative design processes going beyond the course contents and disciplinary expectations. It also respected the collaborator's preference to experience surprises. The cooperation level advanced to that of the inter-disciplinarity and further to the transdisciplinarity when the researchers engaged intensively in discourses on a framework of scholarship on critical making pedagogies (Tan et al., 2015) and on a pedagogy of critique session (Yam et al., 2015). Their understanding of design thinking evolved and included creative and critical making.

Tools

Design education aimed to nurture culturally appropriate behaviour, socially conscious thinking, creative problem posing, and humanistic attitudes towards complex social issues. Within the action research team, schedules of investigation were set up and tasks were assigned to the members of the community of practice. Inclusive learning changed the positions of the elements of values in collaborative learning (*convergence*) such as interactive structures of small groups and space of ideation within the persons via digital devices and craft-making processes. It changed the elements of collaboration (*emergence*) such as respect for and care of views of the others, respect for authoritative conversation, and respect for harmony among groups. We construct reality, organize our experience and memory mainly in the forms of narrative (stories, excuses, myths, reasons, and so on) (Bruner, 1991). Narrative is a dialogical *tool* to construct reality. In small groups, the design students learned how to share openly before the other people (*canonicity*) and what was worth telling (*breach*) (Bruner, 1991). Space of ideation was set up as a structure of interaction for a group of four or five members. The participants of the course received feedback and comments on their design plans and implementations of plans. They used post-it sticky notes and accommodated anonymous written comments. Small group settings and written feedback in anonymity removed the fear of losing "face" and enhanced values of sharing, respecting harmony, and constructive authority. The participants of the course were free to choose time slots of consultation and of small group critique sessions from an open schedule timetable. The one-to-one consultation sessions with the instructor focused on removing design thinking "blocks" and constructing productive design making paths.

Education in the twenty-first century aspires to create networks of community of practice within the structure of the subject that motivates the intuitive and analytical minds to be ready for the world of possibilities (Bruner, 1982). Quality teaching and creative learning motivate the person to grow (Dewey, 1910, 1997) beyond the information given (Bruner, 1982). Over a period of thirteen weeks, the designer students worked on creative designs that were related to complex social issues. Design thinking takes the goal of doing as a mean and an end. Doing in thinking is an action-*tool* that generates plans with practical solutions. The plans of creative design were contextually sensitive and related to creative imagination or realistic events, stories, and publications.

Plan serves as a creative tool for transformational learning. The plan of nurturing design thinking included transforming environment of learning and convergent processes of becoming. The learners engaged in designing a digital poster with social awareness, a digital layout of a magazine, and a digital newsletter with multiple types of articles. Their assignment tasks challenged their capability to plan and implement plans of design within a contextual relevant disciplinary boundary (*typography*, *convergence*). Their designs emerged from rule-based and non-rule-based designing processes (*breaking rules of typography*, *divergence*) and from synthesizing the two types of designing processes (convergence *in* divergence).

The social issue of concern or the chosen theme served as a functional structure to integrate the selected readings. The structure expanded the space of knowing, intuition, conditions of creativity such as effective surprises (beyond common ways of experiencing the world, Bruner, 1969, p. 22), available materials (affordances), and ideation of creative designs with the audience. The course of typography assumed that all designer-learners possessed some understanding of creative design either from their direct experiences with the creative design industries or from learning other related subjects in the visual communication program (*principle of* *continuity*). The course participants were challenged to share their digital designs and designing processes verbally during classroom critique sessions and consultations and in writing as part of the portfolios for final assessments. The contents of their reflective writings on designing and creating serve as evidence of "*heteroglossia*" with discourses of multiple, coherent or conflicting, voices that were dialogically interrelated (Bakhtin, 1981, p. 324).

We investigated the effectiveness of the implementation of the lesson plans after the thirteen-week meetings in the first cycle of our project (January–April, 2015). Volunteer participants were interviewed (April–May, 2015). The outcomes of the interviews were integrated into the lesson planning of the forthcoming cycle of teaching (January–April, 2016). The second cycle of teaching ended with another set of interviews (April–May, 2016). The continuous loops of feed forward and backward enhanced the quality of integration (*systematic, structural,* and *functional*) and the quality of cooperation (towards *transdisciplinarity*) at the lesson planning and implementation levels. Improvement in culturally appropriate and creative pedagogies was evidenced in the elements of harmony among group interaction and collaboration, caring conversation, and respect for the personal and proximal spaces.

A Community of Designers

To understand life in its social, ecological, and biological complexity, since the past century, professionals have embarked on interdisciplinary studies (Klein, 1990). Table 5.1 summarizes the main points of this chapter.

To conclude this chapter, we present how values for good (resilience, responsibility, harmony, care, respect, and integrity) have set the directions of Singapore's narratives towards construction of a community of designers for creativity in everyday life. Singapore is a society with multiple ethnicities (i.e. Chinese, India, Malay, Euroasian, and others) and diverse religious beliefs (Buddhism, Christianity, Islam, and Hinduism). Unity in diversity or multiculturalism has been the inclusive narratives of the city nation. Singapore gained its independence in 9 August 1965 after it was separated from the Federation of Malaya. It is situated at the southern tip of the Peninsular Malaysia above the equator with scarcity of land areas (719.1 km^2). The focus of narrative norms is according to the preoccupation of ages and with the circumstances that surround the production (Bruner, 1991). The "true" story of Singapore's transformation is credited to the *values* of diligence, honesty, harmony, and openness to opportunity, resilience, and creative drive to construct something new to solve any immediate problem of its time. Narratives of Singapore after her independence were such as: "Preparing for the rainy days", "No one owes us a living", and "Change is the only thing that is constant".

In the first decade (1965–1975), Singapore's creative design efforts focused on developing identity, building homes, constructing infrastructures, and establishing institutions (*convergence in divergence*). The design-based activities in

Table 5.1 A framework of cross-disciplinary creativity for designing

Cross-disciplinarity	Creativity	Design thinking
Integration • Systematic (*convergence in divergence*) • Structural (*convergence in divergence*) • Functional (*emergence*)	**Assumption: mechanism** • Convergence • Divergence • Emergence	**Person in the world space** • Experiencing • Proximal
Cooperation • Multidisciplinary (*convergence in divergence*) • Interdisciplinary (*convergence in divergence*) • Transdisciplinary (*emergence*)	**Assumption: principle** • Continuity • Interaction • Complementarity	**Contextual space** • Dialogical • Cultural-historical
	Assumption: value • Harmony • Authoritative conversation • Respect	**Creative tool** • Narrative • Plan

manufacturing were such as dress-making, woodworking, printing, and the like. Reforms in education focused on developing characters, imagination, and technical skills. To progress, Singapore implemented plans of creative processes of socialization that enhanced self-esteem. The Singaporean adults guided the young (equalization, Adler, 1991); the young helped the elderly (compensation, Baltes, 1987); and together they went beyond the existing situation and create something novel for the future (rejuvenation). Foundations of education were implemented to ensure basic literacy, numeracy, and to inculcate multicultural values.

In the second decade (1975–1985), Singapore's creative design of the city was benefited from the country's flourishing economy in tourism, recreation, and the private residential and commercial markets. The design industry flourished in the arts, cultural, and fashion sectors. Schools moved beyond building foundations towards nurturing higher-order thinking at the secondary education (*convergence in divergence*).

During the third decade (1985–1995), Singapore's narratives focused on reviving itself from the global economic downturn. Creative tools that synthesize knowledge, experiences, and expertise include dialogue, conversation, reflection-in-action, cooperation, and collaboration. Cross-disciplinary tools that translate knowledge to practice include association, comparison, analogy, blending, and metaphor (Boden, 2004; Dillon, 2006). The Singapore Trade Development Board raised the consciousness to promote design as a tool to create competitive products and as a professional practice. Designers adopted new technologies and related modes of working using computer and mobile to broaden space of networking and designing. Associations for design were established. During this period, developing creative talent and imagination moved beyond Singapore art education in the secondary schools but towards nationwide creativity and holistic education. Towards to the end of the decade, higher-order thinking programs were infused into school and university curricula to develop creative thinking, critical thinking, and problem-solving competencies.

In the fourth decade (1995–2005), Singaporean fashion designers, visual communication designers, and photographers received invitations to work for international projects. High-quality education programs incorporated digital and media space of experiences as well as information communication opportunities. The fifth decade (2005–2015) of creative design in Singapore attained innovative grounds and began to move consciously back to craft, tradition, and culture and reinvent them (The Decades, 2016). Tacit or personal knowledge is the basis of scientific knowledge (Polanyi, 1986). *Continuity* in experience intercepts with *interaction* for development (Dewey, 1997). Creative industries and education revived their roles in the multicultural society of Singapore. Narratives of Singapore's education included "Teach less learn more", "innovation and enterprise", and "holistic development".

Narratives that are *coherent* and *congruent* transpire possibilities and becoming (Bruner, 2004). Singapore's creative design development and movement in the past half a century exemplifies designing within values of harmony, respect, and authoritative conversations. The city's transformation has influenced the reception of design thinking as a skill in the twenty-first century education for positive growth. Singapore, a vibrant and dynamic city today, is a member city of the United Nations Educational, Scientific and Cultural Organization (UNESCO) (rejoined in 2007). In May 2015, Singapore launched the Master plan of Design 2025 with a strong aspiration to improve life by infusing design and design thinking as a skill of every person in the society. To date in Singapore, an inclusive society, at its polytechnics and universities, there are numerous programs at the diploma, degree, and master levels on fashion, industrial, urban, visual communication, and the like design specializations. Narratives of Singapore's education are such as value-based learning, multiple pathways, and serving the large community.

Conclusion

This chapter presents an account of events that have occurred and will occur in teaching and researching creative ways to nurture design thinking in culturally appropriate environments among undergraduates of visual communication design studies (Bruner, 1991). Boundary crossing to the personal, proximal, and cultural-historical boundaries engages collective efforts to construct structures of communication and spaces of interaction within which plans and implementation of plans unfold to solve every day complex problems (e.g. creating a city of design or a inclusive society). Positive growth is deliberate, effortful, and intentional (Cropley, 2006). The growing minds get ready to broaden repertoires of skills, build resources, pose questions, challenge conventions, and solve practical problems (Fredrickson, 2004). The minds in openness, harmony, conversation, and respectful collaboration deconstruct genuinely the existing arrangements and systems of knowledge. In contemplation, the minds combine elements of knowing and knowledge and integrate them to form new relations to realities. Boundary crossing for the good (Taixu, 1989) and personhood (Rogers, 1961) involves a series of effortful processes to select and to synthesize information, knowledge, and purposeful knowing (*convergence in divergence*) for co-constructing realities and for possible *emergence* of humanistic values and genuine meanings. In collaboration, the creative minds develop socially acceptable strategies, build collective efficacies, and enhance converging yet practical perspectives (Tan, 2015a, b).

Narrative is a conventional form, transmitted culturally, and constrained by the mastery level of the person and his(her) conglomerate of prosthetic devices, colleagues, and mentors (Bruner, 1991, p. 4). Our *transdisciplinary* cooperation in the action research project complemented the initial conceptual understanding of cross-disciplinary creativity and design thinking. Dialogues, reflective writings, and products of designs from the designer-learners showed that they upheld their own values in action including maintaining harmony in the group and self, respecting views of the others and own, and engaging in authoritative conversation in the classroom or outside. In planning and implementing their designs, the designer-learners saw what was available from their surrounding that fit their body structure and capacities (affordances), knew how to relate to the affordance in visualization, and in action they grasped the affordances and made the prototypes (see e.g. Glaveanu, 2013; Ingold, 2013). The creative design experiences continued when the design-learners "retreat" to their personal space and intuitive feelings. They resolve conflicts and go beyond constraints. In experiencing freedom of contemplation, ideas emerge from the random-like images and intuitive feelings orientate possible creative combinations of plans (Bruner, 1969; Vygotksy, 2004).

The chapter ends with a question for exploration: In designing for the good, how do our narratives accrue to culture, tradition, or history? (Bruner, 1991) The presentation of the development of Singapore as a city of design exemplifies values-oriented boundary crossing creativity that interrelates tradition, history, culture, and narratives. We hope our chapter has provided some insights into nurturing design thinking in the context of positive growth across disciplines and beyond cultural boundaries, towards humanism and creative life.

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Chapter 6
Domain Generality and Specificity in Creative Design Thinking

Matthew Worwood and Jonathan A. Plucker

Abstract An emphasis on design thinking is increasingly prevalent in both professional and educational settings. From maker spaces to prototyping labs to the infusion of creative design thinking into K-12 instruction, principles of design thinking are making their way into a range of educational contexts and interventions. Many of these initiatives are based on creative thinking research and activities, making this research base relevant to the design of design-based educational interventions. In particular, the domain-specific and domain-general aspects of creativity have been studied and debated for decades, and a limited consensus has emerged on the extent to which creative thinking requires a mix of specific and general skills and personal characteristics. But little work has been done to explore the extent to which this previous theoretical and empirical work applies to creative design thinking, yet assumptions about the domain and task specificity of creative design thinking (or lack thereof) have a significant impact on both short- and long-term effects of design-based interventions. In this chapter, we review existing literature on creativity and domain specificity and then examine the degree to which that work is relevant to creative design thinking. Similarities and differences provide insight into design thinking in general and in creative contexts in particular. The chapter ends with an exploration of the implications of the research for teaching creative design thinking and which domain-general skills are particularly applicable.

Keywords Creativity · Domain specificity design thinking · Creative problem-solving · Education

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Introduction

In recent years, we have seen a surge of interest in design thinking and its associated principals that have been made popular by consulting firms that specialize in the process of design and innovation. Some of the leading pioneers of this methodology are found referenced in books, websites, and conferences on the subject of creativity, design, and innovation. Universities have begun to incorporate design thinking principles within their programs, with some even offering specific courses or degrees on the subject. K-12 schools have started to follow this trend by establishing maker spaces and restructuring traditional learning environments to more commonly reflect some of the practices documented by Stanford University's Hasso Plattner Institute of Design, as well as design practitioners, such as IDEO[1] founder David Kelley and IDEO CEO Tim Brown.

The disruption caused by the rise and use of digital media has only increased the attraction toward design thinking, as companies look to abandon with tradition and deliberately seek out creativity in order to remain competitive and current. For them, design thinking is a process that has a track record of success in multiple industries, leading to innovative products and services that have been transformative across the domains. Furthermore, the emphasis design thinking places on the user can be considered paramount within a digital culture that cares deeply about the way it interacts and experiences online products and services. This perspective is apparent even within the now famous article published in *The Atlantic* by Bush in (1945). Considered to be part of the early origins of our digital culture, this article titled "As We May Think" describes in detail an idea for a machine that will transform how we as a culture produce and share information. In the description, Bush takes the time to communicate exactly how the user will experience and interact with his invention, which resembled what we have come to know as the Personal Computer and Internet.

Design thinking has obvious parallels to creativity, another construct that is highly valued due to its link to workplace success and quality of life (National Research Council, 2015; Plucker, Kaufman, & Beghetto, 2015). Scholars have been comparing and contrasting research and education efforts within these two areas, with an emphasis on how the largely distinct research areas can inform each other. One critical area that has received attention is that of domain specificity versus domain generality. In a field such as design, which necessarily cuts across and is influenced by an almost unlimited number of domains, how does research inform our approach to design education? For example, if research suggests that creativity is largely domain or even task-specific, then design educators would be wise to embed design education within domain-specific content; if the research points to

[1]IDEO is an award-winning global design firm that takes a human-centered, design-based approach to helping organizations in the public and private sectors innovate and grow.

Read more at https://www.ideo.com/about/#Uprom8wIDu2xAQcd.99.

domain generality, then design educators attempting to teach design creativity would want to emphasize knowledge and skills that generalize across domains.

Domain Specificity and Generality in Creativity

Conceptual and empirical understanding of creative domain generality and specificity has advanced significantly over the past two decades. For much of the past 100 years, creativity was assumed to be largely domain general, with similar cognitive, affective, and motivational factors contributing to creative accomplishment across a wide range of domains and fields.[2] But near the end of the twentieth century, scholars in a number of fields (e.g., anthropology, psychology, education, sociology) began to note the importance of person-environment interactions in learning, creativity, and talent development, and this emphasis led to considerable interest in the possible domain specificity of these constructs (see Barab & Plucker, 2002).

For example, if learning a specific concept or skill is a function of both the individual learner and the learner's interaction with her environment, then the specific content being learned becomes paramount, hence the emphasis on domain specificity. This perspective quickly became dominant, at least in education circles (see notably Baer, 1993, 1994; Tardif & Sternberg, 1988; Weisberg, 1993). In particular, Gardner's (1983, 1988, 1993) multiple-intelligence theory and later creativity work made the case that psychologists and educators should no longer regard individuals as globally creative, but rather as creative in specific domains.

The emphasis on domain-specific approaches within the field of creativity was a reaction to the perceived overreliance on divergent thinking tests to study and identify creativity. These assessments have historically been based on domain-general content. Major thinkers within the field (see Baer, 1993; Csikszentmihalyi, 1990; Gardner, 1983) have objected to the heavy emphasis placed on divergent thinking measures as an index of a general capacity for creativity, and these scholars have been leading proponents of domain-specific conceptualizations of creativity and problem-solving.

But other researchers have cautioned that the pendulum may have swung too far in the direction of domain specificity. For example, Plucker (1999, 2004, 2005) noted that empirical studies of specificity and generality reach conclusions that can largely be predicted by the methods used to study creativity in each study, with divergent thinking tasks, activity checklists, and personality scales tending to support generality, and alternative assessments, and case studies tending to provide evidence of specificity. And research on infant cognitive development (see Dawson & Gerken, 2009; Kirkham, Slemmer, & Johnson, 2002) and adult problem-solving

[2] In this chapter, we use Csikszentmihalyi's (1988) distinction between domains and fields and Plucker, Beghetto, and Dow's (2004) definition of creativity.

(Sharif & Oppenheimer, 2016) supports domain-general conceptions of cognition and cognitive development and cautions against the dangers of overfocusing on specificity and inadvertently constraining development and reasoning effectiveness and efficiency.

More to the point, Plucker and Beghetto (2004) theorized that researchers may be misinterpreting the appearance of domain specificity with creativity being domain-bound. They argue that just because creativity looks domain-specific does not mean the underlying cognitive, affective, and motivational knowledge and skills are also domain-specific. If one drives the same car to work along the same roads every day, we would not conclude that they only know how to drive on that road, or more to the point, that they do not know how to ride a bicycle or run or walk. We make choices for reasons of efficiency, productivity, safety, etc., that may make our actions look highly constrained but in reality tell us nothing about domain specificity.

Plucker and Beghetto (2004) extend this logic to the relationship between creativity and domain specificity, arguing that there is a direct relationship between a person's age and experience on one hand and task commitment and motivation on the other as they interact to influence the domain specificity of an individual's creativity. As people age or gain experience in a certain domain or with a specific task, their creativity will necessarily become more domain-specific. As we know from expertise research, performing at elite levels often results from very large time commitments (Ericsson, 1996; Gardner, 1993; Lubinski & Benbow, 2000; Simonton, 2002; Sternberg, 2005).

The Plucker and Beghetto (2004) model's emphasis on lifespan development is an attempt to acknowledge that the social contexts in which people live and work impact one's creativity (see also Plucker, Beghetto, & Dow, 2004). For example, the role of marriage, children, caring for elderly parents, and other family-related events on creativity can be significant, both as positive and negative influences (see notably Simonton, 2002).

The second dimension of the Plucker and Beghetto model is interest and commitment to a particular topic or problem, noting that "[P]eople are usually cognitive misers, exhibiting a tendency to restrict and, therefore, preserve cognitive resources. In short, creativity may look task-specific, but in part because people make choices in life that force specificity upon them" (2004, p. 161). A person who only deals with domain-general techniques and approaches to creativity will rarely scratch the surface of a problem, yet someone who focuses tightly for long periods of time on a particular task is likely to experience functional fixedness. The Plucker and Beghetto model can be easily applied to creative design work: The longer an interior designer works in her domain, the more likely she is to apply her creative thinking almost exclusively to interior design; similarly, a motion graphics designer, over time, will focus her professional creativity on screen-based graphics design. As they progress in their careers, they focus their creativity on narrower slices of a domain due to restrictions of time and other resources. Those creative skills are still broadly applicable to a range of tasks across domains; but we suspect the number of designers who have the luxury of unlimited resources that facilitate cross-domain creativity is very small, indeed.

Plucker and Beghetto (2004) believe that the optimal condition for creative production is a flexible position somewhere between generality and specificity in Fig. 6.1, with the individual moving between positions as the current task or problem dictates. Adapting a term from Dawson and Gerken (2009), the situation of creative thinking within domains may be better thought of as *domain sensitivity* rather than domain specificity.

Application to Design Thinking

Design thinking is a form of creative problem-solving (CPS) that requires a specific set of thinking skills to address a problem. Therefore the endeavor is more than just following a sequence of organized stages. Educators and those invested in business management must learn how to facilitate the process and create an environment that welcomes the thinking that will be conducive during a team's pursuit of an outcome that can be considered creative. For example, let us focus on Ideation, a typical stage that appears in most forms of CPS methodology and usually takes place once a problem has been "tamed" (Churchman, 1967; Rittel & Webber, 1973). If a group of students were required to follow the principles of design thinking as part of a class project, but lacked divergent thinking skills, such as the ability to produce and consider many alternatives (Torrance, 1979), they would compromise their capacity to generate new and useful ideas to address the problem. In this event, the facilitator (e.g., teacher) must intervene with support strategies that can assist the student team complete this stage. This intervention requires an understanding of the process

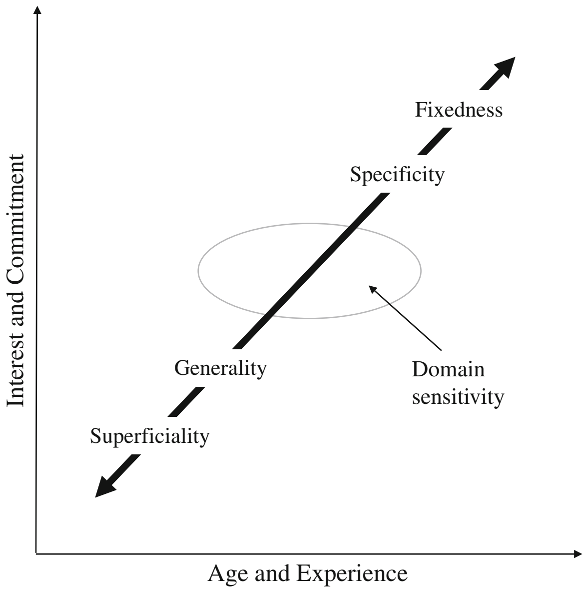

Fig. 6.1 Modification of Plucker and Beghetto (2004) conceptualization of domain specificity and generality of creativity

so that as a showcase of the “right” idea for the project is avoided. If the perception of the intervention is assumed to be the proposal of right idea students might disengage from the ideation stage of the process by choosing to accept the idea given to them by the teacher. Therefore, while students have participated in the Ideation stage of the process, they have done so within engaging the type of thinking skills needed to make the process a success.

Whatever the domain, the absence of divergent thinking skills, such as the ability to produce and consider many alternatives, will likely yield outcomes that are safe and within “habit keeping” as opposed to “habit breaking” (Wallas, 1926). For this reason, the design thinking stages that involve ideation must be facilitated in a way that encourage team members to go beyond the obvious, and apply the type of thinking skills that will most likely produce an abundance of ideas, which in turn, will increase the overall amount of good ideas that the individual or team can choose from (Osborne, 1963). This requires education and the management of design thinking in business, to familiarize itself with the type of thinking that can assist individuals or teams during each stage of the design thinking process, and the strategies that can be deployed as part of this endeavor.

Creative Problem-Solving

The thinking skills needed for problem-solving has been a matter of public discourse for many years, even predating the study of creativity, which is often cited as starting in 1950, as part of Guildford’s inaugural speech to the American Psychology Association. Almost 30 years prior, Graham Wallas, a social psychologist, had wondered about the thinking process that brought about the making of a “new generalization or invention.” After examining the achievements of a German physicist, Wallas (1926) was able to identify “a continuous process” which he described as having a beginning, middle, and end.

> The first in time I shall call Preparation, the stage during which the problem was “investigated… in all directions”; the second is the stage during which he was not consciously thinking about the problem, which I shall call Incubation; the third, consisting of the appearance of the “happy idea” together with the psychological events which immediately preceded and accompanied that appearance, I shall call Illumination. (pp. 91–92)

It has been argued that CPS research and its resulting methodology can trace its origins back to the stages first identified by Wallas (Torrance & Safter, 1999), though the topic can also be found outside the field of creativity. For example, Rittel and Webber (1973), Rittel (1987), and Churchman (1967, 1974) explored the differences between a problem that was well-defined, and one that was less-defined, as part of their approaches to design and system management, respectively. In recent years, the disruption caused by digital technology has only increased the need for proven practices in problem-solving, mainly as business and industry scramble to maintain a constant flow of innovative ideas to stay current. It would appear that design thinking has emerged as one of the more popular forms of problem-solving, integrating general approaches to design with traditional CPS methodology to solve today's ill-defined or "wicked" problems (Rittel & Webber, 1973).

Rittel (1987) suggests that designers like to "think before they act" (p. 1) taking the time to formulate their actions thoroughly before making a commitment to a direction. He also speaks generally about their process and the type of think they apply to a problem.

> Many forms of mental activity take place in the course of design. Designers think more or less coherently; they figure, they guess, they have sudden ideas "out of the blue", they imagine, speculate, dream, let their fantasy wheel freely, scrutinize reckon, they "syllogize". (p. 2)

Like prior CPS methodology, the principles that have become commonly associated with design thinking are interdisciplinary and have transcended across domains, forming a generalized approach to problem-solving that can be applied to business and beyond. For example, in researching for this chapter, the literature that explored ill-defined problems was not from one single discipline, but instead ranged from social management systems (Churchman, 1967, 1974), and mechanical engineering, to traditional fields of design (Buchanan, 1992; Rittel 1987). Even one of the most notable CPS pioneers, Alex Osborn, emerged from business after working as a partner at one of the world's largest advertising agencies, BBDO.

The success of design firms like IDEO, who have been particularly transparent with their approach to problem-solving (selling them as services), has helped lead the charge for design thinking (Gobble, 2014), with IDEO CEO Tim Brown crediting the company's founder, David Kelley, for popularizing the term as a domain-general approach to problem-solving.

> One day I was chatting with my friend David Kelley, a Stanford professor and the founder of IDEO, and he remarked that every time someone came to ask him about design, he found himself inserting the word "thinking" to explain what it was that designers do. […] I now use it as a way of describing a set of principles that can be applied by diverse people to a wide range of problems. (Brown, 2009, pp. 6–7).

As such, the goal of this paper is not to examine the relationship between design thinking and past CPS methods but instead highlights the relationship creative domain generality plays within the universal principals that exist as part of the design thinking process.

The Human Approach

To explore the interplay between creative domain generality and design thinking, we believe it is important to first clarify our perception of design thinking to limit potential confusion within academic discourse. In its purest form, design thinking, like other alternative methods of CPS, is part of the interplay of creativity.

It pertains to a sequence of thinking events that take place as practitioners deliberately work to produce an outcome that can be considered new and useful.

In the *Universal Traveler*, Koberg and Bagnall (1972) put forward a design process developed by extracting the essential characteristics of prior creative problem-solving methods. In their book, they referred to the design process as a "problem-solving journey," using design and CPS terms interchangeably. Like nearly all forms of creative problem-solving, the journey begins with a stage, or stages, devoted almost entirely to clarifying an ill-defined problem, which Rowe (1991) describes as a problem where "both the end and means of the solution are unknown at the outset of the problem-solving exercise" (pp. 40–41). Rittel and Webber (1973) referred to this type of problem as being "Wicked" in nature, requiring individuals or groups to understand the problem or mission, gather information, analyze information, synthesize information, and wait for the create leap. The ambiguity that surrounds an ill-defined problem is very different to that of a well-defined problem, which involves solutions that are already described, and with the required actions immediately apparent. In his book, *Design Thinking*, Rowe (1991) emphasizes the generalized approach designers take when working to solve a problem, for while there are irregularities in their modes of operation, there are conventional procedures for handling information that can be analyzed and likened to existing methods of Creative Problem-Solving.

Buchanan (1992) stated that designers rarely receive a definition of the subject matter that they are to explore as part of an assignment. Instead, they receive just the problem and a set of issues to consider when designing the solution. In these types of situations, designers must apply a sequence of thinking tools that assist them in their journey to solving that problem.

> They allow the designer to position and reposition the problems and issues at hand. Placements are the tools by which a designer intuitively or deliberately shapes a design situation, identifying the views of all participants, the issues which concern them, and the intervention that will serve as a working hypothesis for exploration and development. (Buchanan, 1992, p. 17)

Buchanan's (1992) explanation highlights some of the unique elements that make up the general principals of design thinking. Not only must the practitioner of this process "discover or invent a *particular* subject" (p. 16) within the presented problem, but they must also identify the participants who will benefit from the outcome of the process. This method is the "human-centered" approach to problem-solving (Brown, 2009; Gobble, 2014), which is a principle that appears absent from previous CPS methodology. For while, general approaches to problem-solving nearly always come with a clarification and ideation stage; the over-emphasis on the user is something that appears unique to design.

The centrality of the concept of "human experience" (Gobble, 2014) in design thinking is particularly evident in the literature. Faste states that the "user must be constantly considered as a fundamental reference for decisions" (2001, pp. 327–328), throughout the process, and thanks to digital technology, practitioners of design thinking now have greater access to information (Gobble, 2014). For example, practitioners designing a video can easily find out the average length of time a user will engage with content within their social media feed, and those designing for the Web can access data on where, when, and how users interact and experience their product or service. Within instructional design, educators can investigate how learners learn, and modify or adapt the learning experience based on the data that they have obtained from the learning management system.

The Iterative Process

In Buchanan's reference, he states that designers must identify a "working hypothesis for exploration and development" (1992, p. 17), likened to an iterative process, where rapid prototypes are generated to test out initial ideas and gather additional information about the user. Referring back to the work of Rittel and Webber (1973), and the dealings of wicked problems, ideas put forward must be carefully explored and tested. Often they have a tend to generate negative or undesirable consequences for the user, and it can be difficult to know these before the implementation of the solution. Once again, this is mainly apparent within the world of digital media, where products and services are often released to a small group of potential users, before being shared with the general public; this is usually referred to as the Alpha testing stage. However, iteration is not exclusive to digital products, for nearly all ideas are initially flawed from the start, needing to be corrected, modified, elaborated, or sometimes even changed entirely within the problem-solving process. (Torrance & Safter, 1999).

With emphasis always placed on the user, each iteration is examined continuously from their perspective, with questions and observations designed to improve upon the solution and gather more information about the needs of the person, or people who will are intended to benefit from the outcome. Within this part of the process, there is a distinct sense of play and failure as part of the experience. Catmull, a founding member of Pixar and now VP of Disney Animation, emphasizes the importance of "fail early and fail fast" (Catmull & Wallace, 2014, p. 109), and Kelley of IDEO states that "prototyping is problem-solving," noting that "prototyping doesn't just solve straightforward problems. Call it serendipity or even luck, but once you start drawing or making, you open up new possibilities of discovery" (Kelley & Littman, 2001, p. 38).

The iteration that exists within design thinking allows initial ideas to make themselves known almost immediately, challenging practitioners to take the ideas they are processing internally, and express externally.

Design Thinking

It is difficult to argue that design thinking is not part of the broader interplay that exits within the field of creativity. It is a process of problem-solving that has been deployed by businesses to solve complex problems within a variety of domains, including those applicable to technology companies who work hard to establish cultures of innovation within their R&D environments.

Design thinking is a sequence of stages that begins with an ill-defined problem and concludes with an agreed upon solution that benefits the end-user. We consider design thinking to be a human-centered process of problem-solving applied to a situation that requires the design or redesign of a product or service that has the intent to make itself known to an outside individual or group. It is a deliberate approach to be creative, building upon ideas through a process of iteration until an agreed-upon solution has been identified. This interpretation is a creative process because there is an intent for an idea to be generated and make itself known to others (Plucker, 1998). However, design thinking is not only used to produce new and useful products but also can be used to improve existing ones as well (Brown, 2009). Furthermore, the emphasis on a human-centered approach, and the regular reference toward its application in business suggests that design thinking is a process that is primarily concerned with the design and development of an outcome that is useful to an outside individual or group and not only to the practitioners engaged in the process.

Digging Deeper into the Relationship with Creativity

As previously discussed, the principles contained within design thinking can trace their roots back to multiple domains, but they were perhaps most apparent along industrial or engineering designers looking to formulate best practices within their respective fields. What is important to note is the general principles to emerge from this process are not confined to a single field or area of design, but instead are "*universal* in scope" (Buchanan, 1992, p. 16) and therefore can be applied to multiple domains.

The specified generality of design thinking does not mean to suggest that anyone in any domain implements its process. Of course, there are content-specific skills that will be required depending on the situation. For example, an individual or group, who has been contracted to design a solution in the field of motion graphics, will have little success if they lack skills in typography, color theory, and animation. They will also need to have proficiency with the software, knowledge of industry vocabulary, and experience in how to bring all these elements together. Furthermore, their success will likely be determined by other domain-specific skills that have been developed over time and in the practice of "being" a motion graphics designer. This example supports the notion that practitioners of design thinking deploy different tools to solve domain-specific problems, but the principles that guide their process remain the same no matter the domain (Faste, 1981). Once more, we also argue that certain stages of design thinking rely heavily on specific creative thinking skills, which tend to be domain general.

Design thinking begins with the presentation of an ill-defined problem to an individual or group, who intend to produce a solution for a known user. At this stage, which we will refer to as *stage one*, practitioners of design thinking will need to apply a combination of analytical and creative thinking skills to clarify the problem and generate potential ideas for the solution. While the analytical skills might be domain-specific the creative thinking skills applied at this stage are domain general; for no matter what field you are working in, practitioners of design thinking benefit from creative thinking skills that aid divergent thinking and navigating through the type of ambiguity that accompanies an ill-defined or wicked problem. In an effort to new or different ideas, skills such as an ability to remain flexible, be open, combine and synthesis, and produce and consider many alternatives (Torrance, 1979; Torrance & Safter, 1999) are particularly helpful during stage one of design thinking, However, these skills are just as applicable to the early stages of other CPS methods.

What makes design thinking different is the emphasis on the end-user and the use of prototyping to solicit feedback and additional information (data) about the problem. This aspect requires practitioners of design thinking to "get out" of their minds and make their initial ideas known to others. This need to rapidly explore and share ideas is what creates a natural relationship with the concept of play and failure, and design thinking, because their outcome is nearly always one of discovery. As each prototype is generated, the practitioners of design thinking learn something new about their idea and/or the user and through iteration can make changes or modifications to their idea along the way. At this stage, which we will refer to as *stage two*, the types of creative thinking skills that are particularly helpful are the ones that help make connections and assist in seeing things from multiple perspectives. The ability to look at a problem from different perspectives, combine and synthesis ideas into potential solutions, and put your ideas in context (Torrance, 1979; Torrance & Safter, 1999; Ward & Kolomyts, 2010) are creative thinking skills that can be applied to this stage regardless of the domain. Perhaps even more applicable to prototyping is de Bono's concept of Lateral Thinking (1970), used in conjunction with analytical thinking as part of a deliberate creative process. In Lateral Thinking, "you might have to be wrong at some stage in order to achieve a solution" (p. 12) and there is a need to see things from multiple perspectives and deliberately seek out what might be irrelevant information.

Conclusion: Educational Implications

The education system has witnessed a resurgence of project-based learning and constructivism, particularly within the movement for teaching twenty-first century skills. Some strategies prioritize opportunities that allow students to collaborate in groups, which often force them to combine a variety of soft skills in order to navigate their way through a problem (Plucker, Kennedy, & Dilley, 2015). Digital technology has supported this effort even further, combining the concepts of constructivism with digital tools that allow students to produce new and useful products that can be experienced beyond the four walls of the classroom. These outcomes have led to maker-type spaces emerging in many schools and communities around the country, and there appears to be a genuine desire for students to “invent” new and innovative solutions. For this reason, the adoption of design thinking within education environments makes sense, as it not only offers a structured process for teachers, but it also aligns itself with the popular trends underway within K-12 education.

However, the benefit of design thinking cannot only be accomplished by describing it prior to an activity or assignment. Instead, educators must actively seek out the type of situations where it can be best deployed, which require an opportunity for students to experience an ill-defined (or wicked) problem that impacts an individual or group that is previously unknown to them, or at the very least exists outside the classroom environment. If an outcome is pre-determined by the instructor, or aspects of the problem defined, the opportunity for students to actually participate in design thinking and/or engage the creative domain-general skills that we consider part of the process will be diminished or perhaps eradicated. Furthermore, within this framework, there must be an opportunity for the students to gather new information about the user and for this to be obtained independent from the teacher. Without this element, the human-centered approach to design thinking might be absent from the experience, and students will likely revert back to common assumptions about the problem.

From our perspective, the goal of these activities should be for students to learn how to balance domain-specific and domain-general strategies to creative design thinking; in other words, to become *domain sensitive* when designing or otherwise creating. Plucker and Dow (2010) describe a model for creativity enhancement in which attitude and motivation are seen as crucial domain-general aspects of creativity, with domain-specific skills and strategies taught as needed as students solve real-world problems. This basic approach should work equally as well for creative design thinking.

During problem-based design experiences, educators should not confine themselves to the sidelines, but instead assist their students on their journey of discovery. Facilitating divergent and convergent thinking strategies is one example, but encouraging students to make their initial ideas known in the form of some type of prototype, while having the opportunity to improve upon that initial idea by exploring it from the perspective of the user, is also within upholding the principles of design thinking. Through this process, the educator can encourage the domain-general attitudes that lead to long-term creative success by guiding their students to new but also valued discoveries, by helping them make useful observations about their idea, or asking the right type of questions about the user. Throughout this process, a teacher must continuously challenge the students to think critically and consider how their idea will impact those who are supposed to benefit from the solution, and perhaps rewarding based on the number of discoveries made, as opposed to how many things they got right.

Finally, because design thinking is domain general, with a common language and principles, we argue that aspects of the process can be deployed across disciplines and grades. Therefore, from elementary school to higher education, there is an opportunity for educators to break down the silos that too often exist within education and work together to develop best practices for the application of design thinking within teaching and learning.

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Part II
Thinking Outside the Box: Interdisciplinary Process and Action in Creative Design Thinking

Chapter 7
The Multivariate Approach and Design of the Creative Process

Julien Nelson and Marion Botella

Abstract Creativity is often described as an essential aspect of the innovative design process. As such, many authors have proposed models aiming to describe existing creative practices, both at the macro level—i.e. the stages involved in a creative process—and at the micro level—i.e. the underlying cognitive processes. Conversely, many other models are of a *prescriptive* nature: their goal is not to describe existing practices, but to structure them in order to help professionals deal with the uncertainty that is inherent to creativity. Whatever the type, such models aim to answer the following question: how can creative work be structured in order to ensure the optimal deployment of creative potential? The multivariate approach posits that creative behaviour is made possible by interactions between multiple resources including cognitive, conative, emotional and environmental factors. Like existing models, the multivariate approach has shown potential for both descriptive and prescriptive modelling of the creative process. In this chapter, we will review existing research on the multivariate approach of creativity. We will begin by describing the theoretical and methodological background of such models. We will then go on to describe some of the results obtained by multivariate modelling of the creative process in recent years. Finally, we describe some prospects for future research, specifically concerning prescriptive modelling—that is, the design of the creative process.

Keywords Creative process · Multivariate approach · Prescriptive modelling

Introduction

Creativity is defined as the ability to produce work that is both novel and suited to task constraints (Amabile, 1996; Sternberg & Lubart, 1999). Attempts to define this ability have long been accompanied by a debate regarding its domain-general or domain-specific nature (e.g. Baer, 1998; Plucker, 1998). *Multivariate*, or

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componential, models of creativity attempt to resolve this by describing creativity as comprising general, domain-specific, and task-specific abilities and involving the confluence of multiple resources (Barbot, Lubart & Besançon, 2016; Lubart & Guignard, 2004). Typically, these resources include conative, cognitive, and emotional factors, which are internal to the creative individual, as well as factors related to the external environment. Understanding the nature of these resources and their interrelations is essential in studying variability in creative work between individuals, as well as for addressing a range of societal issues, including education, recruitment, and job design, particularly in the creative professions. The goal of this chapter is to propose a brief review of existing research on multivariate models of creativity. We will begin with an overview of the main multivariate models and go on to describe two applications of this approach: the design of instruments to assess creative potential and the design of work processes in creative organizations.

Multivariate Models of Creativity

Componential models of creativity are defined as "seeking to specify the basic components, or elements, that work together to produce creative behaviour" (Sternberg, 2011, p. 226). In the present section, we describe three main models inspired by this multivariate approach, drawing from earlier reviews by Lubart (1999) and Sternberg (2011).

Amabile's Componential Model

The earliest effort to propose a multivariate model of creativity is most probably the work done by Amabile (1983a, 1983b). This framework comprises three types of resources: domain-relevant skills, creativity-relevant skills, and task motivation. Domain-relevant skills include the factual knowledge of the domain, the technical skills necessary for completing creative tasks, and domain-specific talents. The latter is defined as a natural aptitude for a particular, domain-specific skill. Domain-specific skills, then, represent the base materials from which individuals can make a creative contribution to a specific domain. Creativity-relevant skills include a set of skills that is specifically mobilized for producing a creative output, independently of the task domain. These include specific cognitive styles, knowledge of heuristics for generating novel ideas, and work styles conducive to creative production. Finally, task motivation refers to each individual's attitude towards the task and to perceptions of one's own motivation for undertaking the task.

In addition to describing the components that interact with each other to produce creative behaviour, Amabile (1983b) also proposed a model of creative production comprising a linear series of four steps—(1) problem or task representation, (2) preparation, (3) response generation, and (4) response validation. The contribution of this model is twofold. First, it illustrates that both domain-general and domain-specific skills and resources are necessary for producing creative output and specifies which kind of resource is mobilized at what stage in the process. Second, it also acknowledges the role of the social and organizational environment, in addition to individual differences.

The componential model has exerted a considerable impact on the study of differences in creative output between individuals and across domains. However, two main limitations are frequently pointed out in the literature. First, few details are provided regarding the theoretical models underlying each of the components, their structure, and their interactions, leaving many questions open (Sternberg & Lubart, 1991). Second, the environment is conceptualized only in terms of its social and organizational aspects, whereas its physical characteristics may also play a part in influencing creative behaviour (Dul & Ceylan, 2011).

Kaufman, Cole, and Baer's APT Model

The Amusement Park Theoretical (APT) model was proposed by Kaufman and Baer (2005) to account for the gradient between domain-generality and domain-specificity in creative abilities. Just as its name implies, it is based upon the metaphor of an amusement park and describes these abilities following three different levels: (a) initial requirements refer to all the resources that are necessary, but not sufficient, for creative production: intelligence, motivation, and a suitable sociocultural environment; (b) general thematic areas, i.e. clusters of domains, e.g. scientific discovery, everyday problem-solving, arts and crafts, each of which requires more specific abilities; (c) domains, i.e. more narrow clusters of creative professions and activities; and (d) micro-domains, i.e. specific creative tasks. The main contribution of the APT model is that it acknowledges explicitly that creativity is not a unitary construct: beyond the standard division between domain-general and domain-specific requirements, each domain of creative endeavour implies its own optimal "mix" of abilities.

Sternberg and Lubart's Investment Model

The investment model (Sternberg & Lubart, 1991, 1995) was proposed in part to address the relative lack of theoretical foundations in the componential model, mentioned above. The term *investment* refers to the fact that creative individuals must be able to "buy low and sell high", i.e. pursue ideas that are initially under-explored or out of favour, then be willing to move on once these ideas have achieved acceptance in the domain. According to these authors, creativity results from the confluence of six key resources: intelligence, knowledge, intellectual styles, personality traits, motivation, and environmental factors.

One of the advantages of this model is that it draws from multiple theoretical works to conceptualize each of these six resources. For example, intelligence is defined in reference to Sternberg's triarchic theory of intelligence (1985), which distinguishes between three types of intellectual skills: synthetic, analytic, and practical. In the context of creative achievement, Sternberg (2006) argued that each of the three were important: "*the synthetic skill to see problems in new ways and to escape the bounds of conventional thinking, the analytic skill to recognize which of one's ideas are worth pursuing and which are not, and the practical-contextual skill to know how to persuade others of – to sell other people on – the value of one's ideas*" (p. 88). Hence, creative ability is in part influenced by general cognitive abilities and processes, e.g. problem-forming, insight, and selective encoding, comparison and combination of information.

Likewise, thinking styles are conceptualized in reference to Sternberg's (1997) theoretical framework: such styles can be defined as "a propensity for using one's abilities in a certain way or ways" (Sternberg & Lubart, 1991, p. 11). According to Sternberg and Lubart (1991), three intellectual styles are particularly characteristic of eminently creative individuals: the legislative style, characterized by a preference for playing by one's own rules and ideas; the progressive style, characterized by an orientation towards novelty rather than conservative attitudes; an ability to shift between the global style, characterized by a preference for seeing "the big picture"; and the local style, characterized by a preference for narrower details of specific tasks.

The inclusion of personality as a resource in this model comes from the observation that specific personality traits can reliably be found in highly creative people. These traits include, for example, openness to new experiences (Feist, 1998), tolerance of ambiguity (Zenasni, Besancon & Lubart, 2008), and willingness to take risks (Glover, 1977).

With respect to Amabile's componential model, the investment model differs in three major aspects (Sternberg, 2006). First, it acknowledges that there are threshold effects for each resource, and that creative behaviour may not be possible if these thresholds are not met. For example, individuals with a complete lack of domain knowledge will probably find it more difficult to formulate a creative contribution to that domain than more knowledgeable people. Second, it also notes that partial compensation between resources is possible. For example, highly motivated individuals may surpass the adverse effects of a work environment detrimental to creativity. Third, these compensation effects are not undifferentiated, and these key resources may interact in complex ways.

More recently, Lubart and colleagues (Lubart, Mouchiroud, Tordjman & Zenasni, 2003) proposed a simpler model where creative potential is considered to result from a confluence of four different factors: cognitive, conative, emotional, and environmental factors. This model is represented in Fig. 7.1. Recent research on the link between creativity and emotions has shown that both concepts are closely linked. Creators, as artists, present specific emotional traits—as personality traits—different from the general population (Botella, Zenasni & Lubart, 2015). Moreover, even if contradictory results exist about the effects of mood induction on

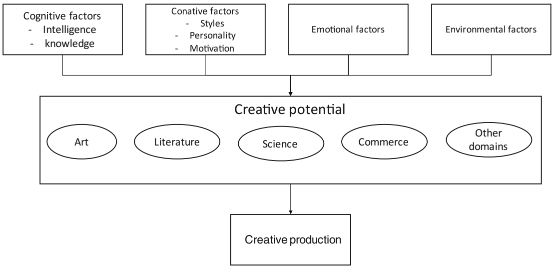

Fig. 7.1 Multivariate model of creativity (from Botella, Zenasni & Lubart, 2015)

creativity, empirical studies indicate that emotions have an impact on creative performance. Emotional traits and states are therefore considered as a specific factor in the multivariate approach.

Finally, although emotions are often described as playing an instrumental part in creative production, the term itself is frequently confused with related affective constructs such as mood or temperament (Ekman & Davidson, 1994). Within the multivariate approach, the emotional component refers to emotional traits and states (Botella et al., 2013). Emotional states are typically brief episodes of high intensity; they are transient states that occur in response to a stimulus present within the environment. In contrast, emotional traits refer to stable individual characteristics that moderate the nature and quantity of emotional experiences (Zenasni & Lubart, 2002). Thus, traits such as emotional clarity and the capacity to perceive feelings are positively correlated with creative performance (George & Zhou, 2002), as is emotional intelligence (Wolfradt, Felfe & Köster, 2002). It is in reference to this model in particular that we will now discuss the practical implications of multivariate models of creativity.

Some Implications of Multivariate Models of Creativity

Assessing Creative Potential

According to many authors (e.g. Baer & Kaufman, 2006; Barron, 1988; Runco, 2004), a major starting point for modern research in creativity was Guilford's address to the American Psychological Association (Guilford, 1950) followed by his work on the Structure of Intellect model (Guilford, 1956). This model places a strong emphasis on divergent thinking, i.e. the ability to produce multiple or alternative answers from available information (Cropley, 2006). Hence, many early tests of creative ability focused only on the cognitive aspects of creativity, and more precisely on divergent thinking ability. Hence, divergent thinking tasks are present in the Torrance Tests of Creative Thinking (Torrance, 1966) and in the Wallach–Kogan tests of creativity (Wallach & Kogan, 1965). Divergent thinking ability is then assessed through a number of standardized criteria: fluency, originality, flexibility, and elaboration (Plucker & Makel, 2010).

Divergent thinking, however, is not the only cognitive resource involved in creative thought, and alternate tests were later devised to test other abilities also related to the cognitive component of creativity. The best known of these is probably the Remote Associates Test, or RAT (Mednick, 1968): participants are presented with several series of three stimulus words; for each one, they must find a fourth word linking the other three together. Other tests, such as the Test of Creative Thinking–Drawing Production (TCT-DP; Urban & Jellen, 1996), focus more on convergent-integrative thinking. Hence, most classical tasks aiming to test creativity focus on domain-general cognitive mechanisms. Instead, from a multivariate perspective, it is important to consider creativity as a multifaceted, domain-specific set of abilities (Barbot, Besançon & Lubart, 2011). Hence, one of the more recent efforts to develop tools to assess creative potential, Evaluation of Potential for Creativity (EPoC; Lubart, Besancon & Barbot, 2011) proposes to overcome these limitations by testing both divergent-exploratory and convergent-integrative processes in two different task domains: verbal and graphic, with further domains in course of being added to the battery.

Several instruments have also been devised to assess the conative and environmental components of creativity (Barbot et al., 2011). Conative factors refer to individual preferences regarding ways of thinking or behaving and include personality traits, cognitive styles, and motivations to create. Hence, the use of standardized questionnaires may serve to identify the characteristics of creative personalities (Gough, 1979). Similarly, following Amabile's claim that task motivation was a key component of creative production (see here above), many scales include items aiming to assess levels of extrinsic or intrinsic motivation. However, as Barbot et al. (2011) note, problems with the use of self-report scales to assess the conative components of creative potential are twofold: (a) such scales may lead to self-report biases, e.g. due to the halo effect or social desirability; (b) they usually only capture generalized constructs and do not take into account domain- or task-specific tendencies.

Concerning the environmental component, several authors have proposed scales attempting to measure the extent to which the environment is thought to support—or conversely, hinder—creative work. The KEYS scales (Amabile, Conti, Coon, Lazenby & Herron, 1996), for example, comprise 78 items assessing in particular six dimensions of the work environment that are supportive of creativity—organizational encouragement, supervisory encouragement, work group supports, sufficient resources, challenging work, and freedom—and two dimensions that represent obstacles to creativity—organizational impediments and workload pressure. As Amabile and her colleagues noted, though, the KEYS scales only assess the social and organizational dimensions of the work environment. Later authors pointed out that the work environment might also impact creative behaviour through its physical characteristics (Dul & Ceylan, 2011). For example, McCoy and Evans (2002) devised a 21-item scale measuring seven dimensions of the perceived physical characteristics of the work environment in its relation to creativity, five dimensions supporting creativity—a proximity to nature, a sense of challenge, a sense of freedom, support for creativity, and overall coherence—and two hindering creativity—a threatening character and upholding the status quo. It should be noted, however, that such scales only assess individuals' perceptions of how their environment supports or hinders their creative endeavours, and that few empirical studies have focused on the relationship between these perceptions and actual creative performance—for a recent exception, see Dul and Ceylan (2014).

Multivariate models of creativity can thus serve as the basis for the design of tools to assess creative potential at the general, but also at the domain-specific or task-specific levels. In this case, investigations rely on (a) having participants carry out creative tasks in a specific domain, and (b) soliciting domain experts to elicit a set of cognitive, conative, emotional, and environmental resources which they deem necessary to achieving a creative output. As Barbot, Besançon and Lubart note, however:

> Although these approaches have proved useful to identify the most central resources, they may be limited to estimate the relative importance of each resource because various relevant sub-groups of experts tend to value these resources differently depending on their own experience with the creative outlet under investigation. (Barbot, Besançon & Lubart, 2016, p. 2)

For example, in a study of essential skills in creative writing, Barbot, Tan, Randi, Santa-Donato, and Grigorenko (2012) asked five populations of experts of this creative domain—teachers, psychologists, published writers, linguists, and art educators—to rate the relative importance of skills related to creative writing, from six possible categories: general knowledge and cognition, creative cognition, motivational and conative factors, executive function, linguistic and literary skills, and psychomotor function. Their results show that different kinds of domain experts view different skills as being essential for creative achievement in writing.

To address this limitation, Lubart, Zenasni and Barbot (2013) proposed a different approach, with a tool named "creative profiler". Instead of relying on the subjective criteria of domain experts to judge the potential of a creative individual, this tool constitutes a creative profile-based results obtained using (a) self-report questionnaires and (b) performance metrics in standardized creative tasks, which are intended to assess five key cognitive resources related to creative potential—divergent thinking ability, analytic thinking ability, mental flexibility, associative thinking ability, and selective combination ability—and five key conative resources—tolerance of ambiguity, risk-taking proclivity, openness to new experiences, intuitive thinking style, and motivation to create. This profile is then compared to a profile modelled from the responses of a sample of individuals who are recognized as being highly creative in the particular domain under consideration.

Designing the Creative Process: An Application to Innovation Design

The creative process is defined as "the sequence of thoughts and actions that leads to a novel, adaptive production" (Lubart, 2001, p. 295). Starting with the seminal work of Wallas (1926), several authors have proposed descriptive models of the creative process (Amabile, 1988; Busse & Mansfield, 1980; Cagle, 1985; Doyle, 1998; Goswami, 1996; Hadamard, 1945; Ochse, 1990; Osborn, 1957; Rossman, 1931; Stein, 1974; Taylor, Austin, & Sutton, 1974; Treffinger, 1995). These models are generally linear in structure and comprise between three and seven stages. In spite of the diversity of terminology employed, most models exhibit consensus regarding the presence of four main stages in this linear process: problem analysis, idea generation, idea evaluation, and communication. Although these process models are usually presented as domain-general, similar models have been proposed in specific domains of creative endeavour, e.g. art (Mace & Ward, 2002).

The creative industries are noteworthy in that they have, in recent years, been increasingly recognized as an essential engine for economic development, with the term “creative workers” encompassing professions from artist to scientists, engineers, industrial designers, etc. (Florida, 2014). Most creative work, in this respect, is risky: the creative individual may, in reference to the standard definition quoted above, produce work that is either not novel or suited to task constraints, or both; or indeed, fail to produce the creative work at all. For this reason, creative professions have increasingly been subjected to managerial frameworks, whose goal is to ensure that these risks are averted and that their creative potential is used to its full extent. Such frameworks generally rely on *prescriptive* models of the creative process.

In contrast to descriptive models, which describe the creative process as it truly is, prescriptive models describe the work as it is defined by the work organization (Daniellou, 2005). Such models are also linear, and almost exclusively domain-specific. We will focus our argument below on the field of design, more precisely engineering design. In this field, several models of the design process have been proposed and are routinely based both for the training of engineers and to structure design projects in companies (Howard, Culley & Dekoninck, 2008). The goal of such models is to ensure that a design process progresses whilst respecting the three traditional main criteria of success in project management: optimizing time, cost, and quality of the output (Atkinson, 1999). Typically, these models also comprise multiple stages: each stage is characterized by (1) a set level of abstraction in the creative problem-solving process and (2) the provision of goals and the production of intermediary representations of the object being produced. In this way, throughout a creative design project, the work shifts from early and vague representations of the final product (e.g. design sketches) to detailed design specifications (Le Masson, Weil & Hatchuel, 2010).

Conclusion

Creative design is an interesting example of complex creative work, because in most cases, no single person can possess all the resources necessary for completing a project. The work is inherently collaborative (Midler, 1995). Hence, the rationale behind prescriptive models is that they allow collaborators in a design project to structure the creative problem-solving process. Indeed, although design is often described still today as solving an ill-defined problem (Simon, 1996), a design project implies instead solving multiple interrelated problems at different levels of abstraction.

However, as their name implies, prescriptive models of the design process only provide a structure in terms of the succession of stages (i.e. tasks and subtasks) needed to complete a creative design work. They do not take into account the other determinants of creative potential, as presented in this chapter, i.e. cognitive, conative, emotional, and environmental factors. The literature outlined in this chapter certainly provides some initial elements to design situations that are well-suited to designing training and work situations to improve creative performance in innovation design. Yet, this literature is currently lacking in two areas, which could constitute interesting areas for future research.

First, multivariate models pave the way for the study of domain-specific creative abilities in the field of engineering design. At present, several studies have focused on the cognitive elements of task expertise (for reviews, see Cross, 2004; Lawson & Dorst, 2013). In contrast, the emotional aspects involved in design activity have been the subject of far less scrutiny (see however Bonnardel & Moscardini, 2012). Numerous studies have examined the personality characteristics of engineering students using standardized instruments such as the Myers-Briggs Type Inventory (e.g. Felder, Felder & Dietz, 2002; McCaulley, 1990). However, there currently is a lack of studies pertaining to professional designers. Furthermore, some authors have noted a paucity of information regarding the personality characteristics of design students and professionals (Shen, Prior, White & Karamanoglu, 2007). In particular, to our knowledge, no study to date has sought to assess the creative potential of these specific populations.

Second, creative design is, by its very nature, a team-based enterprise. Therefore, it is not enough to identify the particular confluence of resources that make designers work creatively. They must also be able to work creatively *as teams*. From this point of view, Shen et al. (2007) propose three strategies for constituting teams that are of particular interest to us: (1) select team members based on a heterogeneous mixture, i.e. gender, age, nationality, specialization and (2) select them based on their personality type and/or learning style. Typically, design teams are constituted following the first strategy, under the assumption that the diversity of points of view is a necessary condition of creative performance. For example, ethnographic studies of design teams highlight the fact that these teams are usually constituted of members of different specialties, with a diversity of experiences in the field (Bucciarelli, 1994). However, more research is needed to understand the social dynamics of groups of designers in order to provide the means to define (a) optimal group configurations and (b) optimal work environments for design projects.

Such collaborative creativity is complex to study (Peilloux & Botella, 2016), but examples of multivariate approach presented in this chapter can contribute to consider all the factors involved in the design creative process. To structure as well the macro-process and the micro-processes involved in design practices would lead to ensure the optimal deployment of creative potentials of designers. As we saw throughout this chapter, it is important to conflux general, domain-specific, and tasks-specific abilities to address a range of societal issues in creative design professions.

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Chapter 8
Critical Issues of Advanced Design Thinking: Scheme of Synthesis, Realm of Out-Frame, Motive of Inner Sense, and Resonance to Future Society

Yukari Nagai and Toshiharu Taura

Abstract In discussing “design thinking,” which is expected to lead innovation at the social level, this chapter first explores the synthetic scheme of concept generation for design thinking from the perspective of creativity. The characteristics of design thinking through high-order concept generation are clarified in comparison with those of first-order concept generation. The comparison is based on the results of an experimental study for a deeper understanding of design-led human creativity, particularly, “design creativity.” Subsequently, this chapter challenges a creative leap that suggests “out-frame” realm of design thinking. It will overcome the conservative “in-frame” thinking. By clarifying the features of creative design thinking initiated by inner sense, we confirm a meaning of design creativity inspired by concept generation rooted in resonance experiences during design thinking. As it encourages creative exploration, inner sense can be situated as a motive beyond problem solving. Further, the essential features of individual creative design thinking, which form the fundamental competence of design thinking in interdisciplinary group work, are discussed. Based on discussion of individual design thinking, we identify the core motivation of “advanced design thinking” through interdisciplinary co-creative design that goes beyond empathy to find a meaningful curriculum for group work in the future. Finally, this chapter concludes with a summary of the critical issues of advanced design thinking, aiming to lead future social innovation that may cause qualitative changes to society.

Keywords Design creativity · Advanced design thinking · Concept generation
Inner sense · Out-frame resonance

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Introduction

To comprehend the knowledge of human beings from a creative perspective, we expect to form an integrated image of the different aspects of creativity to attain totality. Although an overall structure for understanding creativity remains uncertain, each individual is given a certain field and opportunities to develop their own creativity on any occasion in society or the real world, which is interdisciplinary. In this real world, "design" is a lively term. Recently, the term "design" is used in a broader sense, encompassing engineering and industrial designs, as well as color and styling. This chapter pays special attention to design when considering human creativity as it is strongly connected to invention not only at the technological level but also at the social one, which produces new conditions of daily human life.

Research has attempted to clarify human creativity, particularly as regards relationships between creativity and design (Amabile, 1996; Boden, 1996, 2004; Csikszentmihalyi, 1998, 2014; Runco, 1994, 2014; Runco & Richards, 1998, Sternberg, 1999; Sternberg & Lubart, 1999). The challenge as regards creative cognition approach has highlighted the cognitive process of individual creativity and extracted its unique features, which deeply relate to design, by generating and exploring the process at a cognitive level (Finke, Ward & Smith, 1992; Ward, Finke & Smith, 1995). In this chapter, the cognitive process of generation and exploration in design will be explained as an ability of synthesis.

Different focuses, such as processes and products, have caused a complex structure among discussions of creativity. A creative process does not always produce a creative product in the real world. Given the different aims of creative tasks and the influence of expert evaluations, a large gap exists between creativity in the process and resulting product as well as certain relationships between them; accordingly, multiple levels of human creativity have been classified into several types (Beghetto & Kaufman, 2007; Runco, 2014). Connections between the different types of creativity remain unclear; moreover, the connection between flair, insight, intuition, and competency beyond the skills of design is uncertain. For a deeper understanding of human creativity, "design creativity" is a crucial issue (Taura & Nagai, 2010; Nagai & Taura, 2016). Hence, we investigate the cognitive aspect of design (design thinking) and categorize carefully the types of design thinking to find a core structure.

"Creative thinking" can provide a basis for discussion on design thinking. The structure of social creativity levels that can be driven by an individual's creativity is an important issue of the contemporary era. At an individual level, creative thinking is explained as a cognitive feature of human creativity, in contrast to productive thinking. Creative thinking includes design as a knowledge extraction process, whereas productive thinking mostly concerns the behavior of making, including the reproduction of objects, for example, birds' nests (American Psychological Association, 2015). In engineering design, creativity is possible only at the early stage of original design, whereas the main production process is fixed, as it is a repeatable manufacturing process. In the context of the industrial era, there is no opportunity for creative ideation during the main process as it progresses under technology management. For instance, the aim of management is to keep the costs down by rational decision making, specifically, problem solving. However, from a business perspective, successful results correspond with global market development that takes a new direction. Strategic management to enhance the value of products or services is expected, that is, innovation management to connect the theories of engineering and society, such as business, economics, humanities, psychology, and social science within a rich diversity. In the context of the post-industrial era, the production of valuables requires multiple views of interdisciplinary decision making.

To enhance such individual creativity by growing a creative mind in a social context, a new approach other than the combination of methods is expected. The existing methods are useful, but they provide mediocre ideas. For example, quality function deployment (QFD) is a method for finding customer needs or requirements and translating them into specific plans to produce products that meet those needs. QFD is adopted to solve issues in current products or services. However, a quantitative method such as QFD is not adequate to find the potential value among future contexts. Creative exploration is probably needed, and it will be expressed through deep impressions from undergone experiences. It is difficult to realize the same in predictive calculation.

Considering those limitations, design thinking can be a suitable approach for enhancing motivation to find new value, especially at the qualitative level (i.e., meanings), and it can be especially effective for determining what is to be created as a target of design, as it encourages intrinsic motivation for human creativity. In addition, it is necessary to change a perspective from an objective problem to a personal issue, such as ego, emphasized by deep empathy through design thinking. This suggests the resonance that links an individual and the social motives of design (Nagai, 2014).

Following the outlined considerations mentioned above, we discuss the critical issues of creative design thinking relevant to the present and future eras. Figure 8.1 shows the issues to be discussed in this chapter.

Advanced Design Thinking

In this section, let us discuss "advanced design thinking," that is, contemporary design thinking needed in the present era of advanced technology. For identifying the nature of advanced design thinking, we first review the recent history of and previous studies on design thinking. Subsequently, we discuss the characteristics and extract key issues of advanced design thinking.

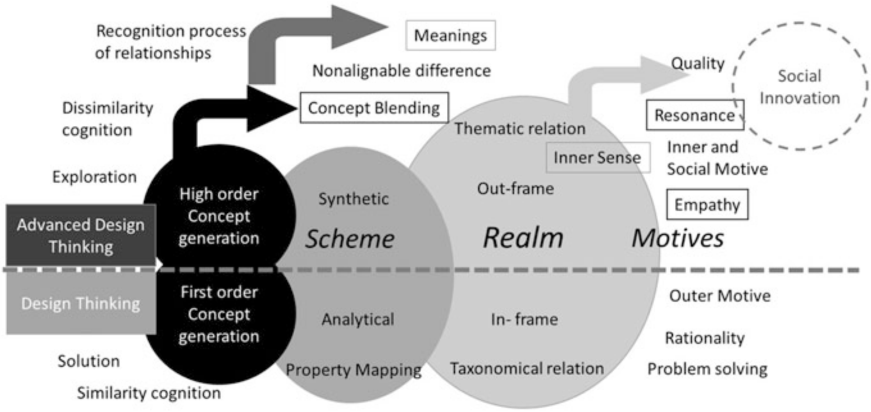

Fig. 8.1 Issues of advanced design thinking

Overview of Design Thinking

Design was essentially considered a way of thinking (Simon, 1996). Design thinking is now popularly seen as a creative strategy to the formation of future society. It is expected to lead innovation although the mechanism of innovation and the connections between an individual creativity and innovation have not yet been identified clearly. Originally, design thinking referred to expert knowledge; for example, how designers thought to solve problems and make creative solutions during the design process (Cross, 2006; Lawson, 1980; Rittel, 1984; Rowe, 1987). It developed through the connection to knowledge management for value creation (Nonaka & Takeuchi, 1995). Moreover, it applied a method of social innovation (Brown, 2009; Brown & Wyatt, 2010; Lockwood, 2009).

Recently, design thinking has been adopted in education to enhance creativity and innovation through interdisciplinary group work by combining majors, such as engineering, business, and others. For example, design thinking was used in Stanford University's education plan in 2005, Hasso Plattner Institute's in 2007, and Northwestern University's in 2009. Japan Advanced Institute of Science and Technology (JAIST) developed education of innovation design in 2014. An international workshop (Design Engineering School) by Kobe University and Carnegie Mellon University was carried out in 2016 (see below). Thus, design thinking must be understood as a standard model of advanced education by creative practice from the perspective of innovation. However, why design thinking enhances human creativity has not yet been sufficiently clarified.

Human creativity (i.e., design) has never been stagnant despite its cenogenetic nature. Results have produced both wealth and crises in society. Therefore, to create a future society based on the results of creative activity in the present and past societies, a comprehensive viewpoint including post-design (Taura, 2014) which is obtained by reconsidering design and its cognition (design thinking) is indispensable. Considering such situations, we propose an ideological framework of advanced design thinking for enhancing human creativity at the social level in subsection.

Advanced Design Thinking for Leading Social Innovation

Innovation can be explained as an aspect of social value rather than technological invention (Nagai, 2014). Historically, the example of innovation is the invention of the heat engine that led to the development of ideas for vehicles and transportation systems. A recent example is the semiconductor, which led to the development of social technology for the internet of things (IoT), such as smart phones. Innovation is the representation of a level of creativity embedded in a social system (i.e., social creativity). Hence, design attracted the attention of social science and business related to lifestyles, particularly the "creative industry." Various studies of innovation confirm that social change is driven by design (Brown, 2009), or social change is an important aspect of design creativity (Editorial board IJDCI, 2013).

In this chapter, we discuss the features of advanced design thinking from the perspective of social innovation. In this way, we will understand both the personal and social aspects of design creativity and their connection. The personal aspect represents the basic mechanism of creative thinking (individual cognition), whereas the social one refers to the social motive to develop human creativity (social cognition).

By discussing the details of how design and creativity complement each other like two sides of a coin, we propose contrary relationships where design drives human creativity (design-led creativity). As regards quality of social innovation, individual creativity is powered by design thinking, creating togetherness with social creativity. For a basic understanding of creativity through design thinking, it is necessary to understand the cognitive features of individual creative cognition. Design thinking has been viewed as a critical issue connecting individual and social creativity. Further, we examine the competency of advanced design thinking, which is strongly urged, especially as regards advanced technology for future social innovation.

For a careful discussion comparing advanced and conventional design thinking, an exploration of individual cognitive process while having a concept generation is examined in the next section.

Concept Generation for Advanced Design Thinking

"Concept generation" is the essential scheme of design thinking. Taura and Nagai (2013) define "*concept generation* [as] the process of *composing* a desirable concept toward the *future*, and *design creativity* [as] the degree to which an *ideal* is conceptualized" (p. 9). This section discusses two types of concept generation for design thinking related to experiment findings identified as cognitive aspects. We infer that one of two different types of concept generation is a driver of advanced design thinking.

Design Thinking Through High-Order Concept Generation

A design process typically begins as a plan that occurs at the conceptual level, which works to obtain tangible or intangible results. In general, ideation process is a popular and simple step for generating design concepts. Recently, supporting tools, methods, and systems for individuals' idea generation have been greatly developed; group ideation techniques such as "brainstorming" (Osborn, 1963; Vargas-Hernandez, Shah & Smith, 2010) are also popular practical exercises in the education industry. Further, concept generation is viewed as an essential feature of design thinking as regards originality, which is a revelation of synthetic scheme of human creativity. For example, a unique idea of blade-off cutter knife (art knife) was created by combining two different features: chocolate and glass (cf. Fig. 8.2). As a result, the blade-off cutter knife changed the long history of knife design; knives made of stone originated more than 10,000 years ago. Since then, people have been concerned about damaging knife blades as they could lose their sharpness. However, the idea of the blade-off cutter knife is to retain sharpness by breaking the blade.

The inventor of the blade-off cutter knife explained that "the idea came to my mind suddenly like a flash."[1] Indeed, the detailed process of concept generation tends to be difficult to remember or trace. To clarify a concept generation process for design thinking, a systematized process of concept generation for design has been developed by examining recognition processes of "similarities and dissimilarities" (Taura & Nagai, 2013). In this chapter, we define a general concept by extracting particular properties or features of an object (e.g., function, attribute) as "abstract concepts" on applying the theory. For example, "white" is a description of an abstract concept on the attribute of "snow." According to the systematized theory, concept generation was classified into two types: first-order concept generation based on similarity-recognition process and high-order concept generation based on dissimilarity-recognition process. In particular, high-order concept generation represents an essential phase of creative design thinking as it acts to expand concept spaces beyond existing knowledge by exploring the different meanings of a concept.

[1]See http://www.olfa.co.jp/en/contents/cutter/birth.html.

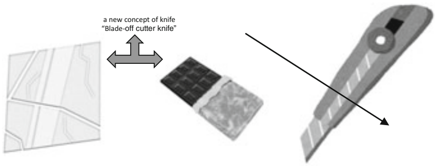

Fig. 8.2 Concept generation of blade-off cutter knife

Let us consider concept generation from the two base concepts: "tomato" and "snow" (cf. Table 8.1). We can grasp the new concept of a "white tomato" through the property mapping of first-order concept generation, that is, that the new concept is a kind of tomato. Conversely, if we perform the following steps and create multiple abstract concepts, a new concept, powdered ketchup, will arise that is generated from tomatoes and snow. A new out-frame concept can be generated by obtaining abstract concepts, including snowflakes, tomatoes, and snow, respectively and combining them to create flavoring with snowflakes.

Respecting the above classification, we stipulate that the abstract concept generated by combining multiple entity concepts is a high-order abstract concept. Hence, the high-order concept generation can be explained as the process of generating a new concept based on high-order abstract concept.

The relationship between properties and features is crucial in determining whether the generated concept may extend beyond the existing categories of the base concepts. With regard to the example of snow tomato, when the red color (a color property) of a tomato is replaced with a white one (a color property) of snow, the concept of a white tomato is obtained. In this case, the relationship between white and red is in the same dimension (a color property), thereby representing an "alignable difference" as regards similarity-recognition process. Conversely, in the case of powdered ketchup, the relationship between the extracted properties of flavoring and snowflakes is called a "nonalignable difference" as regards dissimilarity-recognition process. In this case, flavoring and snowflakes do not align in the same dimension.

Table 8.1 Examples of concept generation from base concepts: "tomato" and "snow"

Generated concept	White tomato	Powder ketchup
Characteristics of the generated concept	A tomato that is white in color. A kind of tomato (in an entity concept of tomato)	Powdery tomato-flavored seasoning. We can sprinkle it like snowflakes on meals
Meaning	Color	Powder, motion, taste
Recognition process	Similarity	Dissimilarity
Creativity	Mediocre	Original

Table 8.2 Methods of concept synthesis according to the recognition process of relationships

Type of concept generation	First-order	High-order	
Recognition process of relationships	Similarity	Dissimilarity-recognition	
	Alignable	Alignable	Nonalignable
	Taxonomical	Taxonomical	Thematic
Scheme	Analysis	Analysis/ synthesis	Synthesis
Methods of concept synthesis	Property mapping	Concept blending	Concept integration in thematic relation

The above considerations suggest that dissimilarity plays an important role in generating an innovative concept that extends beyond the existing categories; this is out-frame design thinking. Therefore, we use a term of innovation to denote the notion of extending beyond the existing categories. We distinguished high-order from first-order concept generation (cf. Table 8.2).

Thematic Relationships in Concept Generation

We classify high-order concept generation into two types by focusing on the recognition process of relationships. Previous studies identified two types of relationships between concepts, namely "taxonomical" and "thematic" (Markman & Gentner, 1993; Markman & Hutchinson, 1984). The former represents a physical resemblance between the concepts, whereas the latter represents the relationship between the concepts through a thematic scene. Taking an apple and an orange as an example, the relationship that focuses on their shapes (round) is taxonomical. Conversely, as regards an apple and a knife, the relationship focuses on the apple being cut by the knife is a thematic relationship.

To enhance design creativity, we expect that the exploring process to uncover different meanings of an existing concept for concept generation as abovementioned. According to the former relationship, high-order abstract concepts can be interpreted as abstract concepts involving an innovative concept, which inherits partial properties from both of the base concepts but differ from them. We define concept generation based on "concept blending" (Fauconnier & Turner, 2008). The theory of concept blending was developed from "mental space theory" (Fauconnier, 1994): "Blending is in principle a simple operation, but in practice gives rise to myriad possibilities. It operates on two input mental spaces to yield a third, the blend. The blend inherits partial structure from the input spaces and has emergent structure of its own" (Fauconnier, 1997, p. 149). The concept of powdered ketchup is an example of concept blending. Table 8.2 shows concept synthesis methods according to the recognition process of relationships.

For the reasons mentioned above, concept generation will be classified into three types as regards recognition of similarity, dissimilarity, and relationships (i.e., taxonomical or thematic).

Findings from an Experimental Study on Concept Generation

High-order concept generation is expected to create an innovative concept, which extends beyond the existing categories. It is relatively dependent on the base concepts from which the new concept stemmed. The detailed process of concept generation for design thinking was carefully investigated by respecting concept generation types (Nagai & Taura, 2006; Taura & Nagai, 2013). We carried out a series of experiments adopting design tasks to compare the concept generation processes. In this subsection, we excerpt the result of the experiments.

According to the theory-based classification, concept synthesis methods for concept generation involve property mapping, concept blending, and concept integration in thematic relation (cf. Table 8.2). These theories (e.g., abduction, general design theory, dissimilarity, relationships, concept blending) and concept generation methods have been discussed independently, but the relations among them have not been clarified. We have found a meaningful connection among them from the perspective of creativity, by collating the linguistic interpretation of combined words (Wisniewski, 1996). We conducted an experiment to compare concept synthesis with linguistic interpretation by focusing on the recognition types (i.e., commonality, alignable difference, and nonalignable difference). In the experiment, the subjects were required to perform the following three tasks: interpret a novel noun–noun phrase (interpretation task), invent a design idea from the same phrase (design task), and list the similarities and dissimilarities between the two nouns (similarity and dissimilarity listing task). The first and second tasks were performed to compare concept synthesis with linguistic interpretation. The third task was intended to confirm if the recognition types are manifested during the design or interpretation tasks or if they are derived from a subject's trait. Prior to the experiment, we conducted a preliminary experiment to select the noun–noun phrases to be used. For example, the phrase "desk–elevator" and "ship–guitar" were selected.

The design ideas were analyzed according to concept generation types (i.e., property mapping, blending, and thematic relation). The design idea features, which were provided by the designers who were required to provide a number of words that explained the design ideas, were analyzed based on recognition types. For example, a design idea of a table that can be modified by replacing the surface, formed from "desk–elevator," was categorized under property mapping, and a design idea of a guitar using a wave (the string is plucked by waves) was categorized under blending (cf. Table 8.2).

Further, the creativity of the design ideas was examined as follows. First, the design ideas were evaluated based on originality and practicality. Second, the

Table 8.3 Matrix of relations between concept synthesis methods and linguistic interpretation

	Property mapping	Blending	Thematic relation
Linguistic interpretation	Property mapping (e.g., a knife-shaped fork)	Hybrid (e.g., one-half is a knife and the other half is a fork)	Relation linking (e.g., a knife and fork set)
Concept synthesis	Property mapping (e.g., white tomato)	Concept blending (e.g., powdered ketchup)	Concept integration in thematic relation (e.g., humidifying refrigerator)

design idea features and those enumerated based on explanations of the responses to the interpretation task were judged to determine if they were emergent features. The interpretation and design idea features were classified based on recognition types. In the chi-square test, a significant difference was detected in the proportion of the recognition types between the interpretation and design idea features (cf. Table 8.4). The results of the residual analysis indicated that the proportion of nonalignable differences in the design idea features was higher than that in the interpretation feature, whereas the proportion of commonality was low. Thus, more attention was paid to nonalignable differences in concept synthesis than in linguistic interpretation (Table 8.3).

From the results of the experiment, we found a higher potential for creative design thinking for concept blending. Moreover, there is a higher possibility to explore the different meanings of a concept using concept integration in thematic relation.

As mentioned previously, high-order abstract concepts can be interpreted as abstract concepts involving an innovative concept generated from the thematic scenes (e.g., situations, roles, etc.) of base concepts. We define concept generation based on the thematic relation as concept integration in thematic relation. Therefore, the designer must carefully consider not only the designed product's attributes, such as shape and material, but also its function and interface; in other words, careful consideration of the human aspect is important. Accordingly, integration of the base

Table 8.4 Mean of the proportion of recognition types among the responses classified into each type for the interpretation and design tasks (based on the similarity and dissimilarity listing task)

		Property mapping	Blending	Thematic relation
Commonality	Interpretation task	0.392	0.775	0.41
	Design task	0.39	0.451	0.405
Alignable difference	Interpretation task	0.205	0.133	0.186
	Design task	0.249	0.163	0.117
Nonalignable difference	Interpretation task	0.403	0.092	0.405
	Design task	0.361	0.386	0.478

concepts in the thematic relation is expected to play an important role in concept generation. With respect to the example of a snow tomato, the new concept of a refrigerator that can humidify food is generated from the scene where a tomato is stored in snow.

Realm of Advanced Design Thinking

Although we classified the synthetic scheme of concept generation in design, a way of shifting from first-order to high-order concept generation has not yet been clarified. Thus, we discuss a realm for in- and out-frame concept generation for design thinking by focusing on the meaning of the creation process from the perspective of the cognitive process. We pay attention to the difference between in-frame design thinking and out-frame design thinking to identify the characteristics of cognitive features of advanced design thinking.

An interesting phenomenon of "creative leap" was, thus far, spurred by several studies of design that was similar to a myth of design creativity (Cross, 1997; Goldschmidt & Tasta, 2005; Nagai & Noguchi, 2004). To understand leap during design thinking, intuition in design process has been studied. However, it is seemingly difficult to manage or build a method to control it. Then, notions of "frame" have been viewed as key issues for enhancing design creativity, especially through observations of design practice that lead to shift of perspectives (Dorst, 2015). Relatedly, methods of "analogy by design" based on the knowledge of mental leap (Holyoak & Thagard, 1999) by analogy were developed (Linsey, Markman & Wood, 2012), with reach in bio-inspired design. Those studies and discussions were conducted based on a process model of problem solving.

However, as this chapter pays attention to scheme of synthesis in design, a process model of problem solving seems insufficient to explain (or trace) a highly creative design thinking involving a myth of design creativity. To chase a process of concept generation that can be seen as essential in creative design thinking is possible by the collection of the verbal protocols used think aloud method for "protocol analysis," which are obtained protocol data from verbalized utterances by individual (Ericsson & Simon, 1993; Gero & McNiell, 1998; Taura & Nagai, 2013). Additionally, when we map the obtained concept that is verbalized in utterances (words), it can be represented as "spaces of concept" (concept space). An expansion of concept space during design thinking has been observed by challenging concept synthesis in design through experiments (Nagai & Taura, 2006).

We confirm the functions of the frame by referring to design thinking, representing patterns of thought or behavior and their applications of the actual design process. For considering frame, the distribution of concepts shows clusters (Junaidy & Nagai, 2013); for example, during a design task in an experimental case study, a cluster of concepts generated by designers was distributed in frames that were different from those of craft artisans on a conceptual square map by object surroundings. In the experimental case study, both of the designers and traditional craft artisans were assigned to design a fruit bowl. By comparison, the former obviously showed a wider frame than the latter. This means that the designers' thoughts have largely explored the attributes of the objects (cf. Fig. 8.3). The most important finding from the investigation of concept space and its expansion process is that a boundary is defined from the inside of the human mind (i.e., inner criteria). It works to expand a concept space and forms a realm of out-frame design thinking.

As regards the results of the investigation of differences between designers and traditional craft artisans, a potential method is suggested by shifting the direction of recognition to expand concept space during concept generation. It will break a conceptual boundary and reorganize the realm of design thinking from in-frame to out-frame. This process seems similar with yielding mental space to construct new meanings of things (Fauconnier, 1994). Further, we will pay attention to the quality of generated concept and thinking process as the outcomes (designed products) must be meaningful to people in design.

Another important feature of design thinking reveals new meanings of things. Here, we explore the realm of high-order concept generation in design thinking to understand the identification and elaboration of concepts. This is a potential point

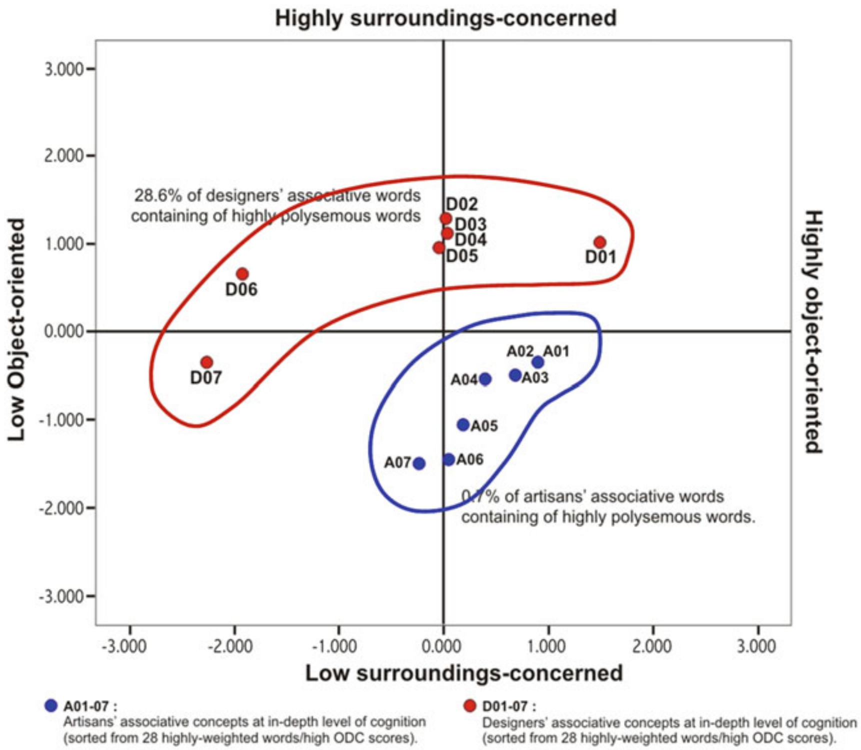

Fig. 8.3 Comparison of concept space between designers and craft artisans

Table 8.5 Key issues of design thinking between conventional and advanced programs

	Conventional design thinking	Advanced design thinking
Realm	In-frame	Out-frame
Motive	Outer sense (visible requirements)	Inner sense
Competence	Empathy	Resonance
Condition of group work	Diversity	Interdisciplinary
Type of group work	Collaboration	Co-creation ("concertedness")

that may expand the concept space that evokes certain exceptional meanings to expand on existing meanings, which relate to the abstract level of the concept. To enhance such expansion of concept space or generation of mental space, recognition of thematic relations among things is remarkably effective for forming a frame.

As regards several aspects of previous design thinking, further creative design thinking is required in an advanced post-industrial society. Therefore, it is necessary to shift from in-frame to out-frame design thinking, which is enacted by high-order concept generation. The out-frame realm of design thinking will be under the competency of advanced design thinking in interdisciplinary innovative knowledge. The features of in-frame design thinking and out-frame design thinking are based on analytical and synthetic schemes, respectively (cf. Table 8.5).

Prospects of Advanced Design Thinking

We consider the motives of design and other critical issues for advanced design thinking in this section. According to the transition, a drastic social system reorientation is needed with the emergence of the motives of design outside the conventional realm of design, achieved through creation of semantic contents, replacement of reasoning from induction to abduction, and visualization of invisible issues. In this subsection, we express motives of advanced design thinking in consideration of the present and future society. Subsequently, we discuss ways to enhance "advanced design thinking" in education to estimate a potential methodology of group work through "design-led creativity" toward innovation, which will be developed at the social level. Additionally, we will focus on the motives of design and a mind of "concertedness," that is, co-creative activity among people (i.e., resonance).

Motives of Advanced Design Thinking

The scheme (synthesis) and realm (out-frame) in advanced design thinking mentioned above reflect social motives in complementarity. Further, we consider the bipolarity between an individual's ego and social cognition (cf. Fig. 8.4). Inner sense is that which involves inner criteria and intrinsic motivation and can be the basis on which a new concept is generated by referring to existing concepts; inner criteria are those that explicitly or implicitly underlie the designer's mind and guide the process of concept generation (Taura & Nagai, 2013). As mentioned above, a boundary was defined as being from inside of the human mind (inner criteria) through an investigation of concept space and its expansion process. We infer that this is caused by "inner sense."

Inner sense works as an important impelling force by forming an "inner motive." Design can be motivated not to solve existing problems but to pursue ideals. The inner motive is found, for example, in engineering design in pursuit of ideal functions with which a future artificial object must be equipped, as well in industrial design, as the creation of ideal shapes or interfaces appeals to users. The designer's inner feelings and criteria play an important role in envisioning ideals because what the designer recognizes as ideal is a reflection of nothing but the standards he/she upholds. Based on these standards, the designer generates new concepts with reference to existing ones. Therefore, the inner motive may be related to the synthetic method used to generate ideal concepts that do not yet exist. Breakthrough products, which bring qualitative change in society, are inspired by the inner motives of design and originate in synthetic design thinking, which discovers new meanings as hypotheses in the unobserved. We have considered that the reason for designing evolves a motive of design. A motive of design is not identical to the need for products or requirements or specification for products. It also does not correspond to the compensation that individual engineers or designers receive from their organizations or parties requesting the design. Rather, it explains why the need for designing a particular product has arisen, why this need represents the requirements or specifications for the product, and why the engineers or designers concerned are

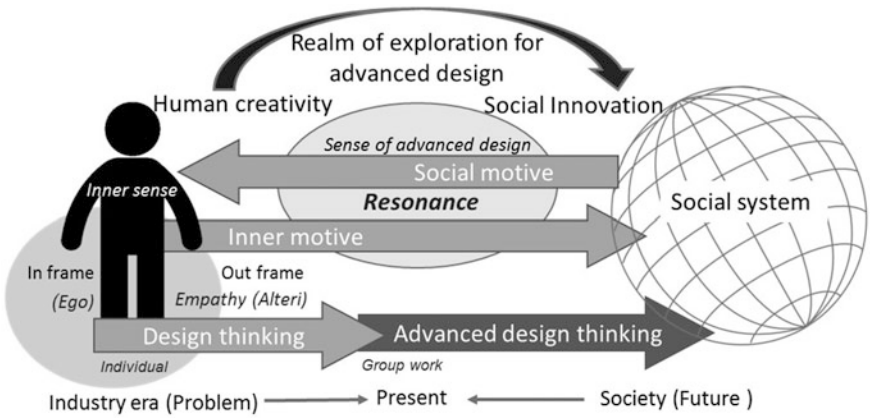

Fig. 8.4 Relationships between individual creativity and society

rewarded in a particular manner. Advanced design thinking corresponds with such breakthroughs.

In contrast, people used to believe that design meant problem solving in conventional design thinking. In other words, design used to be seen as a process driven by a problem. Such ideas were promoted in the context of industry, where human creativity was understood in an industrial social system framework. The significance of design was thus valued in correspondence with the values of an industrial society, such as efficiency. The body of knowledge acquired in an industrial society is called production technology. Efficiency-oriented technology brings quantitative (quantitative innovation) and not qualitative change (qualitative innovation) in society. It can enhance product reliability and reduce prices, but it cannot achieve breakthrough products, which are not generated in a context of efficiency. Analyses of existing products and societal needs can lead to problem detection and product improvement, not breakthrough products. In fact, many proposed design process models have been considered within the framework of problem solving. In problem-solving scenarios, the goal is often clear: designing in response to customer requests, in pursuit of damage reduction following natural disasters and accidents or other adverse situations. In these scenarios, the problem-solving style of design usually consists of analyzing the gap between the goal and the existing situation, followed by the formation of a problem-solving strategy based on this analysis. The outer motive can thus be said to be related to the analytical method. At present, it is imperative to reconstruct our knowledge of design to conform to the above: advanced design thinking with inner motive.

Challenges of Advanced Design Thinking in Group Work

We discuss the fundamental competence of design thinking in interdisciplinary group work based on the essential features of individual creative design thinking. The above subsection presented our critique of the incompatibility of the problem-solving framework for design, despite the adoption of problem-based learning in many design practice cases. As mentioned, many higher education institutions have adopted group work “design thinking,” that is, design school. In many cases, group work is carried out by interdisciplinary teams tasked with finding a potential idea for products or services that will solve the problems found by the student groups. In a few cases, the resulting idea is applied in an actual social situation, with industry support.

However, the connections between individual design thinking and group work are not yet clarified. Careful investigation during design thinking group work is needed. Further, a theoretical background is needed to reveal the effect of design thinking to support practical results in teaching. The mental aspects and the curriculum are crucial in this regard.

Although there is a gap between design thinking in individual and group works, we suggest critical points for both modes of advanced design thinking, i.e., inner sense and resonance. The “empathy” phase is popularly used in current design thinking workshops. To reinforce it, we consider out-frame resonance in individuals, whereas social resonance driven by the inner sense can be expected by developing a realm of design for sharing the ideal system. Inner sense represents the motive of the creative design process and may enrich the quality of design thinking through group work. Inner sense also enhances the out-frame resonance that drives the explorative process. Interdisciplinary group work provides more chances for learning resonance of design thinking.

As an ongoing study, we are observing certain activities of a creative design workshop in an innovation design course as a case study. The workshop comprised 48 graduates divided into seven groups and required the graduates to undertake design tasks (e.g., a meaningful item for protection from natural disasters). The workshop was conducted at JAIST from June to July 2016. In this workshop, further, “resonance beyond empathy” (i.e., out-frame resonance) is strongly expected to be developed through group work for design thinking.

For instance, a curriculum at The Design School by Kobe University and Carnegie Mellon University, a collaborative international workshop for advanced engineering design graduates aimed at enhanced design capability, started to use a method based on design creativity, which was the proposed advanced design thinking method initialized by concept generation. A method of metaphor (bio-inspired design) to create a new concept, virtual reality environment to simulate how the designed product will be used in the new scene, and modeling tool (CAD) to simulate the mechanism of the product are adopted.[2] This reveals the effects of the related issues of synthetic scheme, out-frame realm, and connection between inner motive and new meanings of design in future. Finally, we suggest key issues and increased competence through interdisciplinary group work based on knowledge of advanced design thinking in comparison with conventional programs of design thinking (cf. Table 8.5).

Conclusion

We summarize the critical issues of advanced design thinking: scheme of synthesis, realm of out-frame, motive of inner sense, and resonance to future society for social innovation. Between the two types of design thinking from the perspective of creativity, which is considered a particular feature of advanced design thinking, high-order concept generation may be understood as a motive force of design creativity. It suggests an essential relationship between design and creativity, which means “design-led human creativity.” A deeper understanding of this phenomenon will contribute to the comprehensive knowledge of human beings from the creative perspective.

[2]For further information http://www.research.kobe-u.ac.jp/eng-mech-design/2016DS/index.html.

Our investigation began with the examination of two types of concept generation and the recognition of dissimilarity (recognition of differences) between the two. The investigation showed the potential power of innovative design (high-order concept generation). Throughout the discussions based on design-led human creativity, we asserted the importance of a synthetic scheme for future innovation that departs from existing conventional analytic schemes. For the emancipation of essential human creativity, it is indispensable that it be free from the dogmas of the industrial era, despite their continued effectiveness in the present. We expect to reorient design thinking toward social innovation that produces qualitative change in the social system.

Advanced design thinking, driven by the inner sense and out-frame resonance schemata, releases human creativity from the dogma of problem solving.

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Chapter 9
The Project or the Specificity of Design Thinking

Stéphane Vial

Abstract Design is fundamentally linked to the project. But design does not have the monopoly of the project. The goal of this chapter is to show that there is a specificity of the concept of design "project" and to propose a definition of it based on French uses of the term. Going back to the origin of the project in the Renaissance as methodical design, I will show that design belongs to projectual logics rather than to projective anticipation logics although one may be inferred or induced by the other. I will then argue that the project belongs to design by essence, and I will propose five distinctive characteristics of the design culture specific to design as well as a definition of the design project. In addition, I will conclude with an examination of the recent contribution of information technology to the theory and methodology of the project, particularly through agile methodology, which has the potential of inspiring designers.

Keywords Project · Design · Method · Project cultures · Project disciplines
Design project

Introduction

For a designer, nothing seems more natural than the concept of project. In design schools, it is what one calls the design work that engages students in the studio. 'As the place where, in principle, one teaches and learns the act of design and project management in design, the studio is considered a strategic place in all design

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schools' (Findeli & Bousbaci, 2005, p. 39). In the professional world, it is also the name given to a work in progress, but also (more surprisingly) completed achievements. So much so that, most design or architecture agencies dedicate an entire section to 'Projects' on their website or in their portfolio. In the field of design, *project* is the name given *to a unit of design work*, whether completed or not. While the artist creates work for the public, the designer creates projects for users. Therefore, from the point of view of practice, not only does the concept of project seem more natural in design but also more structural. It is as if there was a fundamental and founding assumption that is summarized in the following equation: 'making design = making project'. In this perspective, one can call it a tropism of the design project, in the sense that design is entirely focused on the project. Design and project are seen as somehow synonymous, which seems to be confirmed by the most advanced literature on the subject (see, e.g. the following formula in Findeli and Bousbaci: 'theories of project in design (or theories of design)' (2005, p. 38).

Yet, as everyone knows, design has no monopoly on project. Everyone makes projects. People often ask 'What are your plans for summer?' (in French, 'faire des projets' means 'to make plans') in the sense of: 'What do you intend to do this summer?'. On this point, the lexicographical data is clear: first appearing in the fifteenth century, 'project' is a term of everyday language, both in French and in the 'main' European languages (*progetto* in Italian, *project* in English, *projekt* in German).[1] From the Latin *pro-jacere* (to throw forward), which led to the old French word *pourget* or *pourjet* (1470), which then became *project* (1529) and *projet* (1637),[2] its etymological sense is thrown (-*ject*) forward (*pro*-), whether it is abstract elements developing in time (an idea, a plan to achieve) or tangible elements unfolding in space (a 'projected architectural element' such as a balcony).[3] In the eighteenth century, one could even say in French 'avoir des projets sur quelqu'un' ('having *plans* on someone') meaning 'planning to marry someone' (today one can sometimes say, in familiar language, 'avoir des vues sur', i.e. 'to have *views* on someone'). It is also worth underlining that the vast expansion of the term 'project' in everyday language can be compared to the broader existential use made of it by modern phenomenology (Boutinet, 2014, p. 12 and following), notably Sartre:

> Man is, indeed, a project which possesses a subjective life, instead of being a kind of moss, or a fungus or a cauliflower. Before that projection of the self, nothing exists; not even in the heaven of intelligence: man will only attain existence when he is what he purposes to be. (Sartre, 1970, p. 23).

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[1]On the subtle nuances between these languages; see Boutinet (1990, p. 13).

[2]Descartes, *The Discourse on Method*, II "le *projet* de l'ouvrage que j'entreprenais".

[3]On the etymology of the 'project'; see, in French *Le Robert—Dictionnaire historique de la langue française* (1998, book 3), *Le Trésor de la Langue Française Informatisée* (online) and Boutinet (1990, pp. 13–14, p. 116).

Beyond linguistic diversity, one must of course consider the variety of social, cultural and theoretical practices of the project (including those of design and existential phenomenology, which are only types of practices among others). Not only does everyone make (or have) plans (*projets* in French) but, in a few decades, the figure of the project has become the organizational matrix of most human activities in contemporary postmodern societies. In his monumental work *Anthropologie du projet* (1990), of which Findeli and Bousbaci rightly say that it is 'the richest theory of the project available' to this day (2005, p. 47), psychologist Boutinet gave a complete and almost exhaustive overview of the concept of project and how it has become a social reality or a 'culture'.

However, it should be noted that Boutinet (1990) discussed the concept of project in a very broad sense. By 'project' he meant any socially observable conduct of anticipation, whether individual or collective. 'Speaking of an anthropology of the project is in the end questioning how individuals, groups, cultures experience time' (Boutinet, 1990, p. 5). In contrast to traditional societies considered as 'hors-projet' (projectless) or 'sans-projet' (without project) (Boutinet, 1990, p. 2) as they focus on the preservation of the past and the ritualization of the present (especially due to religious fatalism), contemporary postmodern societies are keen to control the future and actively seek to anticipate, predict and prepare.

This is the objective of the multiple contemporary conducts of anticipation (*conduites d'anticipation*) (Boutinet, 1990) or conducts geared towards a project (*conduites à projet*) (Boutinet, 2014), i.e. 'career project' (career plan) for young people, 'planning project' for a region/area, 'educational project' for teachers, *projet de loi* (literally 'legal project', which means in France 'draft bill'), 'business plan', 'societal project' and of course 'architectural project' and design project. All these terms established by usage stress to what extent the project has become, more than an 'incantatory concept' (Boutinet, 2014, p. 23), 'a figure that is trying to impose itself in many spheres of our existence' (Boutinet, 1990, p. 9).

In a technological society subject to the requirements of ever-increasing performance, we are even more drawn towards a 'prospective time', which, if we do not adapt to it, we marginalize ourselves and regress, as do the excluded, to the precariousness of projectlessness and its share of 'current constraints', which prevents us from 'taking the necessary perspective to anticipate' (Boutinet, 1990, p. 3). Thus, motivated by 'a kind of voluntarism keen to control, direct or redirect everything' (Boutinet, 2014, p. 7), 'we charge the future with all our hopes' (p. 58) and build our lives according to this concern. This is why for the last thirty years one has observed 'a profusion of anticipatory behaviour that borders on projective relentlessness' (Boutinet, 1990, p. 323) and constitutes 'a major fact of our time' (p. 1).

The whole point of Boutinet consisted of seeking a kind of anthropological constant in the 'variety of project situations' (1990, p. 8), that is to say, to 'identify the different functions performed by any project in our culture compared to what can happen in other cultures' (p. 5). His monumental work leads to a typological analysis of the various forms of observable anticipation and culminates in a gigantic taxonomy of projects (Boutinet, 1990, p. 127; 2014, p. 56) that we recommend the reader to refer to (cf. Fig. 9.1).

Fig. 9.1 French-based taxonomy of conducts geared towards a project according to Boutinet (2014, p. 27)

1) __Individual projects linked to the stages of life:__

- *Youth project*
  > career plan
  > integration project (social, professional)
  > life projects

- *Adult life project*
  > professional project (employment, identity, career)
  > family project
  > personal project
  > lateral project

- *Retirement project (or plans)*
  > Change of career project
  > Life-changing project

2) __Object and action projects__:
  > Architectural project
  > Technological innovation project
  > Development project
  > Pedagogical project
  > Therapeutic project…

__3) Organizational projects:__
  > Reference project
  > Participative project
  > Service project
  > Project management…

__4) Societal projects:__
- *sectorial:*
  > Educational project
  > Cultural project
  > Urbanistic project

- *global:*
  > attestatory: reform project
  > contestatory: revolutionary project, self-managed project, alternative project

In this 'society of project accumulation' (Boutinet, 1990, p. 126), everything becomes the (subject or matter) of a project. If this is remarkable from an anthropological point of view, it nevertheless poses a problem for design on an epistemological level. Indeed, what sense should we continue to give the tropism of the design project ('*making design* = *making project*')? Should the design project ultimately be regarded as a mere anticipation behaviour among others, immanent to the time, which illustrates a form of postmodernity where everything is already a project? Does it only translate in the field of design a deep inclination to be concerned about the future that is emerging in all areas of postmodern society? Or does the design project have a meaning and value of its own that transcend the general determinisms of our hyper-projective era? In a word, what is the status of the design project at the time of a widespread culture of anticipation? If it does exist, what is its specificity?

This epistemological question should not leave designers indifferent as, according to the answer given to it, design and project are intimately associated or totally disassociated. My goal in this chapter is therefore twofold: firstly, to try to show that there is a specificity of the concept of the design project; and secondly, to try and offer a definition of this concept. The benefit I expect is the following: explaining the legitimacy of the designers' projectual claim, that is to say, to put it in simpler terms, the ability of designers[4] to claim the *necessity* of the project and to

[4]The term 'design' is not used here in the restricted historical sense of 'industrial design' but in the broad sense accepted by the international research community, including a variety of design fields.

define design as a discipline of project by essence, whose *specificity* I will try to define here. This will not prevent us from highlighting, at the end of this chapter, the fact that other disciplines have embraced the project over the last thirty years, especially information technology (IT), which teaches us a lot about the methodology of the design project.

The Project or the Creation of Methodical Design

One generally associates the emergence of design to that of industry, going back to the nineteenth century, with the rise of the decorative arts movement.[5] One less often associates its emergence with that of the project. Yet, as shown by Boutinet (2002) design is fundamentally linked to the project and to its architectural origins in the Italian Renaissance.

The architectural project was invented in Florence around 1420 by the architect Brunelleschi:

> To separate and unite simultaneously two critical times in the act of creation applied to the construction of a building: the time working in the studio, dedicated to the design of the model, and the time working on site, realised in the construction of the work from the model previously designed. (Boutinet, 2002, p. 224)

Before that, development and realization were combined with the trial and error process that it implied (Boutinet, 2014, p. 9). The project is therefore the brainchild of a dualism, or even, a division of labour: design and realization. The objective is 'both to distinguish and unify a time of design and a time of realisation in the act of building' (Boutinet, 1990, p. 10). The Italian language subtly highlights this distinction with the terms *progettazione* (intellectual development activity) and *progetto* (realization activity), which French also differentiates in its own way with the words *dessein* (intention, goal, aim) and *dessin* (drawing, figure, sketching) (Boutinet, 1990, p. 13). 'These two similar meanings of *dessein intériorisé* (internalized intention) and *dessin extériorisé* (externalized drawing) are combined in the Italian term *disegno*, as in the English term *design*' (Boutinet, 1990, p. 116). In other words, *design* is originally a term that unites the two fundamental dimensions of any project. The two terms are therefore historically synonyms.

> Somehow, the advent of the architectural project in Italy was to be confused with the history of the concept of *disegno* that Italians have divided into *disegno interno* and *disegno externo*, and that three centuries later, the French language translated, using the same etymology, into two separate concepts, but closely associated within the project: *dessein* relating to development and design and *dessin* relating to achievement and realisation; the

[5]However, as noted elsewhere, one must remember that design did not exactly emerge *with* industry but *with the assumption* of industry, that is to say, from the moment when decorative artists, after having long rejected industrial production, decided to adopt it and take an active part in it (Vial, 2014, p. 14).

> English language, although using the same etymology, remains more concise and even more syncretic with its concept of design. (Boutinet, 2014, p. 10)

Historically, the first meaning of the term *design* is therefore not that of *industrial design*, but of *project*. It was only during the age of industrial production and consumer society, i.e. during the twentieth century, in order to give a name to a new profession, that the term *design* acquired the restricted meaning of *industrial design* (which, for the last twenty years, has no longer been able to cover all current forms of design). To avoid confusion, one must distinguish between (at least) two meanings of the term *design*, which correspond to two different historical moments: design as a *project of methodical design* (Renaissance) and design as *industrial creation* (twentieth century). In this perspective, industrial design is a relatively recent form of the design project. We can also identify a third meaning of the word design that we can only briefly mention here, and under which can be gathered all the new forms of design that have appeared since the late 1980s and which are not (or cannot be reduced to) industrial design (e.g. ecodesign, interactive design, service design, codesign, social design, etc.).

Therefore, if one does not want to lose one's way in the linguistic and conceptual complexity that too often leads design theorists to give up defining design[6] which philosophy allows us to consider as unacceptable, it is important to understand what led to the emergence of the project in the Renaissance. Why did architects of the Quattrocento invent the project, this dualism of design and realization? The explanation is simple: it was an operational necessity in the face of mounting complexity. It was then no longer possible to improvise and rely on luck to escape the inevitable ups and downs of any construction. Only methodical anticipation could help control 'the complexity due to the diversity of materials used, and also due to the increasing number of specialized professional corporations, and to new construction methods' (Boutinet, 2014, p. 9). However, complexity is not new; the builders of the pyramids and cathedrals had already experienced it. What characterizes the Renaissance is that the management of this complexity was part of the modern project to systematically rationalize the world. This is why the invention of the project in architecture is nothing other than the creation of the rationalist method in the field of design. Design was then a meth-*odic* work, that is to say, a path (*odos* 'the road, the route') that was sequenced, split, cut and framed by reason. Because, as Descartes has shown, any method is a rational and orderly division of labour, that is to say, both decomposition into sections, parts, components and distribution into phases, stages, levels. The proof is that, even today, all the methods used in the design project do nothing other than try to model this division (see, e.g. the famous *Double Diamond* model developed by the Design Council).[7]

[6]Erlhoff and Marshall in their *Design Dictionary* affirm that '*it is impossible to offer a single and authoritative definition of the central term in this dictionary: design*'. (2008, p. 104). See also Vial (2014, pp. 2–3).

[7]*Design Council*, 'Introducing Design Methods', online at: http://goo.gl/dXXUA5.

The invention of the project in the Renaissance with Brunelleschi is therefore the idea of the rational method applied to the design profession (technical domain), in the same way as the invention of modern science in the seventeenth century with Bacon, Galileo and Descartes is the idea of the experimental method applied to the knowledge profession (scientific domain). As Kant said in his *Critique of Pure Reason*, ‘Reason only perceives that which it produces after its own design’. Design as a *design project* must be understood as a *methodical* design project.

This sheds light on the often misunderstood etymology of the word *design*. Originating from the Latin term *de-signare* (‘to mark with a sign’) found in both the Italian *di-Segno* (diagram) and English *de-sign*, design must be understood as a methodical design project, as an anticipation through *signs* (i.e. drawings). The invention of the project by Brunelleschi is nothing more than ‘a methodology of *disegno*, that is to say, a methodology for anticipating the work to be realised: the objective was, thanks to the laws of perspective he had recently developed, to represent through drawing the projected construction’ (Boutinet, 2014, p. 10). Here, signs are representations in perspective, i.e. the images of the project.

Cultures and Disciplines of the Project

Now is the time to reap the fruits of our reasoning. Understanding the emergence of the project as methodical design was not intended to challenge an already identified and analysed historical moment, but to isolate the source from which the project took two different paths and to identify two distinct approaches (cf. Fig. 9.2). The first is anthropological and leads to the ‘cultures of project’ as analysed by Boutinet (1990) as social practices of anticipation: we call it *projective logics*.

The second is epistemological and leads to the ‘disciplines of project’, that some call ‘design regimes’ (Hatchuel & Weil, 2008), covering trades or professions as technical cultures of design, which we call *projectual logics*. By distinguishing

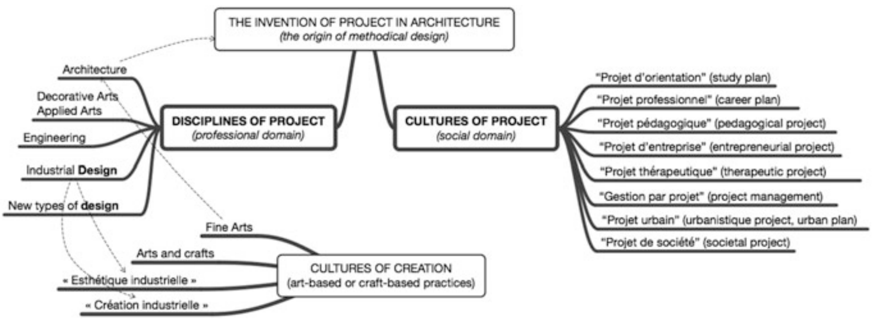

Fig. 9.2 French-based genetic model of the logics of project

between *cultures of project* (social domain) and *disciplines of project* (professional domain), one highlights the historical genesis of the various logics of the project, by differentiating the area of anticipation (projective logics) from the area of design (projectual logics) incidentally underlining the relationship the latter has with creation (artistic domain). This has the great advantage of manifesting a first aspect of the specificity that design has in relation to notion of project, regardless of the multiple contemporary conducts geared towards the project.

Indeed, if it is true that contemporary society is saturated with conducts geared towards a project, which are emblematic of its obsession for the future and anticipation thereof, design cannot be reduced to one of them as if it was just a trait of the time. Indeed design *is* project, but this has been so long before our time. It is *naturally* project, if one may say so. Basically, essentially, necessarily. Boutinet (1990) himself provided the reason for this, even if he did not grasp all of the consequences, probably because his main concern was not to define design and its specificity.

The idea appears in this sentence: ‘Some objects in their manufacturing cannot do without the project as a required intermediary’ (Boutinet, 1990, p. 110). Among these objects, he quotes the ‘building project’ (i.e. the architectural project) and the ‘technical device project’ or the ‘technical object project’ (i.e. the design project).[8] To rephrase this, one can say that architectural objects (buildings) and design objects (technical objects) *cannot do without* the project as a *required* intermediary. The epistemological value of this statement has not been sufficiently evaluated. It clearly establishes that in design and architecture, there is a *necessary and consubstantial link* between the project and the object, that is to say, it is impossible for one to exist without the other. In practical terms, one must understand that it is simply impossible to construct a building or make an industrial object (or to develop a service, an interface, a communication device, etc.) without the project methodology (i.e. the methodical separation and union of design and realization). And it has nothing to do with the postmodern era. It has always been so, at least since the Renaissance, whenever there existed a certain level of complexity.

There is a major logical and epistemological consequence to this: the project belongs to design by essence, whatever the time in history. Of course, nowadays, design can be considered (from an anthropological point of view) as a practice of project among others (Boutinet, 1990), but it is certainly not (from an epistemological point of view) a practice of project like any other. Because, in design, the project is not a contextual trait (postmodern), but a structural trait (timeless). Whatever the complexity, there has not always been the need for the project (as methodical design) to offer, for example, professional guidance to young people (‘career plan or project’) or entrepreneurship (‘business plan’ or ‘start-up project’).

These practices of anticipation have always existed, especially in terms of individual career plans that still require a representation of the spectrum of

[8]We leave aside here the ‘projet de loi’ (draft law) also quoted by Boutinet (1990) in this category and that seems to belong to another field.

possibilities, but they were not explicitly stated in terms of 'project' (a term that the postmodern era uses exponentially[9]), nor embodied in institutions that have made a profession out of them ('career advisors'). However, it has always been necessary to use the methodology of the project to construct a building or make an industrial object, once a certain level of complexity was reached. Design is therefore by essence a discipline of project. There is no design without a project that is inevitable. If Boutinet (1990) managed to outline the projective logics that have governed the social practices of anticipation for the last fifty years, it is by analysing the projectual logics that have been at work for five centuries in the technical practices of design. The project, in an anthropological sense, is only a generalization or extension of the project domain in an architectural sense.

However, as shown by our genetic model of the logics of project (cf. Fig. 9.2), if design is indeed a discipline of project, it is not the only one. Here, the necessary and essential relationship between design and project is only the first stage of the specificity of design. Indeed, architecture, engineering also constitute disciplines of project. As is often the case in a schematic model (Fig. 9.2), it is probably simplistic to present them as *technical* cultures of design as they are far from being only technical, particularly with regard to architecture or design, but if we have chosen this term, it is more to define their status compared to other elements of the model than to express their intrinsic nature.

Architecture, design and engineering have in fact one thing in common: they give rise to material artefacts. Here 'technical' means 'relative to the artefactual environment'. Therefore, if it is true that 'the design project is among the phenomena of the world of which there is reason to wonder' (Findeli & Bousbaci, 2005, p. 39), attempting to characterize its specificity, and therefore that of design, means isolating what distinguishes it from other disciplines of project.

Therefore, which characteristics of the culture of design exclusively come from conception or come exclusively from architecture or engineering? They may have in common *the fact of project*. But, obviously, there is a *certain way to make project* in design that is characterized by its finality, its methods, its philosophy; the practice of the design project probably distinguishes itself from that of engineering by its mastery of formal language, its sensitivity to usage and its concern for the user experience. It may distinguish itself from architecture by the subject addressed (design was created mostly by architects) although construction is a highly specialized field of design involving specific project management. Finally, the practice of the design project differentiates itself from art, which is not a culture of design, notably due to its social purpose. One can therefore consider design as a *particular culture of conception*. To this end, without pretending to be exhaustive, I suggest below five distinctive characteristics of the culture of conception specific to design.

[9]For the period from 1882 to 1959, Boutinet found four bibliographical references including the term 'project' in the catalogues of the *Bibliothèque nationale*; for the period from 1990 to 1999, he found 2'143 (1990, p. 4, note 1).

These are the hypotheses, to which my reflection has led, but which, to verify their relevance, would need to be developed and tested through further research.

(1) Design is a *project discipline* as well as architecture and engineering (cf. Fig. 9.2).
(2) Design is a project discipline based on a *specific creative culture*, which is not reducible to that of architecture, the decorative arts, engineering or marketing. By this, I mean a creative culture *sui generis*, which has its own 'epistemological originality' (Findeli, 2003, p. 168) and more generally belongs to the '*third culture*' defined by Cross (1982, p. 221) and Archer (1979a, b). According to the latter, when removing refinement and complexity, only three skills essential to the foundation of any education remain reading, writing and arithmetic the 'three Rs' in English, *Reading, wRiting, aRithmetic* (Archer, 1979b, p. 18).
Reading and writing correspond to the essential skills that have founded the field of Arts and Humanities (literary culture), while *arithmetic* is the essential skill that founded the field of science (scientific culture). The third way is the skill which is based on *modelling* or *giving shape* (creative culture). If the essential language of science is mathematical notation and that of humanities is natural language, then 'the essential language of design is modelling' (Archer, 1979b, p. 20). More recently, the following definition of the design project emphasizes this aspect rather well:

> In design theory (as in architectural theory where the concept originated), a project refers both to the sequence of actions required to produce a new artefact and the means usually used to represent the different stages of development of this artefact (sketches, drawings, plans, models, prototypes). (Léchot-Hirt, 2010, p. 29)

(3) Design is a project discipline with its own *mode of knowledge* or *understanding* through which it contributes to the contemporary *episteme*. The idea that there is a '*mode of knowledge*' exclusive to designers is based, according to Baynes (1974), on the intuition of Read (1945) according to whom there is a 'mode of knowing' distinct from mathematics, science or literature. If design is a 'third culture' (Cross, 1982), then it is not only a way to design and build artefacts but also, through them, a way of knowing and understanding the world (Findeli, 2003, 2006, 2010).
(4) Design is a project discipline that is *philosophically committed to an ideal for a better and sustainable future*, whose goal is to improve the 'inhabitability of the world' (Findeli, 2010, p. 292). But this idea is rather old and dates back to Simon who wrote in 1969 in *The Sciences of the Artificial*: 'Everyone designs who devises courses of action aimed at changing existing situations into preferred ones' (p. 111). Or more recently: design is fundamentally future-oriented because 'Designers are people who are paid to produce visions of better futures and make those futures happen' (Koskinen, Zimmerman, Binder, Redström, & Wensveen, 2012, p. 42). That is why we have shown elsewhere that design creates 'idealects' (Vial, 2013), that is to say, methodical and reasoned concepts that formulate desirable and achievable ideals describing the world as it must be.

(5) Design is a discipline of project in progress in which the concept of project changes over time. For Findeli and Bousbaci (2005), there are three successive models of the design project: the *object-centred* model (until the beginning of the modern movement), the *process-centred* model (since 1950) and the *agent-centred* model (since the 1990s). One must also note that this development gradually attests to an 'eclipse of the object as a focus of design project theories' (Findeli & Bousbaci, 2005, p. 47).

These are the five criteria, though worthy of further research, that allow us to confirm my hypothesis: there is indeed a specificity of the design project. To complete my argument, I propose the following definition: *Making design projects means designing, in reference to an ideal of the world, a complex artefactual device that gives form to usages while producing knowledge, in response to a request or dissatisfaction, and through a constantly evolving rigorous methodology aiming at, in a creative and innovative manner, improving the inhabitability of the world.*

Conclusion

The emergence of new forms of design since the late 1980s (including interaction design and service design) coincides with the emergence of new project methods. Among the most recent, *design thinking* is probably the most fashionable (it is spreading like wildfire in colleges and agencies, and not just design agencies, as engineering and marketing are very interested in it too).[10] However, in the age of the digital revolution, other disciplines have embraced the project and are giving it a new lease of life that could enrich the design project. We will briefly consider here information technology, which has made a remarkable contribution in the past fifteen years to the theory and methodology of the project in the form of *project management*.

The concept of 'project management' in the broad sense appeared in the USA in the 1940s and 1950s in the military and aerospace industry, especially at NASA, before spreading to civil engineering and technological development (Boutinet, 1990, p. 239). Designed to be developed laterally within businesses and involving a project team and a project manager that (partly) escape a vertical hierarchy, project management aims at stimulating creativity and innovation, notably in the area of 'Research & Development' (*R&D*). Closely associated with technological development, 'it is similar in many aspects to the technical device project' (Boutinet, 1990, p. 237) and, therefore, maintains close ties with the design project. We can indeed say that project management has significantly changed the way of conducting a project by completely remodelling the process. One can observe this phenomenon in the field of computer and information systems where, facing unprecedented complexity involving a very large number of agents interacting with

[10]For a general introduction to the concept of *design thinking*; see Vial (2014, pp. 49–54).

each other, the way of organizing design work had to be completely reviewed. This led to the advent of project management software (with their online platforms) used to centralize the division of tasks, problem-solving through 'tickets' and exchange of information and messages between employees, documents to share, planning, etc. (the *Basecamp* software is an example of this).

But it mainly gave rise to the agile project management methodology as defined in 2001 by 17 experts in the *Agile Manifesto* (Beck et al.) and based on incremental and iterative development. This methodology has totally revolutionized the field of software design in general, but also the entire chain of digital design, therefore providing sound methodological foundations to emerging disciplines such as interaction design. As emphasized in this *Manifesto*, the agile methodology puts the emphasis on 'individuals and interactions over processes and tools', on 'working software over comprehensive documentation' or on 'responding to change over following a plan' (Beck et al., 2001). Among the twelve principles of the manifesto, adapting to change is one of the most remarkable: contrary to what usually gets most designers' backs up, it invites us to 'welcome changing requirements, even late in development' and to conduct frequent and cyclical deliveries. Co-design is also at the heart of agile methodology: 'The sponsors, developers and users should work together daily throughout the project." These methodologies are applicable to any design situation and, on this point, contrary to what they usually believe, designers have much to learn from developers (i.e. computer scientists and computer engineers).

It is therefore not a coincidence that computer scientists are among the few to have shown interest in the concept of project and to have tried to define it. It is obviously not possible to provide here a review of the computer literature on the subject. I will, however, reflect on the definition proposed by Munk-Madsen during a research seminar held in Norway in 2005. Considering that '*Project* is a central phenomenon in the field of IS [Information Systems] as systems normally are developed and implemented in projects' and that, practically, 'everybody who talks about system development methodology will also use the word project' (p. 5), he suggests the following definition: 'A project is an organizational unit that solves a unique and complex task' (p. 6). One must note the emphasis placed on the notion of complexity, which Boutinet (2002) showed to be at the origin of the methodical project in the Renaissance. One must also note the concept of *organizational unit*, to which we nevertheless prefer the term *design unit*. According to Munk-Madsen, this definition has the merit of embracing both traditional and agile project methodologies. What differentiates these two categories is the frequency with which one uses what Munk-Madsen calls 'mutual adjustment' in the coordination of the project, this frequency being very high in agile methods. Information system research thus has a lot to teach us about the theory of project.

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Chapter 10
From Design Thinking to Design Doing

Tue Juelsbo, Lene Tanggaard and Vlad Petre Glaveanu

Abstract In this chapter, we propose a broader conceptualization of "design thinking" as "design doing." This chapter moves in two related directions. First of all, taking its departure in empirical examples, this chapter illustrates how craftsmen and designers work through the body, vividly showing how design and form-giving can be seen as a kind of making. Secondly, we will investigate the potentials and possible pitfalls of using tools and codified methodologies such as design thinking. We will argue that the creative process by its nature is inherently messy and it is not necessarily and at all times guided by rules and methodologies even though they can play an important role. Both mess and order(-ing) are required and in fact build on each other within the creative process. We need methodologies to teach upcoming designers and professional and eminent designers that great status and power is connected to the formulation of these principles and the adherence to them. Creative design thinking might help us get the most creative ideas but it is through the active realisation of these ideas in everyday life that they come into being. We will conclude the chapter with the premise that creativity is just as much about mess as it is about methodology. It might even be the case that the notion of design distracts us into thinking that we can always design for creativity.

Keywords Embodied creativity · Situated action · Creative actors
Affordances · Resistance

Introduction

> Actors find themselves confronted with new situations that force them to come up with creative solutions – a process which cannot simply be captured by a functionalist logic (Joas & Knöbl, 2009, p. 522)

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This chapter is about thinking as doing, messy processes, encountering resistance from materials, and making a creative dent in the universe through action. When asked about his own creative process and where his ideas come from, the installation artist Olafur Eliasson replies:

> It's not like there's this void when one work is finished until a new idea makes its presence known. Ideas arise in extension to the works— as a result of a dialogue. I definitely don't feel that creativity comes from within, and rather than getting an idea, you give an idea form and in that way test whether it's good enough. I'm more occupied by why I should complete an idea than how I should complete it. It's hugely inspiring. (Bonde, 2009, n.a.)

Eliasson is one of the best-known installation artists worldwide and he resides in Berlin where he runs a large workshop and production facility employing hundreds of assistants, artists, and craftsmen. The quote from Eliasson's interview with journalist Lisbeth Bonde highlights some of the points we would like to make in this chapter. It also resonates with Joas and Knôbl's call to go beyond functionalist logic when thinking about the creative process (Joas & Knôbl, 2009). The popular and romantic notion that ideas appear out of the blue does not seem to agree with Eliasson. Instead, he points to the notion that ideas are very much constituted and shaped by what is already there and from the existing materials and artworks. In this dialogical space between artists, materials, and historical underpinning, new ideas are crafted rather that found. Instead of thinking of the creative process as an isolated process of our consciousness, Eliasson speaks of the experience of giving form to ideas and of asking oneself why a task should be completed. This is in many ways similar to how, we shall come to see later in the chapter, design thinking is described with its focus on discovering the "whys," working with limitations, prototyping, and testing.

There are subtle but important ontological differences here, as we will discuss based on our empirical examples. Rather than privileging the thinking part in the interview, Eliasson stresses the notion that the creation of new ideas requires blood, sweat, and tears, and that the material with which we work is or becomes alive when we take it into our hands. Instead of being an object one can manipulate mindlessly, the material "pushes" back, affords us certain actions and not others, "affecting" us in a similar manner to how we "affect" it through our manipulation (Gibson, 1979). And this happens regardless of how we might or might not have designed or thought-out the process. This intersection between human doing and knowing represents a flexible engagement with the world, entailing open-ended processes of improvisation with the social, material, and experiential resources at hand (Juelsbo, 2016). Creativity and design thinking as a process is thus far from being a purely interpersonal psychological mechanism in an immaterial consciousness. Rather, it plays out in the relationship between an active subject and an environment that challenges and confronts the subject with the necessity of doing something new (Tanggaard, 2013).

This necessity and the situations or environments Joas and Knôbl (2009) point to in the introductory quote will be elaborated on and discussed in the following sections. Our claim is that the dangers of working with the term "creative design *thinking*" might lead us into dead ends or non-constructive dualistic trenches as both creativity researchers and practitioners come to recognize.

Building on Eliasson's example, our central argument is that creativity cannot be understood as an isolated intellectual exercise based primarily on divergent or other forms of thinking and that we do not make people more creative just by training their cognition. As mentioned above, creativity is instead something that people do when confronted with tasks and situations that require new means of relating to the world around them. From this perspective, the results of creativity are not primarily signs of lateral thinking on behalf of individuals (De Bono, 1992), but are instead signs that people do new things and that existing social practices have undergone valuable changes in this process. Many innovators do not actually start up with a great idea, something Galenson's (2009) distinction between conceptual and experimental innovators testifies too. On the contrary, many creative people work much more experimentally, in a kind of trial and error fashion based on a sort of experimental creativity, or as one might describe it, of "fooling around" (Tanggaard, 2014). We shall look at a few examples of this before we discuss the implications of seeing thinking as acting in the world and pick up on Joas and Knôbl's (2009) points about the interplay between actors and situations in creativity.

Empirical Data: Methods *and* Materials Matter

The following two case studies are grounded in the qualitative research tradition, an important part of which is dedicated to understanding and interpreting actions and meanings in people's lives and their everyday practices (Brinkmann & Tanggaard, 2010). The aim is not to discover how many people do this or that but, rather, to understand the opinions and meanings around which individuals or groups of people construct their lives. The aim thus is not to interview as many people as possible but, instead, to carefully analyze the varied, manifold, and informative discourses that people use when speaking about their practice.

We will look at two different examples from the world of (a) businesses emulating design processes and (b) art and design. The first case revolves around technicians and engineers in Grundfos where the empirical materials were generated in connection with a 12-month intervention project. This project had the purpose of investigating inventiveness and creativity in three specific innovation projects at the production company Grundfos, the world's largest water pump producer. The second case consists of interviews and observations performed with a working duo of an artist and a craftsman specializing in lithographic printing. This is part of an ongoing research project investigating the notion of craftsmanship and cultural psychological perspectives on creativity in the more traditional creative domains of music, art, literature, etc.

Working Intuitively with Our Hands—Innovation in an International Production Company

Grundfos is an international production company with 19,000 employees that has in recent years focused on optimising production, lowering production costs, shortening the time from draft to actual product, and differentiating themselves in the market via design. This resulted in a new way of driving the early phases of development processes, where they tried to handle uncertainties as early in the process as possible via focused “learning loops” in a process quite similar to design thinking. Using these learning-focused processes, they sought to discover the needs of their customers and tackle challenges and uncertainties as early in the process as possible. Learning goals regarding specific uncertainties were defined, which the team was then given a limited time period to tackle (for a more exhaustive explanation, see Tanggaard & Juelsbo, 2015b).

Three project groups from the Research and Technology Department in Grundfos were included in our empirical study. Group 1 concerned itself with operation-oriented developments close to the core business (incremental optimising and development of existing water pump products), and groups 2 and 3 sought to develop more radical solutions for tomorrow’s challenges, where the focus was further away from the pumps and the company’s present core business (e.g., water cleaning, sensors, and intelligent solutions). Group composition was heterogeneous for all three groups, reflecting different engineering disciplines and including trade-specific technicians with one project leader in each group. Despite internal differences, all three project groups were meant to work in the earliest part of the development phase, where the production phase had not yet begun.

Several of our interviewees were skilled trade-educated technicians in development departments with responsibility for prototype development, technical development, and testing prototypes. In connection to the early phase of the development projects—in popular terms ranging from ideas scribbled on a napkin to a beta product ready to enter into the production development phase—group members were typically teamed up with various engineers and gathered under a project leader.

It is one of these technicians, during an interview, who had put his finger on a key point regarding creative design thinking and planned processes (Tanggaard & Juelsbo, 2015b). The technician described how he and the rest of the development team had been given the assignment of testing different technical aspects of a prototype. He immediately went to the workshop and began to 3D-model the product, while the engineers went back to the development office. For the technician, thought and action are interconnected and this gave him the freedom to attack the problem in his own way. Over the course of a month, he got through four rounds of prototype tests, where he went from working with computational models to the physical prototype, getting new ideas, posing and revising ongoing working hypotheses, reproducing the object physically, revising and testing it in all sorts of ways. It is very much a matter of material, actor and the situation coming together. In connection with his fourth round of "prototyping," he visited the engineers in the office, as some of the aspects he had been testing covered their assigned area. They had not produced a prototype yet and were working on a detailed design plan including a spreadsheet, where they wrote hypotheses for their potential tests and tried to account for variables and outcomes.

This is standard practice among engineers after the introduction of new registration and documentation systems. The technician can, after a month work with the materials, point out that several of their possible tests are now redundant, as he has already covered these and solved several of their professional headaches. He is not subject to the same documentation requirements (e.g., time registration, posing of working hypotheses and reports on these, lists of orders for technical parts and pieces for experiments) in his role as technician, and he has furthermore used his deep professional knowledge and everyday creativity as a craftsman to exceed the parameters of the assignment and solve it faster and more effectively than a whole team of engineers could.

According to the technician, this way of working intuitively, working with and through the materials using "his clever hands" is quite different from the more structured design processes, the engineers are subject to:

> Too much planning, PowerPoint and Excel sheets if you ask me. Sometimes we could benefit from working more before we make plans. A few headlines and rough sketches are enough to get into the matter, the technical stuff. With the current project I'm in the fourth round of testing. I'm sure we'll come up with a solution and then put that into the plan… (Interview extract)

A bit later in the interview, the conversation turned to relationships and embodied knowledge:

> The personal contact and interaction is extremely important. Grundfos is one big, shared network. It's necessary to build relationships or else you can't get anything done around here. And it's not in the plans. A lot of what I know can't be put into plans or databases. It comes out when I'm working. If I don't work with it physically I lose the touch. It takes about a year for a technician to lose his grip if he gets removed from the prototype lab. (Interview extract)

The technician describes here how he starts without a precise idea or feeling inspired, contrary to the design thinking methodology and recently implemented design process in Grundfos. As we shall elaborate in the following sections on design thinking, the method tends to imply that one should divide creativity into distinct phases or spaces starting with inspiration, leading to ideation and ending with implementation. That is not the experience of the technician. On the contrary, he tells the interviewer how he works much more experimentally and how the results might shape the plan in the end. A backward reading of how something came into the world in a kind of trial and error fashion (Ingold & Hallam, 2007).

Putting on the Suit of Another Artist

Turning to the artist and printer—what one might expect to be a more classical domain of creativity and, potentially, of design thinking—their collaborative practice yet again turns out to be hard to describe following the processes and methods of design thinking. When asked about their practice during one of our interview sessions, they strongly objected to the notion that it is primarily about getting the right idea and then, secondly, just a matter of mindless production. As part of the research project, one of the authors of this chapter traveled with the duo to Arles, France, in May 2016 to spend four days observing and interviewing the working couple. Twice a year they set out for a European city to produce a limited series of prints on-site over a fortnight. Søren, the artist, might have done some research on the chosen city (art history books, Google Images, local museums of interest, etc.) and thought of colors and motives, but as they are traveling via plane they are limited to what materials they can fit into their suitcases and bring aboard. The introduction of these obstructions (Juelsbo, 2016) seems to suit the duo quite well. Niels, the printer, could not bring his heavy printing presses from his studio. Also, they had to choose the type of paper, the range of colors and tools that fitted in a suitcase, before leaving for the destination. Previously they had found themselves wanting to produce different work than their chosen materials afforded them and resorted to, for instance, printing with carved potatoes or using a car to apply the right amount of pressure—simply running over the paper and print object with the car. It was what the situation called for and not something they could have planned beforehand (Fig. 10.1).

Arles and the surrounding southern region of France are known to have been the hangout spot for a lot of famous painters (Van Gogh, Picasso, Matisse) that have produced incredible work inspired by the light, warmth and people of the Mediterranean. One of the well-known motives includes "La Chambre a Arles"—the room in Arles by Van Gogh. During one of our interviews, after a long day of printing, I asked Søren why they had chosen Arles as their destination for the recent trip and why he wanted to print yet another version of the room in Arles.

> I use and have used the room in Arles as a wall to play ball against. By painting the picture again and again – taking it more and more apart - I'm aiming to create my own visual language, my own alphabet of paint somewhere between figuration and non-figuration. The room becomes my Petri dish where I can develop the language. (Interview extract)

By painting the picture over and over again, Søren, who is a trained graphic designer before becoming an artist fulltime, steeps himself in the local culture, works on his technique, and imitates in order to be able to surpass the existing. According to Søren, there is no clash between producing something new and taking an offset in the already there—quite the contrary. It is "about donning the suit—putting on the suit of another artist" as he explains it (Interview extract). In line with this, Bruner (1986) would venture that there is no clear distinction between getting to know a culture, recreating and reinterpreting this culture and recent creativity research would agree that solid and relevant knowledge within a given domain is

Fig. 10.1 Niels Peitersen, the printer, Arles, France—photograph by Tue Juelsbo

paramount for creativity (Sternberg, 1999; Amabile, Conti, Coon, Lazenby & Herron, 1996). Other artists have discovered the same—Picasso repainted and reinterpreted Manet and Velazquez, Francis Bacon repainted Van Gogh and Van Gogh himself was hugely inspired by Gauguin whom he also invited to Arles to paint with him (Fig. 10.2).

> Art holds continuous conversations with itself and all art forms are an homage to a large extent. It's all about walking then, knowing that others have walked here before me. (Interview extract)

Observing the working process of the duo, it becomes clear that it is also not just a case of Søren coming up with the ideas or concepts for Niels to print. Instead what plays out in the working kitchen is a continuous dialogue between different actors: artist-printer, printer-paper, artist-paint, etc. Søren draws up the design on a plate of linoleum, cuts out the individual pieces and hands them over to Niels. As they apply one layer of color at a time, the duo walks back and forth between the darker kitchen where they work and brighter living room where they inspect the works color by color. Niels's knowledge of color, composition and the craft of printing constitutes, *together* with Søren's knowledge of art history, his ideas and drawings that will eventually become the finished work. Every color is mixed by hand on-site and applied to the linoleum cutouts with small rolls before a piece of paper is placed on top and color transferred to paper with a good doze of pressure from Niels's hands. It does not always go as planned. Sometimes the colors do not transfer like they are supposed to, the linoleum does not cut the way Søren intends, and the paper acts differently from day to day according to the humidity and temperature in

Fig. 10.2 Niels Peitersen and Søren Behncke, Arles, France—photograph by Tue Juelsbo

the room. They have to work together both as a human duo but also, and importantly, with the other actors that constitute the practice; the paint, the light, the paper, molds, etc.

If we follow the descriptions above, creativity is embedded in a practice that can exercise resistance. It can do so through concrete objects or events that provoke action, yet if we broaden our scope, it can also be the landscape, physical layout, distribution of labor, organisation of tasks, routines, or habits that exert a form of resistance. Ingold and Hallam (2007) write concerning the importance of materials for creativity that:

> The ancient knew this when they derived the term 'material' from *mater*, meaning 'mother'. And they knew too, that even the generation of ideas requires sweat, blood and tears when they extended the meaning of the verb 'to conceive' from the development of an embryo in the womb to that of ideas in the mind. By the same token, creativity is *not* a faculty of a disembodied mind of, as it is taken to be in most psychological treatments of the subject, whose designs are actively imposed upon a world of matter that is effectively dead. (pp. 11–12)

Accordingly, creative people like the technician, Søren and Niels, seem to be in a kind of correspondence with the world, rather than standing up against it:

> In the act of inquiry, the conduct of thought goes along with, and continually answers to, the fluxes and flows of the material with which we work. These materials think in us, as we think through them. Here, every work is an experiment, not in the natural scientific sense of testing preconceived hypothesis, or of engineering a confrontation between ideas 'in the head' and facts 'on the ground', but in the sense of prising an opening and following where it leads. (Ingold, 2013, pp. 6–7)

Fig. 10.3 Niels Peitersen (left) and Søren Behncke (right), Arles, France—photograph by Tue Juelsbo

What we can take away from the two examples seems to be that the notion of creativity is about more than thinking and acting separately, divergent or convergent thinking, or that one can act creatively without taking the material into account as more than just an object to be manipulated. Instead, creative agents try out things and see what happens, move forward in real time, find learning pathways, go along with others; you must set up a relation, a correspondence with the world, in so far as you want to see, learn, understand, and create new things (Tanggaard, 2014). This leads us to the notion of design thinking, put it into context, and the need to discuss the implications of both our data and general research for developing a sociocultural, developmental, and situated perspective on creativity (Glăveanu, 2010a, b, 2014; Fig. 10.3).

Creative Design Thinking in Context and the Importance of Context

Design thinking and, on a larger scale, creativity, have come to be dominant discourses in current times when politicians and policy makers, for example, regard creativity as key for sustainable growth and commercial success. This belief has been tied with a general focus on strengthening education in order to secure "the development of such individuals that can succeed in a knowledge-based economy" (Moeran & Christensen, 2013, p. 2). Reviewing the leadership and management journals, one can find examples of researchers striving to define and strengthen the necessary competences of future leaders and plenty of examples point toward furthering creative skills and design thinking among the employees of various organisations. This might not be an easy task for the general manager that has focused on cost-cutting in recent years but it is deemed necessary if the organisation is to thrive creatively.

Martin, the former dean of Rotman School of Management, University of Toronto, has researched this extensively and is widely known as an expert on innovation and design thinking. In 2013, Martin was ranked third on the *Thinkers50 list*, a biannual ranking of the most influential global business thinkers. In a 2006 interview, he describes design thinking as a certain kind of thinking where you integrate user perspectives and feedback and where the participants engaged in design thinking work with limitations, obstructions, and abductive reasoning (Dunne & Martin, 2006). These competences are now deemed relevant for all employees and not only for designers.

Herein lies a crucial point: within this thinking, the design process has in many ways been liberated from its traditional domains and leaders and educators globally strive to integrate creativity, innovation, and entrepreneurial competencies into their everyday work life and educational settings (Tanggaard, 2016). Martin reveals how he has been greatly inspired from working with Tom and David Kelley from the famed strategic design firm IDEO,[1] and that it was their collaboration that spurred him into believing that organisations should change from traditional work patterns to become more like design shops in their attitude and work methods. When interviewed in 2009 about design thinking and the birth of the term, David Kelley said that he struggled with accurately describing the type of design work they were doing in IDEO when he saw a shift in the company's focus around 2001. IDEO had for many years focused on product design but found themselves increasingly being asked to tackle cases that were quite far from traditional product design, e.g., patient flow in a hospital or the optimal customer experience in a supermarket. Kelley stated that whenever someone asked him about the design work his employees were doing he inserted the word "thinking" into the sentence to explain the nature of the work. Eventually, the term design thinking stuck (Brown, 2009) and people have come to associate the term with IDEO and the Kelley-brothers.

From Designers to Consultants

IDEO and design thinking might go hand in hand but the notion of design as a "way of thinking" in the sciences can actually be traced to Simon's (1969) book *The*

[1]IDEO is an award-winning global design firm that takes a human-centered, design-based approach to helping organizations in the public and private sectors innovate and grow.

Read more at https://www.ideo.com/about/#Uprom8wIDu2xAQcd.99.

Sciences of the Artificial and in design engineering to McKim's (1973) book *Experiences in Visual Thinking*. Rowe's (1987) book *Design Thinking*, which described methods and approaches used by architects and urban planners, was a significant early usage of the term in the design research literature. Faste continued McKim's work at Stanford University in the 1980s and 1990s, teaching the course "Design thinking as a method of creative action" and it was there that David Kelley came into the picture. Kelley was a colleague of Faste at Stanford University and it was through forming IDEO in 1991 that design thinking came to be adopted by business and came to signify how laymen to a large extend know and work with the term and related processes.

One of the reasons behind the great success of Brown, his company, and the whole notion of design thinking might be that it is an ambitious attempt to actually uncover what guides creativity and innovation. Brown identifies three consecutive design spaces, labeled (1) Inspiration, (2) Ideation, and (3) Implementation, and he sees design as led by problem-solving. Some of the methods include, *in phase one*: asking questions, using user-centered observational research, mapping business constraints, cross-disciplinary involvement, sharing insights, creating narratives, addressing appropriate technology, searching hiding integrate potentials, synthesize possibilities; *in phase two*: brainstorming, sketching, scenario-building, creating frameworks, sharing and communicating within the team, prototyping and testing; *in phase three*: presenting the case to the business and implementing new obtained knowledge.

One could argue that design thinking has grown out of an attempt to systematize and map methods, which can be used by consultants and companies to strategically bring forth more creativity and innovation. This is where the term takes on a new meaning as it breaks away from former uses in an analytical, descriptive manner, and turns more prescriptive and potentially dogmatic. If one uses the term in the more consultant-oriented and prescriptive manner, it might clash with observed design processes as the ones mentioned above and made reference to in our short case studies. The attempt to make reality fit the design thinking methods is in some respect counter-intuitive to the processes of creativity in everyday life and, as noted by Ræbild (2015), very few designers actually work guided by these methods. Citing Cross, chair and founder of the long-standing design journal *Design Issues*.

> The working methods of innovative designers are, for the most part, not systematic, there is little evidence of the use of systematic methods of creative thinking, for example. The innovative designers seem to be too involved with the urgent necessity of designing to want, or to need, to stand back and consider their working methods (Cross, 2011, p. 74).

The dilemma involved in trying to describe methods for creativity while creative processes in everyday life are more about working out of necessity without the need for a systematic methodology is what troubles us in the present context. Design thinking is very much a description of a consultancy approach to design while it does not cover the complexities and the mess of an actual designer's work practices.

Beyond design itself, creative processes are almost by definition nonlinear—otherwise, we would have a much easier time predicting rather than just trying to explain creative achievement. Wallas' (1926) famous four-stage model of creativity based on preparation, incubation, illumination, and verification has rhetorical appeal and might well be used to structure post-factum narratives about creating. But what is "inside" these stages, the multiple back-and-forth movements and reiterations, the dialogue between materials and thinking, between creators and their many (present and absent) collaborators remains largely unknown.

Accordingly, our premise is that everyday life creativity is more about mess than about methodology. It might even be the case that the notion of design distracts us into thinking that we can always design for creativity. On the other hand, novices and educational institutions often strive for methods and guidelines to help them get started and, in the end, how can one learn to be creative if not by following methods outlining what others have done before? What would be the middle ground?

Creativity as Being-in-World

If we turn to the opening quote by Joas and Knôbl (2009), the term "situation" replaces an ends-means logic because it is the specific situation in which actions are undertaken that causes perception and cognition to come into play and plans to be formulated—and that demands human creativity: "These situational challenges thus require new and creative solutions rather than the unwavering pursuits of goals and plans formulated at a particular point in time" (Joas & Knôbl, 2009, p. 518).

Empirical studies have shown, time and time again, that human practice is not guided by plans, as we often tend to think. Joas writes extensively about situated creativity in his book *The Creativity of Action* (1996, *Die Kreativität des Handelns*, 1992) and, in line with these practices, we state that human cognition and learning are not isolated processes of mental adaptation but part of life itself. Joas regards life practices and human action as essentially creative. His pragmatic perspective is itself supported by thinkers such as George Herbert Mead and John Dewey, who rebelled against the idea that human actions are fundamentally driven by an ends-means type of rationality. For Joas, it is not that people first make plans (mentally) and then carry out actions (in practice) with reference to the pre-formulated plan. Rather, thinking and acting are seen as two interconnected dimensions of human existence with thinking integrated in acting. The ideas that come to mind spring from our practical engagement in situated activities and not the other way around. We do not export plans into the world we are currently building. The thoughts we have and the plans we make for shaping our surroundings are a result of already being in the surroundings.

Accordingly, working with a situated, distributed and "messy" concept of creativity draws upon a fundamental understanding of creativity as built upon a human capacity for wise and creative action in unexpected situations, a capacity that is necessary in a world undergoing constant change. Creativity is an attribute of not just mental processes and divergent thinking, but also of a fundamental, corporeal, action-based capacity for adequately responding to the unexpected, a capacity for digging deep into failures to make things come alive in ways that were not always foreseeable. And it is creativity again that helps stabilize a world in constant flux. In the words of Ingold, reflecting on the creative work required to build something:

> Builders know all too well that operations seldom go according to the plan. Working in a fickle and inconstant environment, they have continually to improvise solutions to the problems that could not have been anticipated, and to wrestle with materials that are not necessarily disposed to fall, let alone to remain, in the shapes required of them. Completion is, at best, a legal fiction. The reality, as Brand […] wryly observes, is that "finishing is never finished". (Ingold, 2013, p. 48)

In other words, we cannot help but be creative, even if it may be the case that some people exploit these opportunities more than others. This relational and dynamic understanding, specific for a sociocultural approach to creativity, helps us also problematize the popular notion of creative potential (see also Glăveanu, 2015). Instead of locating creative potential inside people and, more specifically, inside their thinking processes, we come to realize that potential resides in the action itself, in the encounter between person and world taking the form of action, making or doing.

Design Thinking and the Cognitive, Domain Generality Bias

When you practice design thinking according to the methodology described by IDEO and Brown (2008), you move through "four mental states." "Divergent thinking" can generate alternatives to the present reality and provide more choices. Next, employ "convergent thinking" to sort your options and decide which is best. Then apply "analysis and synthesis." Analysis breaks patterns down, and synthesis "identifies meaningful patterns" as you reassemble them. Shift cyclically back and forth among these states, generating the new, analyzing it, sifting and selecting, and then examining it in practice and, often, starting the whole process over again. Design thinking is meant to stabilize and even "normalize" the creative process. Those who use design thinking access their nascent creative capacities; the idea of creativity being a capacity one can tap into lying dormant. While moving through these stages, design thinking functions within a framework of three intersecting "constraints." They are "feasibility," which is what can be done; "viability," what you can do successfully within a business; and "desirability," what people want or will come to want. As we know from method books in many domains, we of course acknowledge that the map or methods are not the landscape. So it is in the design process you need flexibility as the map or methods might not cover all details in the situation.

In a recent paper, Tanggaard (2013) argues in line with the above-mentioned discussion that the notion of nascent creative capacities and this cognitive, individualistic bias point to the need for developing a socio-materialized understanding of creativity. A socio-material conception of creativity is based on the assumption that a design is nothing without materials. All ideas for something new—a new house, a new car, a new piece of clothing—require materials. An architect's design does not become a new house without building materials and without the builders who raise the house and make it habitable. Moreover, although buildings in architects' portfolio are often never built, the designs exist in some material form, e.g., on paper or computer, and were created using these materials. Moreover, the architect is creating his or her design with the known affordances of building materials and normally with a particular material site in mind.

This idea that creativity exists in the dialectical relation between individuals and materials in social practices represents a very real break with the individualized conception that creativity originates from intellectual, cognitive achievements or from individual emotional sources. Creativity is, on the contrary, expanded to include the materials that are worked with and that quite concretely comprise that which is created as well as the continually developing creations of the products we produce. As described by Ingold and Hallam: "And because it is the way we work, the creativity of our imaginative reflections is inseparable from our performative engagements with the material that surrounds us" (Ingold & Hallam, 2007, p. 3).

However, for psychological science to discover this, it is required that we move the study of creativity outside the typical test of the ability to think divergently. In this regard, our domain of psychology could seek inspiration in studies of design and architecture. In a recent study of the performative roles of materiality for collective creativity among students learning architectural design, Jacucci and Wagner (2007, p. 73) argued that the "literature on creativity has mostly focused on individual cognitive processes neglecting the influence of material features and the collective character of creativity." They argue that the possible role of materiality is its ability to speak to "multiple senses" and point to the significance of shared experiences, dynamic interactions and bodily engagements beyond the purely cognitive. Through their participant observations of architecture students, the two authors show how metaphors and diverse materials are an important vehicle for communicating complex ideas and concepts shared among the students. Also, the students select and probe different materials through exploring tactile properties, temperature, smell, moisture, and surfaces that carry meaning. That is, the richness and diversity of material features engage and activate our senses, bodily, tactile, olfactory, auditory and visual, as well as different modes of expression.

Moving beyond architecture and design, John-Steiner (1997) also pointed toward the importance of artefacts for creative activity based on her studies of letters, notebooks, and interview materials obtained from artists and scientists. Quite literally, notebooks, sketches, and outlines, but also different kinds of invisible tools play an important role in creative work. In the book, Mann describes how he arranges these invisible tools: "For writing I must have a roof over my head, and since I enjoy working by the sea better than anywhere else, I need a tent or a wicker beach chair […]. For a longer book I usually have a heap of preliminary papers close at hand during the writing, scribbled notes, memory props" (Mann, Winston & Winston, 1975, p. 257). It is here that we find the reason for the experience many of us have: that it is contact with or resistance from the materials with which we work that causes new ideas to arise.

Creativity is fundamentally relational—even if we sometimes experience it as good ideas popping up inside our heads. Thus, architecture and design studies, as well as music studies (Lock, 2011) and John-Steiner's notebook studies point toward the role of human-made artefacts in creative activity to a point neglected or overseen by many psychological treatments of the concept. However, Jacucci and Wagner (2007) also stress the fact that materials have a history communicating preexisting ways of doing architecture, they emerge as part of specific activity and become part of performative action in the future.

It seems all too natural to speak of the creative process, as if there was some generic, one-size-fits-all procedure or mechanism that could apply to any domain of creativity. For example, this assertion would imply that the mental operations involved in conducting scientific research are the same as those engaged in conceiving an artistic product. An illustration of this idea is Wallas' (1926) above-mentioned classic theory of relatively distinct stages in creative work. Yet some contemporary researchers oppose this view (Baer, 2011; Kaufman & Baer, 2002). Each major domain of creativity has its own distinctive methods or techniques that provide the basis for generating creative ideas.

For instance, creativity in the sciences requires the so-called scientific method, a method that would have no utility whatsoever in writing a novel or choreographing a ballet. However, if domain specificity is the rule, then it becomes difficult to comprehend why creativity happens to be associated with certain individual differences variables, regardless of the creative domain. Presumably, these correlations reflect the fact that the creative process depends somehow on the creative person. Creative persons have "what it takes" to produce creative ideas. This controversy may have arisen because the domain-specific advocates are not looking at the phenomenon of creativity at a sufficient level of abstraction (Simonton, 2013). No doubt, much of what an artistic creator does contrasts greatly with what a scientific creator does. Yet if investigators back away far enough to see the forest and not just the trees, the generic features of creative thought may emerge. A candidate for this "big picture" view is Campbell's (1960) theory that creativity requires blind variation and selective retention (BVSR). In simple terms, BVSR maintains that creativity requires a creator to generate ideas without knowing which ideas will eventually prove useful. Creativity is thus inherently risky and wasteful. Although now over a half-century old, recent research indicates that BVSR has the best prospects for describing the generic process underlying all forms of creativity (Simonton, 2011). Creators merely tailor BVSR to the distinct needs of their discipline. The accommodation is, therefore, domain specific.

Epistemology of the Hand

In a paper entitled "Towards an epistemology of the hand", Brinkmann and Tanggaard (2013) argue, in line with the pragmatic perspective upheld here, that experiencing the world—and knowing it—are functions of our practical activities, of our *handling* the world and its problematic situations. What we experience and know about the world are primarily aspects of things that we interact with and manipulate (literally "operating with our hands").

Things are not first and foremost entities independent of organisms that have objective physical characteristics that can be *seen*. Rather, "things are objects to be treated, used, acted upon and with, enjoyed and endured, even more than things to be known. They are things *had* before they are things cognized" (Dewey, 1925, p. 21). According to Dewey, we normally encounter and know things in those contexts of use where they belong, and it is only through active manipulation that we discover their properties: Things "*are* what they can do and what can be done with them—things that can be found by deliberate trying" (Dewey, 1920, p. 115).

As seen in our concrete examples at the beginning of the chapter, immersion in subjects and traditions, experiments and fooling around, as well as resistance from the material are all important aspects in creativity-promoting teaching and creative learning environments (Tanggaard, 2014). None of these elements can exist on their own; they are all part of dynamic interchanges in the genesis of creativity. This includes an understanding of creativity that more fully incorporates a material perspective than most existing psychological theories do. Creativity is not just a matter of receiving ideas in an immaterial consciousness. Creativity consists of concrete renewals that make concrete practices better, more fun, more effective, more sustainable, and so on.

We might need methodologies to teach, for example, upcoming designers that great status and power is connected to the formulation of these principles and the adherence to them. Creative design thinking might help us to get the most creative ideas but it is through the active realisation of these ideas in everyday life that ideas themselves come into being. One might not be able explain the process on the basis of its outcomes (Valsiner, 1987), but we can explain the outcomes by looking at the dynamic sides of the ongoing activity and its immediate context (Tanggaard, 2014).

The rules of research, often formulated in many research-guide books, are good to know, especially for the novice research, but they are not to be confused with the concrete, realized research. The latter requires experience-based researcher skills (observing, describing, and listening, reading, writing) which are accumulated and embodied over the years.

Conclusion

We will conclude the chapter with the premise that creativity is more about mess than about methodology (Tanggaard & Juelsbo, 2015a). It might even be the case that the notion of design distracts us into thinking that we can always design for creativity. Mason's statement that "to create is to act in the world, or on the world, in a new and significant way" (2003, p. 7) rings particularly true here. In this chapter, we have been critical of the way in which mainstream design thinking intends to form the world, and of the limitations it places on the possibilities of people to enlarge the scope of their environmental relations. By this critique, however, we do not mean to devalue design or design thinking. Rather, our intention is to call for a more reflexive design practice and for an expansion of the range of design with regard both to the ways it relates to non-design disciplines and to its role in society. At the same time, by proposing the broader notion of "design doing" and grounding it within pragmatist and sociocultural theories of action, we aim to expand the traditional focus on thinking processes while embedding them within ongoing self—other relations and person—world interactions.

Following this line, it is important not to completely reject the possibility that design thinking and other formalised learning processes can provide creativity-promoting practices. This is because creativity does not just suddenly appear the instant the school door shuts behind us. Instead, places like design schools or other educational settings prepare us to be creative in the situations and work contexts that will come to play significant roles in our lives when we are not in education. As the Danish psychologist Ole Dreier stated in 1994 and as Lave echoed in 1999:

> We often participate in a certain context to realise goals or interests that originate in and "belong" to another context. We thereby make use of certain connections between these contexts, or we and others create and develop these connections in order to realise goals and intentions in one context by participating in another… Human action has potential and varied cross-contextual expansion and depth. (p. 51, our translation)

Creativity-promoting teaching or methodologies like design thinking don't necessarily result in creative actions in the here and now but instead can increase the student's or learner's chances for expressing creativity in other contexts. It is the learner him/herself who carries these transformations across contexts and social practices while these are being transformed. If we are to seriously study to what extent teaching leads to the development of the individual student's creative potential, we must research this both in the practice in which the potential may be realised and in the contexts in which the learner participates. Ideally, creativity should be researched in longitudinal or cross-cultural studies in which individuals' participations and learning trajectories are tracked over time.

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Chapter 11
C-K Theory: Modelling Creative Thinking and Its Impact on Research

Armand Hatchuel, Pascal Le Masson and Benoit Weil

Abstract Creativity has been studied as a psychological phenomenon, and research has focused on factors that influence the human variability and acquisition of such capacity. Still, the creative process remained metaphorically described, and with no rigorous formalization. Moreover, the knowledge background of ideation has been ignored, as well as the interplay between creative ideation and knowledge generation. This paper is an introduction to recent advances in design theory, namely C-K theory or concept knowledge theory (Hatchuel and Weil in A new approach of innovative design: an introduction to C-K theory, 2003, Res Eng Des 19:181–192, 2009) that overcomes such biases and assumes that creative thinking can be formally described with solid theoretical premises that can be experimentally tested. There is now significant literature that assesses its propositions, findings and implications. C-K theory introduces new notions: "concept undecidability", "knowledge independence", "generic expansions" and "knowledge reordering"; they capture key necessary mechanisms of any creative process. Therefore, classic interpretations of creativity (association of ideas, analogy, blending, divergence and convergence) have to be revisited. C-K theory shows that they account for some aspects of ideation, but miss important operators that uncover the generative and expanding logic of creative thinking. It also reveals that specific knowledge structures are needed to allow for creative generation. C-K theory captures within the same formal model, both creative ideation and learning, invention and discovery, fixation and expansion of knowledge. Thanks to its explanatory and predictive power, C-K theory allows a new articulation between theory and observation in the field of creativity. Several findings have confirmed the value of such research potential. Finally, C-K theory stimulates transdisciplinary research through the development of a rigorous design science and the modelling of creative logic in all disciplines.

Keywords Creativity · Design theory · C-K theory · Design science

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Introduction: Creative Thinking as Both Ideation and Knowledge Generation

In this paper, we present a new approach to creativity research coming from recent advances in design science (Le Masson, Dorst, & Subrahmanian, 2013), namely from the development and advancement of C-K theory (Hatchuel & Weil, 2003, 2009). This theory offers a unified and formal model for creative thinking, be it creative ideation or creative design. It also opens new paths and methodologies for research.

Traditionally, creativity has been studied as a psychological phenomenon and without any connections to design. The literature on creativity has mainly explored two different series of research issues: (i) the identification of the psychological, cultural and educational processes that favour creativity as an individual or collective mindset; (ii) the study of specific traits of "creative thinking" (Boden, 1999); classically, creative thinking has been related to "divergent" and flexible forms of thinking; to the capacity to think "out of the box" and to welcome ideas which strongly differ from ordinary ones. But if one asks "how does creative thinking work? What makes it possible?" the literature only brings partial and fragmented answers. For sure, metaphors, analogies, surprising associations of ideas, illuminations, as well as serendipity have long been recognized as usual "traits" of creative thinking. Yet, if we compare the development of creativity research, to other psychological fields like decision making, behaviour under risk or learning, the science of creative processes obviously lacked a sufficient level of formalization and axiomatization at least equivalent to decision theory and probability theory and this limits the analytical understanding and modelling of the creative process, or even the implementation of conclusive experiments.

Revisiting Standard Assumptions of Creativity Research

We argue that the elaboration of a formal theory of creative thinking has been hindered by two unquestioned assumptions that we have abandoned in our research programs.

(a) *The first assumption is the naturalistic perspective that dominates the psychology of creativity*. The phenomenon under study is defined as the observed production of creative ideas or creative ideation, and research aims to capture its natural variability among individuals. It was not systematically intended to identify the type of reasoning or the models of thought through which one can generate creative ideas or explain the possibility and ontological structure of creative thought. Finally, creativity was described as a hidden psychological capacity that could only be recognized by its outputs and may be stimulated or inhibited. Contrasting with such academic trend, our research program was built on the hypothesis that creative thinking was a generic and specific reasoning process that could be made explicit and the subject of analytical study.

(b) *The second assumption is less visible and appears when creativity is compared to design*. It is widely recognized that design can be a creative process. Yet, design is much more than pure ideation. Design is an active process that requires efforts, inquiries, tests, discussions. Thus, a whole set of cognitive activities (learning, comparing, arguing, etc.) contributes to creative design. Therefore, we should have learned from design activity that creative thinking encompasses two different processes as follows: (i) creative ideation; (ii) a process of knowledge generation, in relation with some context and environment. In common words, the creativity research has approached creative ideas as pure inventions of the mind, while design research had to account both for such inventions and for cognitive discoveries that may be provoked or emerge during the design process.

These preliminary remarks have major scientific implications as follows: (a) the ideation process should necessarily be associated to a knowledge process; (b) yet, what are the interactions between ideation and knowledge generation? What is generated by such dual processes? These issues played a key role in the development of the research program that led to the elaboration of C-K theory (Hatchuel & Weil, 2003), and this paper aims to be an introduction to this theory and to its main findings. Before, let us indicate some of the immediate consequences of the previous remarks.

The Missing Background: Revealing the Role of Knowledge in the Creative Process

If creative thinking is interpreted as the design of an idea, even if it is purely mental and partly unconscious, it becomes necessary to associate to creative ideation, a cognitive process where knowledge activation, organization and evaluation also take place in the mind. Actually, it is easy to admit that the memory and past knowledge (of all types) of a subject act as a complex and evolving cognitive resource that will impact ideation. It is however less intuitive to consider that ideation can also impact memory and knowledge. But a new and more rigorous perspective appears: where ideation is distinguished, yet not separated, from its cognitive resources, and both should be seen as potentials for mutual activation and development. This new approach leads, at first, to critically revisit creativity research classical propositions.

Revisiting convergent thinking and divergent thinking. The distinction between divergent thinking (DT) and convergent thinking (CT) is at the root of the psychological description of creative ideation (Guilford, 1959; Torrance, 1988). DT was traditionally seen as enabling novelty, i.e. the definition of some new entity; whereas, CT was needed for value achievement and control, i.e. giving reality and relevance to this new entity (Cropley, 2006; Eris, 2004). Yet, if we do not take into account the knowledge process coupled to the ideation process, the impact of DT and CT becomes undetermined. DT followed by CT can lead to poor creativity if the most original ideas generated by DT are rejected because of a lack of knowledge to elaborate them. Conversely, CT can also contribute to novelty by warranting feasibility to the most creative ideas of the process. Therefore, the divergence/ convergence model is not sufficient to explain novelty and value. What is missing is the specific knowledge content which activates CT or DT and their combinations. Without a clarification of the interplay between knowledge processes and standard notions like CT and DT, it was also not surprising that the impact of “expertise” on the creative processes remained controversial.

The role of expertise: prison or escape tool? The potential tension between existing expertise (skilled knowledge) and creativity is well described. Weisberg (1999) suggests that existing competences limit novelty but are needed for valuable achievement. According to Boden (1990), a creative idea cannot be produced by “the same set of generative rules as are other, familiar ideas” (p. 40). It was also observed that the value would require specific expertise, whereas novelty comes mainly from general and abstract models (Ward, Smith, & Finke, 1999). It is also commonplace that expertise matters: ideas appearing as novel to some people may present no such novelty for an expert. Finally, if we take into account the interaction between ideation and knowledge processes, the impact of expertise on creative processes cannot be predicted in advance. It can be both a resource and an obstacle for the creative process.

The conditions of creative generation: unknown objects and the changing object definitions. Any creative process aims to generate new artefacts and new ideas. This implies a necessary condition that is often overlooked, yet is key to understand the creative mechanisms. We have to recognize the progressive description of objects that are necessarily partly unknown when the creative activity begins. Moreover, as already stated before, “unknown” is always relative to some state of knowledge associated with the creative process. Thus, a crucial and necessary operation of the creative process is the activation of old and new knowledge in order to tentatively define and make exist some unknown objects. The operation that transforms unknown objects into new known ones plays a major role in the formalization of the creative process. In 1990, Boden underlined the notion of “transformational creativity” and stressed the need to change the “generative rules [of] familiar ideas” (p. 40). This formulation may have been misleading for creativity research. Transforming ideas is not enough to obtain a creative process. What is necessary is to transform previous knowledge and previous definitions of objects. “Objects” or “things” are organizers of knowledge that have to be transformed by generative rules (Abadi & Cardelli, 1996). Actually, the basic generative rules of any language or knowledge background are those that stabilize or change the definition, be it syntactic or semantic, of “objects” (i.e. “names”, sorts or relations between names). Thus, any creative process is the transformation of existing knowledge by introducing new objects and maintaining the definition of older ones.

Finally, it is more rigorous and general to define creative thinking as the tentative elaboration of new objects, rather than new ideas. Moreover, the interplay between the redefinition of objects and the generation of new knowledge, ignored by standard creativity research, appears as a central mechanism of creative thinking. So far, these first conclusions indicate that any rigorous and consistent formalization of creative thinking have to capture and integrate these interplaying elements within a same formalized model. These are the objectives of C-K theory that we introduce in the next section.

Elements of C-K Theory: The Dual Expansion of Concepts and Knowledge

C-K theory (an acronym of Concept Knowledge theory) has been introduced by Hatchuel and Weil (2003, 2009) as a model of creative design. It now has important scholarly developments and a wide range of applications in research and practice (Agogué & Kazakçi, 2014). The term "C-K theory" mirrors the assumption that creative design can be modelled as the interplay between two interdependent spaces having different structures and logics: the space of concepts (C) and the space of knowledge (K). The structures and expansions of these two spaces determine the core propositions of C-K theory. In this paper, we only insist on the implications of C-K theory for our understanding and research about creative thinking.

Spaces C and K: Basic Assumptions

Space K is expandable and contains all established (true) propositions (the available knowledge). It makes explicit the missing background of any creative process that was already mentioned. It plays several roles: it is a reference space, a resource space and an output space that is transformed during the creative process. Knowledge is the collection of established true propositions,[1] from the viewpoint of a "creative" person or group of persons.

Space C is also expandable and is the space where "creative ideation" is explicitly organized. Yet, we have to give to this expression a more precise definition: we call "creative ideation", the tentative and progressive definition (or description) of a partially unknown, yet desirable, object. Such definition is always relative to a certain state of K-space. Thus, Space C is the space where new definitions of objects are progressively elaborated. Whereas, Space K is the space that contains all available knowledge that is used by the definitional process in

[1]Regardless of how "truth" is assessed. For instance, emotions can be seen as "truths" that can impact the creative process as any other type of truths, for instance, "scientific" propositions. This flexibility in the construction of space K, gives to C-K theory a very high level of generality and allows to capture and understand creative processes and different types of human activity.

Space C. In standard approaches of creativity, only Space C is observed and Space K is ignored.

More technically, in C-K theory, the attempts at definition of new objects in Space C are called *concepts*. The theory establishes that concepts are propositions about some partially unknown objects and all take shape as: "there exists some X object, for which a group of properties P1, P2, Pk hold in K". Moreover, it can be proved that if concepts are about unknown objects then concepts are undecidable propositions in K (neither true nor false in K). Concepts define unusual sets of objects: they are sets of partly unknown objects, which imply that their elements have an existence that is not warranted in K. The sets of C-Space are special sets which can be defined by classic axioms of Set theory (ZF), excepting those that assume the existence of elements (like the axiom of choice which has to be rejected). Yet important results in Set theory have established that this rejection could be done without impact on the other axioms (Cohen, 1963).[2]

Having defined Space C and Space K, the creative process can be formalized as the process by which undecidable concepts—that are usually called ideas or "briefs" in design activities and are generated and transformed into one or several new objects, i.e. true propositions of K. New ideas or design solutions are selected among these new propositions. During the design process, C and K are jointly expanded through the action of four different C-K operators that reveal the hidden and ignored complexity of creative thinking.

The Design Process and the Four C-K Operators

According to C-K theory, design proceeds in C-space, by a step-by-step partitioning of C sets using propositions coming from K. Beginning with a first concept C0, the partitioning operation is repeated whenever there is a partitioning proposition in K and until some partitioned "Ci" becomes a new object "Ki", i.e. an object which existence is warranted by propositions in K. Under such construction, the following propositions hold (Hatchuel & Weil, 2003, 2009)

Space C necessarily takes a tree expanding structure which describes the expansion of C0 (see Fig. 11.1). This proves why the opposition between divergent and convergent thinking was misleading. Any attempt to define new objects (things, methods, solutions) gives birth to divergence and refinement. Creativity only

[2]Moreover, it has been established that C-K theory was in deep correspondence with the Forcing method in Set theory (Cohen, 1963). Forcing is a major result of Modern Set theory; it has been developed in 1963 by Cohen for the design of new collections of sets (called extension models). Thus Forcing can be interpreted as a method for creative design in the pure world of sets. And to put it shortly, if K-pace is limited to Set theory and number theory, C-K theory becomes the Forcing method. Thus C-K theory can be seen as a generalization of forcing to knowledge spaces where objects are not only numbers or classic sets (Hatchuel & Weil, 2007).

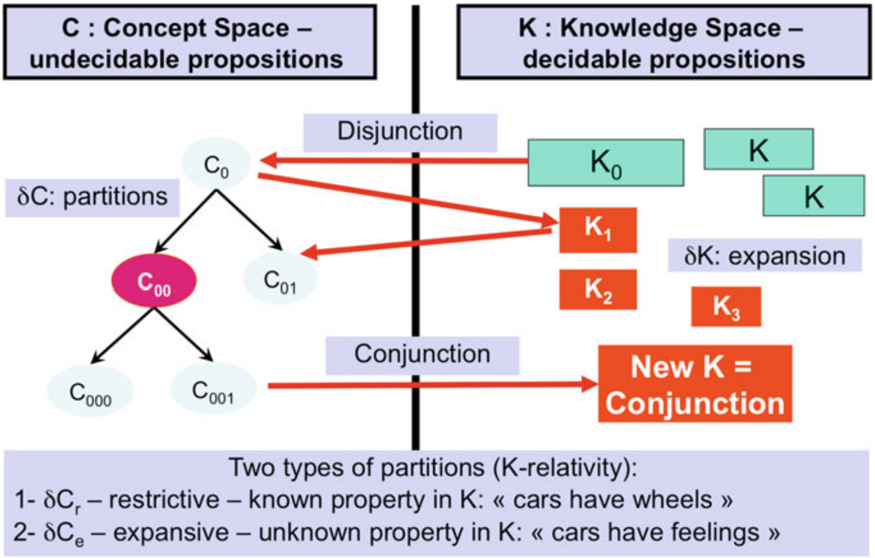

Fig. 11.1 C-K design process and its operators

appears if the interplay between such divergence and knowledge generation gives birth to established new objects.

Space K is necessarily expanded by the operations of evaluation and activation that are triggered by C expansions. In classic terms, creative ideation not only transforms ideas but also provokes the generation of new knowledge, which is the necessary condition for transforming concepts into objects. Again, C-K theory reveals central mechanisms of creative thinking that were ignored by standard approaches guided by a biased notion of "ideation".

C-K theory predicts the necessity of *four types of operators:* $C \rightarrow C$, $C \rightarrow K$, $K \rightarrow K$ and $K \rightarrow C$. Implicitly, standard approaches of creativity focused on $K \rightarrow C$ operations: generating novel ideas. This left in the dark, three other operators. (I) $C \rightarrow C$ operators which organize the progressive refinement and structuring of ideation and are precisely where creative reflexivity lies, i.e. judgements on originality, novelty, value can be developed. (II) $C \rightarrow K$ operators that transform ideation into new knowledge capture all validation practices (sketches, tests, prototypes, mockups, etc.) as well as the introduction of new independent sources of knowledge (discoveries) and finally $K \rightarrow K$ operators which not only contain conventional reasoning, but also reordering operations that allow a new object to be integrated to older objects without creating a loss of meaning and nonsense.

The identification of these four operators reveals a totally new understanding of creative thinking. The latter leads to a complete new phenomenology of creation; they also provide a unique and rigorous formalism, i.e. a scientific model that captures creative design and is lacking since the early days of the field.

The Generic Mechanism of Creative Power: Expanding Partitions and Knowledge Expansions

One key prediction of C-K theory deserves a more detailed description: the distinction between two types of C partitions, i.e. between two types of refinements in the C-space.

- If the partition expands the definition of an object with a new property *that is not known in K as a possible property of this object*, it is called an expanding partition.
- Conversely, if the partition relies on *an existing definition or property of the object in K*, it is called a restricting partition.

For instance, "a house with a red roof" is a restricting partition if "houses with red roofs" are already known in K. "A roofless house" is an expanding partition if there are no such houses in K. C-K theory underlines that this notion cannot be defined per se, it is always relative to a certain K-space that should be made explicit in order to recognize the expanding type of the partition.

It is easy to see that the notion of "expanding partition" rigorously describes a generic operation that unifies a large collection of operations that were usually seen as the "spark" of the creative process: metaphors, analogies, idea associations, illuminations and so on. By generic, we mean that the expanding partition opens the path to the generation of new objects, and it can occur on all types of description of an object (structural, physical, sensorial, etc.) and at all levels of definition of this object. Now, a key finding of C-K theory is that expanding partitions are necessary but not sufficient instrument of creative thinking. New objects will appear only, and only if, K expansions (new K) allow to continue the refinement and definition of expanding partitions until a concept becomes "reality", i.e. a decidable (and decided) truth in K. Figure 11.1 synthesizes the four C-K operators and their interplay. It also illustrates the distinction between restricting and expanding partitions in a C-K development.

A Scientific Model of Creative Thinking: A Synthesis in Five Propositions

C-K theory offers a model that rigorously captures and understands the creative process. This claim can be synthesized through five propositions that step-by-step reinterpret classical notions and offer an operational, predictive and consistent theory of creative design that can be easily tested by empirical observations or applications.

P1. **Design and creativity are C-K processes**. Design usually needs some initial requirements while creativity may have no clear starting point. C-K theory can model both processes. In design, some C0 may be stated at the beginning of the process by some external person that is not the designer. But C-K theory can be equally seen as a continuous and recursive process: propositions in C are generated continuously and expanded through a C-K process. This fits quite well with the description of creativity as a self-triggering mode of thinking.

P2. Novelty and value are K dependent and generated by joint C-K expansions. Even if novelty is defined as some new object appearing for "the first time in history", this is still a K-dependent definition. History is simply the name we give to our knowledge about the past. The same argument stands for value. Any value criteria is a piece of established knowledge in the social system where creativity and design are situated (be it the opinion or emotion of a user or a client). Thus, novelty and value are not external to the design process and are embedded in K. If a client rejects a design, this only means that sufficient knowledge about its needs was lacking or wrong in K.

Novelty is necessarily triggered by one or several expanding partitions. Yet, the knowledge used to form these partitions could have been present at the beginning of the process (existing one) or generated during the process (new one). Moreover, designed solutions will not use all the partitions developed in C, and will be composed by a list of attributes mixing restrictive and expansive partitions. A creative solution is a design that may combine knowledge generated by all different paths in C. Thus, the whole expansion in C and the whole expansion K could have contributed to form novelty. Similar arguments hold about value. A corollary proposition is that novelty and value are not contradictory. C-K theory shows no such thing. Space C and Space K are not in opposition; they are co-generated.

P3. Expanding partitions generate new propositions in C and in K. This is one of the deepest results provided by C-K theory. It can be interpreted as such: the "crazy" ideas allowed to be formed in C-space have two interacting modes of action: (1) they can open a new path in C (a new distinct branch); (2) they can activate new knowledge in K that may, in return, form new concept expansions elsewhere in C. These two different mechanisms explain the seemingly *irrational* process of creativity if rationality is classically defined as the result of standard $K \rightarrow K$ operations, i.e. classic logic. In Space C, thanks to the undecidability of concepts, any strange or surprising associations of concepts ("ideas") can be formulated and expanded without provoking contradiction or nonsense in K. They will have no disruptive impact on K, as long as the generated knowledge has not transformed these strange ideas into a creative and decidable design in K. Thus, C-K operators provide a rational process that transforms irrational propositions into creative designs as well as new valid knowledge (after K-reordering) that makes these designs exist.

P4. C-K theory captures all forms of creativity. The interplay of C-K operators captures a wide range of possible expansions in C and K, as well as well-known types of creativity:

- *Pseudo creativity* is easily modelled by a wide expansion in C which never generates any validating expansion in K. A lot of surprising partitions are produced yet none of them can be transformed into decidable propositions.
- *Bounded creativity* can be related to two different types of C-K expansions. (I) a wide expansion in C is generated, but a small subset of K-space blocks almost all new alternatives. (II) Few alternatives are generated through the activation of a small subset of K. In both cases, we find the existence of a dominant subset of K (fixated knowledge) which either "kills" any new concept or impedes its formation. In practice, these two types of creativity are quite different.

P5. Creative thinking and creative design convey a redefinition of objects and a reordering in K. The path from an undecidable concept to decidable solutions is warranted by expansions in C- and K-spaces. These expansions can be of little impact on the general structure in K. Yet, in some other cases, the definition of a common class of objects (an ontology) has to be changed or created. For instance, when electricity was used to transport sounds or voices, a new complete class of objects appeared (telephones). Thus, the definition of all ways to transmit sound, and even the definition of sound itself, had to be revised. Such reorganization of K is necessary to preserve meaning and consistency (avoid nonsense in K), it is also a condition to regenerate interesting independences that will allow for new C expansions: well organized creative thinking nurtures the creative potential of any K-space.

An Intuitive Interpretation of C-K Theory: Chimeras, Discoveries, Re-ordering of Objects and Knowledge

C-K theory does not contradict standard knowledge about creativity, but it reveals unique and hidden features of creative thinking or design that were neglected or mistakenly treated. In addition, these features invite to perceive creative thinking as a rational, rigorous and consistent logic that were not yet described and explicitly unveiled.

Creative thinking needs "ideas" but not all ideas trigger creativity; moreover, no ideas exist without a knowledge background. Likewise, not all metaphors, analogies, unusual association can be at the root of a creative process. Something additional is required, the new idea must express a "chimera" as follows: (i) a description of a new entity that is defined by attributes that are connecting "independent" pieces of existing knowledge; (ii) such independence is not universal, it is relative and contextual to a specific structure of knowledge. This knowledge relativity was not analyzed and not seen as a resource for creativity. "Chimerization" is an intuitive image that fits well with the abstract notion and process of making expanding partitions. We may also interpret or visualize a chimera as a "hole" in existing knowledge (Hatchuel, Weil, & Le Masson, 2013), and C-K theory can be seen as a proof that creative thinking would not be possible if the knowledge structure did not allow for such "holes".

Traditionally, chimeras are imaginary monsters, half man and half animal. They combine properties coming from knowledge about humans and knowledge about animals, properties that are independent, i.e. not connected in K. Yet, in modern science, a man can live with animal implants. These are no more chimeras; they are successful creative designs. Now, chimerization is only one operator of creative thinking. Discoveries are also needed as creative thinking needs the provocation of surprising learnings. Creative thinking has to be an active and inquiring process. But not all surprises will transform a chimera into a real thing. It is necessary for creative thinking to generate knowledge *in excess*, knowledge that finds itself useless. Chimeras become reality thanks to cognitive conquests. But chimeras are also themselves good triggers for the activation and exploration of new independent sources of knowledge. Monsters stimulate reflexivity and invite to search for new means (new K) to make them exist or to temper their strangeness. Now when monsters come to existence by design, they force to rethink old things and established relations. Creative thinking needs re-organizing, re-structuring, reshaping of existing things. This is not a process that is outside creative ideation, it is an essential part of it. Creative thinking is not only about one new thing, but it also addresses the reordering of the available knowledge that is required to "host" the new thing in a consistent and meaningful way.

The intuitive conception was that creativity was irrational and irrationality was the condition of creativity. As it is often the case, this intuition was not completely wrong. It was biased and incomplete due to unquestioned assumptions that distorted observations and research. C-K theory suggests that creative thinking appears completely rational when its dual logic and knowledge context is clarified. It is a general form of design that is independent of what is designed. It can be also interpreted as the rationality of any generation process.

Conclusion: Implications and Applications of C-K Theory for Research

The elaboration of a formalized model of creative thinking has important impact on research issues and methods. A wide range of new programs becomes possible thanks to the variety of analytical properties and predictions that can be derived from the model. To conclude, we will mention some concrete applications (programs and published findings) of C-K theory.

Capturing forms of creative thinking in different fields (art, science and engineering). C-K theory generates many testable predictions. One of them, mentioned previously, is that the structure of the K-space has to present "independences" that will be transformed, in order to allow for the generation of a new object in C. More operationally, Le Masson, Hatchuel and Weil (2016) show that this general property means that the K-space presents:

- neither *a deterministic structure*: all thinking is reduced to deductions, which means no independence in K;
- nor *a modular structure*: in this case, all thinking is reduced to free combination of existing and compatible bricks, which is another form of having no independence in K.

One could predict that the task of art-based schools would be to restructure students' knowledge in order to *ban* any previous form of determinism and modularity. The validity of this prediction is confirmed by recent research (Le Masson et al., 2016) that studied the teachings of famous Bauhaus professors such as Paul Klee and Johannes Itten. This finding contributes to explain the prominent role of Bauhaus in the creation of new styles in a wide range of industrial designs. Also, it leads to a new understanding of sketching, not only as a way to express and visualize ideas (the classical interpretation), but also as a facilitating means of reordering knowledge so that creative thinking becomes possible (Brun, Le Masson, Weil, 2015).

Relying on C-K theory, it is possible to identify a different creative logic in engineering design and science (Le Masson, Hatchuel, & Weil, 2011). To preserve robustness and easy designs, engineers tend to favour determinism and modularity in the structuring of their actionable knowledge: machine elements, standard assemblies and so on. This approach inhibits creative thinking. However, engineering science also frees the engineer from fixated relationships between functions and organs. Performance specifications, functions, use cases are mobilized to trigger new concepts and the explorations of *unknown combinations*, and hence promote creativity. Moreover, science is regularly reordered to integrate discoveries and new objects or to allow constant regeneration with limited reordering. C-K theory invites to avoid dogmatic views about how to generate and teach creative thinking. The same theory can give birth or guide towards different forms of creative thinking that fits the special expansions of C and K. Such expansions depend on the domain ontology (objects and knowledge) and epistemology (theory of truth).

Building theory-driven experimental protocols. Thanks to its rigor and predictions, C-K theory enables the definition of theory-driven experimental protocols in design and creativity research. Without clear theoretical frameworks, experimental research may lead to weak findings and even to inconclusiveness. This is the case in various and contradictory experiments conducted to test whether examples tend to fix or defix ideation processes (Agogué & Cassotti, 2012). C-K theory predicts that examples will play a different role if they belong to the *fixation* zone in both Space C and Space K, or if they are outside this zone (i.e. belong to the "expanding" zone). The problem is that this fixation zone should be identified before the experimentation. C-K theory allows to build such ex ante analysis and to formulate hypotheses about fixation zones. It allows to design a new set of experiments where the impact of examples becomes highly predictable, proving that without the control offered by C-K theory, hidden variables existed in previous experiments (Agogué et al., 2014).

More generally, C-K theory could have predicted and explained a large variety of findings that appeared in design experiments like the observation of "generative design questions" (Eris 2003, 2004) or the emergence of "noun phrases" and new nouns in design exercises (Mabogunje & Leifer, 1997). C-K theory contributes to confirm the existence of different forms of design reasoning between design professions (Agogué, Le Masson, Dalmasso, Houdé, & Cassotti, 2015; Savanovic & Zeiler, 2007). It also predicts the low generative power of brainstorming, and that the quantity of ideas is not related to originality. Finally, it explains that focusing on defixing concepts generates more new knowledge and that the value of creative design does not come from the number of original ideas but from the consistent use of this new knowledge (Kazakçi, Gillier, Piat, & Hatchuel, 2014).

Supporting a transdisciplinary paradigmatic shift: design science as a science of creative thinking and processes. C-K theory leads to new connections with contemporary mathematics and logic. It stimulates the new notion of imaginative constructivism (Kazakçi, 2013) that generates new bridges between creation and Brouwerian constructivism. C-K theory also helps modelling new approaches of system engineering and technology management (Kokshagina, 2014). It provides solid grounding for the merging of design theory and creative thinking theory. This helps to clarify the ontology of design and can nurture a wide range of human and social studies of design (sociological, anthropological, organizational, epistemological and linguistic studies). An example of such an impact is the notion of "common unknown": the understanding of collective design situations governance (in firms or in non profit organizations) where creative thinking is needed as a means of action as well as in respect to the ends to be generated and reached (Le Masson & Weil, 2013).

C-K theory appears today as a solid scientific ground for a transdisciplinary shift. Creative processes are better understood and modelled within design theory and science. Such new science can contribute to research on human activities that are considered as creative; it can also help studying creative forms in domains where they are less visible or hidden. Finally, creative thinking is no more reduced to a psychological and natural phenomenon, it reveals a forgotten class of scientific thinking, the generic design of unknown objects and its coexpansion with the transformation of knowledge. Through the formalization of C-K theory, such paradigmatic shift has already opened new ways of research and provided unexpected findings. Yet, all this could be only the early steps of a much wider scientific impact.

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Chapter 12
Technological Innovation in Group Creativity

Stéphanie Buisine, Jérôme Guegan and Frédéric Vernier

Abstract This chapter presents ongoing research dedicated to augmenting creativity through innovative technologies. Our hypotheses draw on the pros and cons of the brainstorming paradigm to strengthen the former and overcome the latter. The main efficiency factors we are trying to support are Cognitive stimulation, Social comparison, and Group facilitation, while trying to circumvent Production blocking, Social loafing, and Self-censorship. The first technology reviewed is electronic brainstorming systems: It was shown that such devices enable groups, even large ones, to avoid production blocking. However, it may also increase social loafing, which is detrimental to creativity. We then introduce interactive tabletop brainstorming with which groups can conciliate individual reflection, idea sharing, and social setting. We show that this technology reduces social loafing, and we provide interface designs that further support cognitive stimulation, social comparison, and group facilitation. This series of experiments also highlights a new efficiency factor for creativity, namely the Fun factor: The use of innovative technology in itself introduces playfulness, which seems to increase engagement and creative performance. Finally, we report on a recent series of experiments exploring avatar-mediated creativity as a means to counter self-censorship through anonymity and enhance creativity through avatars' appearance. The results confirm that the choice of avatars in virtual brainstorming greatly influences creativity through processes such as self-perception, priming, and social identity. In many respects, avatars and virtual environments offer a new promising tool to support group creativity. We conclude on the potential impact of these findings on real-world innovation challenges.

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Keywords Technology · Electronic brainstorming system · Interactive tabletop system · Avatar

Introduction

Brainstorming remains one of the most widely used creative problem-solving approaches in group work. This method was imagined by advertising executive Osborn (1953) to help his collaborators reach higher levels of creativity. Osborn's first insight was to identify two antagonist mechanisms competing within the creative process, namely *ideation* and *evaluation*. Ideation relies on divergent thinking and consists in generating ideas, whereas evaluation supports convergent thinking and idea selection. In many respects, evaluation (e.g., "that's impossible/too expensive/ridiculous") interferes with ideation and acts as idea killer in the group (censorship) but also within one's own creative process (self-censorship). Therefore, Osborn's proposal to improve creativity consists in separating ideation and evaluation in time: In a brainstorming, participants should strive to defer judgment while generating ideas and evaluate the pool of ideas only when the time has come. Four rules are provided to help participants suspend evaluation during ideation: *Withhold criticism*, *Welcome unusual ideas*, *Quantity breeds quality,* and *Combine and improve ideas*. Subsequent research aiming to substantiate this method confirmed the efficiency of the four rules, since brainstorming sessions were shown to produce more creative ideas with than without the rules (Parnes & Meadow, 1959; Turner & Rains, 1965; Weisskopf-Joelson & Eliseo, 1961). It was also observed that the presence of a facilitator (in particular an expert one), whose role is to ensure that the rules are respected, further enhances creativity (Kramer, Fleming, & Mannis, 2001; Offner, Kramer, & Winter, 1996; Oxley Dzindolet, & Paulus, 1996; Paulus, Nakui, Putman, & Brown, 2006).

The brainstorming framework was also used in a considerable body of research to better understand the underlying processes of group creativity. For example, the exposure to other participants' ideas was shown to enhance individuals' creativity: This is termed *Cognitive stimulation* (Dugosh & Paulus, 2005; Dugosh, Paulus, Roland, & Yang, 2000; Nijstad, Stroebe, & Lodewijkx, 2002). Besides, the possibility to compare one's own performance to the others' was also shown to increase creativity through *Social comparison* (Dugosh & Paulus, 2005; Bartis, Szymanski, & Harkins, 1988; Harkins & Jackson, 1985; Michinov & Primois, 2005; Paulus & Dzindolet, 1993). However, several characteristics of the brainstorming method also appeared to be detrimental to creativity. For example, a major shortcoming of spoken brainstorming sessions is the necessity of managing speech turns: Each participant has to wait his turn to give an idea, and only one idea can be given within a turn. This severely interferes with ideation process (Nijstad, Stroebe, & Lodewijkx, 2003) and results in *Production blocking* (Michinov & Primois, 2005; Diehl & Stroebe, 1987). *Social loafing* proved to be another key issue: In brainstorming groups, some participants tend to under-contribute in comparison to a situation where they would brainstorm alone (Harkins & Szymanski, 1988; Karau & Hart, 1998; Karau & Williams, 1993; Serva & Fuller, 1997), and other participants tend to over-contribute (*Social compensation*—Williams & Karau, 1991; McKinlay, Procter, & Dunnett, 1999). The simultaneous occurrence of social loafing and social compensation results in the emergence of leaders and laggards in the group. Finally, despite brainstorming rules, *Self-censorship* remains a barrier to creativity (Williams, 2002). To summarize, Table 12.1 provides an overview of known efficiency and inefficiency factors of group creativity.

Using Technology to Improve Group Creativity

Research on group creativity aims to provide tools based upon the aforementioned efficiency factors (or even strengthening them) while overcoming the inefficiency factors of the brainstorming method. This can be achieved through methodological and/or technological means. Hereafter, we provide examples of technology-supported creativity tools and show how they are likely to enhance group creativity.

Electronic Brainstorming Systems

Production blocking may be the easiest factor to counteract since it only requires switching from the spoken to the written channel for idea generation. The term *Brainwriting* (Heslin, 2009; Paulus & Yang, 2000) is sometimes used to refer to the technique of silently sharing ideas by writing them on paper or on digital notes. The latter can be done through an *Electronic Brainstorming System,* which consists in having the participants simultaneously generate ideas on computers networked together (Dennis & Williams, 2002). Electronic brainstorming proved to effectively support group creativity: The same brainstorming rules apply and facilitator's task is made easier since the written channel is less prone to involuntary evaluation from participants. Moreover, it also supports cognitive stimulation by providing an

Table 12.1 Efficiency and inefficiency factors highlighted by research on brainstorming

Efficiency factors for group creativity	Group facilitation (Brainstorming rules + facilitator)
	Cognitive stimulation
	Social comparison
Inefficiency factors for group creativity	Production blocking
	Social loafing
	Self-censorship

increased attention to others' ideas (Michinov, 2012): It is indeed easier to read a large number of ideas on a computer screen than on sticky notes on a wall for instance. Social comparison also applies to electronic brainstorming situations (Dugosh & Paulus, 2005; Michinov & Primois, 2005) and anonymity decreases evaluation apprehension (Nunamaker, Dennis, Valacich, Vogel, & George, 1991), which in turn may reduce self-censorship. Finally, electronic brainstorming avoids production blocking, which enhances idea production (Dennis & Valacich, 1993; Gallupe, Bastianutti, & Cooper, 1991; Gallupe, Cooper, Grisé, & Bastianutti, 1994; Kerr & Murthy, 2004; Valacich, Dennis, & Connolly, 1994), and this benefit was shown to increase with group size (Dennis & Williams, 2002; DeRosa, Smith, & Hantula, 2007; Paulus, Kohn, Arditti, & Korde, 2013).

Table 12.2 summarizes the effects of electronic brainstorming systems: The efficiency factors previously identified in the literature are all supported, and a new one appears, namely group size. Regarding inefficiency factors, production blocking is avoided and self-censorship reduced. However, electronic brainstorming does not solve the problem of social loafing and even increases its detrimental effects because group membership and sense of belonging are lower in this context (McKinlay et al., 1999). Following this pattern of results, we sought a compromise between electronic brainstorming and a setting enabling higher group awareness. This attempt led us to study the effects of interactive tabletop brainstorming systems, as developed in the following section.

Interactive Tabletop Brainstorming

Interactive tabletop systems are multi-user horizontal interfaces (see Fig. 12.1). They implement around-the-table interaction metaphors allowing collocated collaboration and face-to-face conversation in a social setting (Shen et al., 2006).

Table 12.2 Effects of electronic brainstorming systems on efficiency and inefficiency factors of brainstorming

		Support provided by electronic brainstorming system
Efficiency factors for group creativity	Group facilitation	✓
	Cognitive stimulation	✓
	Social comparison	✓
	Group size	✓
Inefficiency factors for group creativity	Production blocking	✓
	Social loafing	✗
	Self-censorship	✓

Fig. 12.1 Example of an interactive tabletop brainstorming system (Schmitt, Buisine, Chaboissier, Aoussat, & Vernier, 2012)

Interactive tabletop systems are particularly well suited for group creativity: In addition to supporting electronic idea generation, they provide sharing and visualization facilities on the table, enabling group members to do without individual computer screens. For this reason, they are expected to increase group awareness. To substantiate this assumption, we conducted a series of experiments using tabletop brainstorming systems, so as to understand the impact of the around-the-table form factor, of the digital nature of the tool, and of particular interface features on group performance.

As a first step, we compared interactive tabletop brainstorming with pen-and-paper brainwriting in several conditions. These experiments highlighted the importance of the around-the-table form factor to group performance, both in interactive and in pen-and-paper conditions (Buisine, Besacier, Aoussat, & Vernier, 2012). More precisely, we observed groups of four members brainstorming around a table or in front of a vertical surface such as a flipchart. When group members were gathered in front of the flipchart, they exhibited high social loafing and high inequity of contribution, with strong leaders and strong laggards in the group. But when the same group members were installed around a table, their respective contributions to group performance appeared to be significantly better balanced. This result suggests that social loafing can be reduced simply by changing the spatial organization of group members. We observed this phenomenon in brainstorming tasks, but group structure may impact performance more generally (e.g., Abric, 1971). It was indeed shown that equity of contribution correlates to the collective intelligence of a group, a factor that explains groups' performance on a wide variety of tasks (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). Our results suggest that groups may be more intelligent around a table.

The form factor is not the only advantage of interactive tabletop systems. Our experiments showed that the attractiveness of the technology and the digital interaction improved subjective experience and increased motivation to engage in the task (Buisine et al., 2012), which is also a moderating factor of social loafing (Brickner, Harkins, & Ostrom, 1986; Shepperd, 1993). Moreover, interactive tabletop systems are evaluated as funnier than pen-and-paper work around the table (Buisine et al., 2012), and this Fun factor may also contribute to increasing creativity (Barré, Buisine, Guegan, & Aoussat, 2014).

Taking for granted that interactive tabletop is a valuable device to improve group brainstorming, we designed a series of tabletop interfaces to further enhance creative processes. For example, we introduced time pressure in brainstorming as a way to test the effect of the Press factor on creativity (Schmitt et al., 2012). In this experiment, the digital interface required brainstorming participants to enter an idea every 60, 30, or 15 s. We also considered time pressure as a support for group facilitation because, in line with Osborn's (1953) rules, it may force participants to give up evaluation and self-censorship. The results showed that time pressure increases fluency (number of ideas produced) and originality (number of unique ideas), but also deteriorated participants' satisfaction (Schmitt et al., 2012). This kind of artifact therefore requires careful assessment to be used in a safe way. In another interface design, we aimed to increase social comparison through the implementation of a graphical feedback. We placed in the center of the table a module showing in real time the number of ideas entered by each participant (in context in Fig. 12.1, in detail in Fig. 12.2). This feature proved to increase fluency as well as motivation (Schmitt et al., 2012).

Finally, we designed an interface based on the SIAM theory—Search for Ideas in Associative Memory (Nijstad & Stroebe, 2006). According to this theory, ideas in a brainstorming do not come one by one but rather in the form of *trains of thought*, which are rapid accumulations of semantically related ideas (Stroebe, Nijstad, & Rietzschel, 2010). Our interface enables brainstorming participants to visualize their associations of ideas and trains of thought (Fig. 12.3). This new interface proved to increase cognitive stimulation and originality of ideas: Groups working with this interface produced more unique ideas, less redundant ideas, and longer trains of thought (Afonso Jaco, Buisine, Barré, Aoussat, & Vernier, 2014).

All in all, interactive tabletop proved to be a useful tool to support group brainstorming (see Table 12.3): Group facilitation, cognitive stimulation, and social comparison are at least as effective as with electronic brainstorming, and our successive experiments showed that specific interface features such as performance feedback or visualization of trains of thought can further support the efficiency factors of group creativity. Interactive tabletop also highlighted Fun as an additional creativity booster. Moreover, this technology reduces social loafing through its

Fig. 12.2 The graphical performance feedback in the center of the interface, showing in real time the number of ideas produced by each group member around the table

around-the-table form factor and associated group awareness. However, several factors are difficult to handle around a table: First of all, group size is necessarily limited because of the form factor. A large group working around a large table or around two adjacent tables is tantamount to separating the group into several subgroups. Secondly, self-censorship remains difficult to manage around an interactive tabletop system: On the one side, the Fun factor may be conducive to freewheeling and unleashed creativity. On the other side, increased group awareness and high identifiability of group members may enhance likelihood of self-censorship. Hence, the effects of tabletop brainstorming on self-censorship remain unclear. Following this research program, we explored how alternative technologies could implement the best compromise between all these factors. In particular, a focus on self-censorship led us to consider the use of avatars in a virtual environment for supporting creativity.

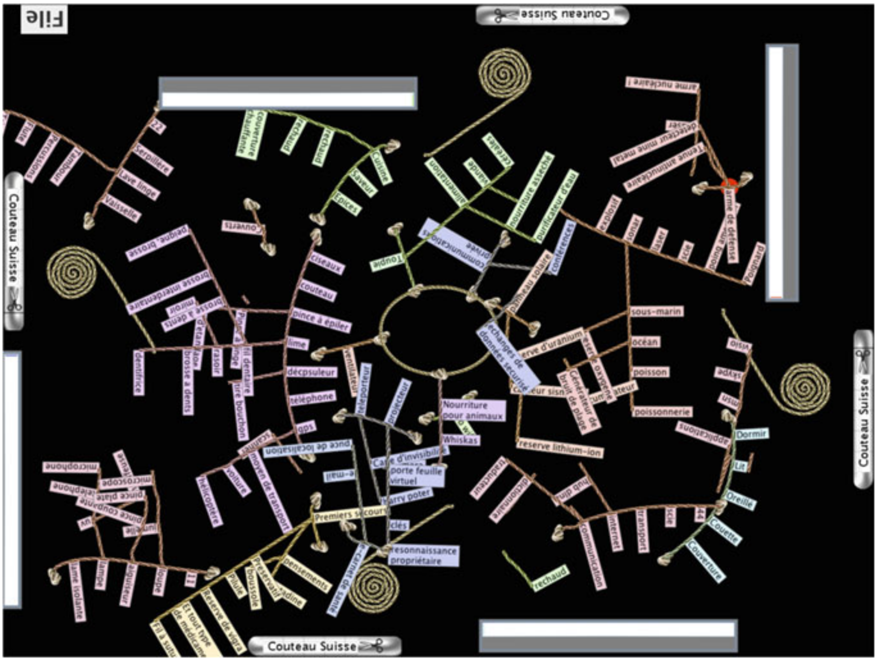

Fig. 12.3 The tabletop train-of-thought interface supporting visualization of association of ideas

Table 12.3 Effects of interactive tabletop systems on efficiency and inefficiency factors of brainstorming

		Support provided by interactive tabletop brainstorming
Efficiency factors for group creativity	Group facilitation	✓
	Cognitive stimulation	✓
	Social comparison	✓
	Group size	✗
	Fun factor	✓
Inefficiency factors for group creativity	Production blocking	✓
	Social loafing	✓
	Self-censorship	✗

Avatar-Mediated Brainstorming

Avatars are digital characters representing users' identity in a virtual environment (Meadows, 2008). They are projections of users or "tangible embodiment of their identity" (Yee, Bailenson, & Ducheneaut, 2009). Through avatars, users can experience multiple identities or highlight certain aspects of their ideal self

(Bessière, Seay, & Kiesler, 2007). Thereby, avatars allow users to change their appearance, their social roles, and their identity in a virtual world. A recent line of research has also shown that users' behaviors are influenced congruently to their avatar's identity. This behavioral modulation was named *Proteus effect* (Yee & Bailenson, 2007, 2009) after the Greek God Proteus who possessed the ability of metamorphosis.

On a theoretical viewpoint, this phenomenon could be explained through the seminal proposals of self-perception theory (Bem, 1972), according to which individuals explain their attitudes and internal states based on observation of external cues, just as an external observer would. This is why a change in self-representation may lead to a change in behavior. Moreover, in situations of anonymity and deindividuation (Postmes & Spears, 1998) like in a virtual world, self-perception reliance on identity cues (and therefore on avatar's appearance) is enhanced (see Yee et al., 2009).

The Proteus effect was observed in several contexts: For example, attractive avatars lead to behave in a more intimate way in terms of self-disclosure and interpersonal distance (Yee & Bailenson, 2007), and tall avatars lead to more confident behavior in a negotiation task (Yee & Bailenson, 2007; Yee et al., 2009). It was also shown that the Proteus effect endures over time and affects subsequent offline behavior (Yee et al., 2009; Rosenberg, Baughman, & Bailenson, 2013; Yoon & Vargas, 2014). This means that the appearance of an avatar influences users' behavior not only in the virtual world, but also in the real world. Likewise, can avatars be used to increase creativity?

In this series of experiments, we used avatars to modify self-perception in order to improve one's creative performance. To do so, the first step was to identify what kind of avatars would be likely to increase the perception of one's creative skills. These experiments being conducted with engineering students, we studied the cognitive representation of creativity in this population. This led us to identify the concept of the Inventor as a common relevant creative figure for engineers (Guegan, Buisine, Mantelet, Maranzana, & Segonds, 2016). Accordingly, we designed and validated avatars featuring characteristics of inventors (e.g., looking like Einstein, wearing a lab coat or using scientist's instruments, Fig. 12.4). We expected that users of these avatars, observing their digital appearance ("I embody an inventor"), would make implicit inferences about their creative skills ("I am creative") and improve their creative performance ("I have a lot of ideas/good ideas"). Consistently, our results show that engineering students using inventor avatars during a virtual brainstorming session perform significantly higher in fluency and originality in comparison to students using neutral avatars and students in a face-to-face electronic brainstorming situation (Guegan et al., 2016). Moreover, this benefit endured over time since participants allocated to inventor condition continued to perform higher in a subsequent face-to-face brainstorming. Subjective data also showed that brainstorming in a virtual environment (either with a neutral or a creative avatar) was rated as funnier than electronic brainstorming system.

The previous experiment managed to increase creativity by making engineers identify with the figure of the inventor. In terms of innovation process, this is likely

Fig. 12.4 Example of an avatar perceived as an inventor

to emphasize engineers' talent to develop products of superior technological value and therefore support a Technology-Driver strategy (Jaruzelski, Staack, & Goehle, 2014) representing high degrees of R&D difficulty (Mantelet, Segonds, Maranzana, Guegan, & Buisine, 2016). Then we wondered whether avatars could be used to help engineers develop User-Centered innovations, motivated by customer needs instead of technological value. To investigate this question, we designed a case study with a major company from the transportation industry. A group of highly qualified employees from the innovation department were attributed inventor avatars like in the previous experiment, and another group was attributed avatars representing users of public transportation (Persona avatars, e.g., a mother with a newborn, a child, an elderly person, a train manager). Both groups were immersed in a transportation situation (metro tour across a virtual Paris, Fig. 12.5) and had to find applications for smart windows in public transportation. As expected, the content of ideas was influenced congruently to avatars' appearance: The inventor condition led to a techno-centered ideation profile, oriented toward technological solutions, while the Persona condition led to more user-centered, needs-oriented ideas (Buisine, Guegan, Barré, Segonds, & Aoussat, 2016). Consistently, inventors' production tended to be better evaluated through industrial criteria and Personas' production tended to be better evaluated by transportation users. These results suggest that avatar-mediated brainstorming could be a powerful tool enabling innovation team to align ideation to their strategy (e.g., technology-centered or user-centered).

Beyond self-perception and personal identity, avatars may also be a convenient medium to emphasize social identity in a virtual environment (e.g., Guegan, Moliner, & Buisine, 2015). Social identity is defined as a part of self-concept linked to group membership (Tajfel & Turner, 1979). In this way, a positive evaluation of one's in-group may contribute to a positive evaluation of the self, leading people to work as a group and for the group and exhibit increased performance (i.e., *social laboring*, Haslam, 2004). Hence in a subsequent experiment, we introduced social identity cues on avatars' clothes as it could be implemented in various professional contexts (e.g., clothes in the colors and logo of a company, sport team jerseys). On the basis of the Social Identity model of Deindividuation Effects (Reicher, Spears, & Postmes, 1995; Spears & Lea, 1992, 1994), we assumed that virtual cues would

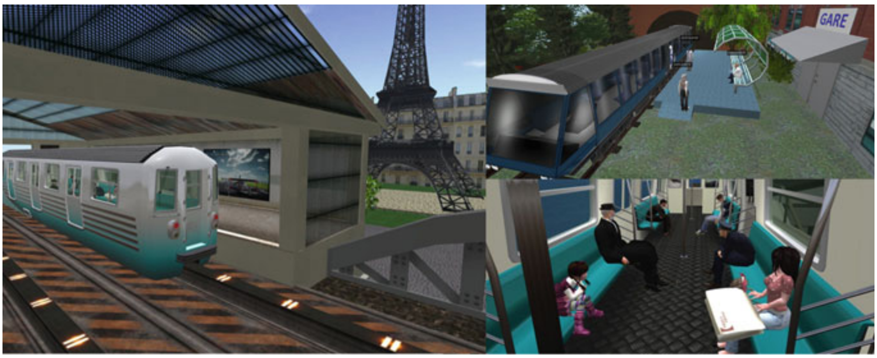

Fig. 12.5 Example of virtual environment and avatars used in a brainstorming session about public transportation

exert a positive effect on group performance (see Tanis & Postmes, 2008). By perceiving themselves as members of a group rather than co-workers who are “gathered together,” individuals should be more likely to engage in online collaborative work. The results confirmed this assumption by showing that social identity cues on avatars’ clothes increased both group identification and creative performance (Guegan et al., 2017). Hence, avatars appeared as a valuable tool to reduce social loafing and support teamwork in a meaningful way. Moreover, in the context of a creative assignment, group identification may influence not only the perception of group members (“we” instead of “I”), but also of their ideas (“our production” instead of “my production”). Because attention to others’ ideas is key to creativity (Paulus & Brown, 2007; Michinov, 2012), increasing the salience of social identity may also improve cognitive stimulation.

To sum up, the use of avatars may provide multiple benefits in the context of group brainstorming (Table 12.4): Group facilitation is similar to electronic brainstorming system and can be conducted remotely through the instant messaging tool of the virtual platform. The facilitator can be represented by an avatar like all participants or can manage the group without being embodied or materialized in the virtual world. Classical efficiency factors such as cognitive stimulation and social comparison are supported and can be further enhanced with relevant avatars’ appearance. Moreover, virtual sessions were repeatedly evaluated as fun in all our experiments, which may contribute to foster engagement and creativity. Virtual brainstorming can also involve large groups to promote diversity of views and increase cognitive stimulation. There is potentially no limit to group size in a virtual world. Idea generation is still performed through the written channel to avoid production blocking and improve attention to others’ ideas. Finally, avatars provide a unique means to stimulate creativity through modifications of individuals’ perception of their personal and/or social identity, thereby reducing social loafing and self-censorship to help everyone reveal his/her best creative potential.

Table 12.4 Effects of avatars on efficiency and inefficiency factors of brainstorming

		Support provided by avatar-mediated brainstorming
Efficiency factors for group creativity	Group facilitation	✓
	Cognitive stimulation	✓
	Social comparison	✓
	Group size	✓
	Fun factor	✓
Inefficiency factors for group creativity	Production blocking	✓
	Social loafing	✓
	Self-censorship	✓

Conclusion

New technologies, when mastered and used wisely, may provide unsuspected support to socio-cognitive processes. In this chapter, we focused on collective creativity and analyzed how several technologies interact with its processes. This research program enabled us to better understand the potentials of the technologies, sometimes to contribute to specify them and design new tools, and above all to gain new knowledge on how group creativity works, and how to increase its performance.

For several decades, the brainstorming method has helped many teams to structure their creative endeavors and has provided a framework to study collective creativity for many researchers throughout the world. As soon as in the 80s, electronic brainstorming systems were used to share and capitalize ideas in large groups, sometimes in co-presence, sometimes remotely, and even asynchronously. Effective in many respects, this tool was nonetheless pointed out to be detrimental to group membership and sense of belonging, which is a source of social loafing and lower engagement in the creative task.

To combine the advantages of a digital platform and of a convivial setting, we studied the use of interactive tabletop systems for brainstorming around the table and rebuilding group awareness. This research led us to better understand the importance of social and motivational factors in group creativity and inspired us the design of several original interfaces to optimize production, sharing, and visualization of ideas. However, the reliance on synchronous collocated collaboration paradigm might appear as a limitation of this technology for group creativity. Companies seeking to develop their teams' creativity also need flexible tools supporting remote collaboration. Hence, the challenge emerged to find a tool supporting remote collaboration and group identification at the same time.

Such a tool was found in the form of avatar-mediated brainstorming and gave rise to a series of experiments confirming the potential of this technology. Avatars have the advantage of triggering self-perception mechanisms that may positively impact creative processes in multiple ways: Anonymity and the use of carefully chosen avatars may reduce self-censorship and social loafing, to the benefit of creative performance and innovation strategies of companies. Avatars sharing social identity cues can help group members focus on team's issues and challenges, and create social laboring. They can also be used to infuse new dynamics, promote a new viewpoint, and change routines (e.g., hierarchical asymmetry, interpersonal relations, leadership) among regular co-workers. All these factors seem likely to help individuals develop their creativity and support innovation processes in organizations.

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