Bounded Creativity in Design Science Research

Completed Research Paper

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Abstract

Although the importance of creativity in design science research projects has been widely acknowledged, efforts to facilitate this creativity while ensuring rigor, have been largely overlooked. This paper presents a more thorough understanding of creativity in design science research, balancing it with scientific rigor and addressing practical problems. With this objective, we analyze creativity within design science research and find that, although creativity is generally associated with "outside the box" thinking, creativity can also be effectively applied within the constraints of problem-solving. We develop a framework explicating how bounded creativity supports both, the design process, as well as the development of innovative artifacts. The framework is evaluated using a design science research project that develops a method for designing creative pervasive games. This research makes a novel contribution by demonstrating how creativity can be induced within the structure of the design science research methodology.

Keywords: creativity, design science research, rigor, bounded creativity, designing, theorizing, site-storming

Introduction

Design Science Research (DSR) strives for both rigor and relevance. However, there is a widely held belief that the rigor in designing diminishes the creativity and innovation of designs (and thereby its relevance). For Brooks (2010), DSR interferes with the epiphanies and conceptual integrity necessary for great designs. Iivari (2007) questions "whether systems development methods allow sufficient room for the creativity and serendipity that are essential for innovation." For Gacenga et al. (2012) design is a creative endeavor and "a concrete and rigorous design approach may stifle creativity, reduce agility and prevent flexibility." In the research reported in this paper, we demonstrate the ways in which these widely-held beliefs represent an incomplete understanding of the relationship between creativity and rigor in DSR.

DSR is an alternative to natural science. Whereas the latter aims at understanding reality, the former creates artifacts that serve human purposes (March and Smith 1995). DSR is largely anchored to Simon's *Sciences of the Artificial* (1996), which promotes professions that create reality in such diverse fields as architecture, economics, and information systems, even though this revised reality is artificial rather than natural. But for DSR authors in the peer-reviewed scientific literature, peer reviews too often focus on methodology and leave little attention to creativity. The work below provides a way for researchers to demonstrate that they have applied rigorous methods while creating an innovative artifact that might solve the examined problem.

DSR raises important issues with respect to creativity in design. Perhaps central in many of these issues is, by definition, the necessity to impose scientific rigor on the design process. Such scientific rigor implies scientific reliability and structure. Scientific reliability is a goal that involves a certain degree of repeatability. Faced with very similar design problems, we should expect that the scientific approach will yield a design and a designed artifact that are similarly successful regardless of the individual designers involved. The design outcome is made reliable by the scientific approach. In this way, the design science outcome is expected to be more predictable than other approaches to design. A fundamental way in which this reliability can be achieved is through the addition of structure to the design process. Examples of such structures include design theories, design science frameworks, and design science methodologies.

Walls, et al. (1992), provide an example of design theory structure that guides the design process for a class of design problems. They offer a design method that guides the designer, and a meta-design that frames the design parameters in such a way that the design outcome is predictable to the extent of the level of the design theory detail. Design science frameworks can add further scientific structure to the design process in design science. For example, Hevner (2007) observes a three-cycle view of DSR that relates the design activities, (including a build-and-evaluate design cycle,) both, to the environment and to knowledge, with a relevance cycle and a rigor cycle, respectively. Design science methodologies can add further scientific structure to the design process. Peffers, et al. (2007), for example, offer a complete process framework for conducting well-formed DSR. Their framework presents a process that may be initialized in several different stages, is iterative in order to provide learning paths as the design process unfolds, and includes the scientific hallmark in its requirement for careful attention to how knowledge is used and generated in the process.

While the addition of such scientific structures as theories, frameworks, and processes are intended to develop rigor and reliability, the impact of these structures on the ultimate designer is not always appreciated. Early work in design research developed controversy as concerns arose that designers in real design settings did not seem to apply such structures and frameworks in actual practice[1] (Cross 2007). This was consistent with observations in software engineering that human problems were unstructured and messy, and that design rationality was artificially imposed on design processes that were also unstructured and messy (Parnas and Clements 1986).

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[1] Design practice is distinguished from design science research as applying existing knowledge, while the latter contributes new knowledge to the existing knowledgebase. Niehaves, B. 2007. "On Epistemological Diversity in Design Science: New Vistas for a Design-Oriented Is Research?," International Conference on Information Systems, Montreal, Canada, pp. 1-13.

The design science research process is inherently iterative and its problem-solving goals provides rich opportunities for creativity, which are crucial to the process of design. Creativity is the generation of ideas that are both novel and useful, usually in response to a problem that needs to be solved (Csikszentmihalyi 1996; Root-Bernstein 1989; Root-Bernstein and Root-Bernstein 1999). It is defined as: "the ability or power to create-to bring into existence, to invest with a new form, to produce through imaginative skill, to make or bring into existence something new" (Merriam-Webster Online 2015).

In this research, we examine the notion of creativity as a complement to the rigor and practicality in DSR. In order to apply creativity within DSR, it is important however, that the design science research process incorporates the creativity in such a way that the analytical processes supporting rigor and practicality do not impede the novelty[2] of the solutions. Supporting and fostering this creativity does not mean that the designs will not be robust, practical, useful or effective. Rigor must remain as a hallmark of the design science research process. Accordingly, the creative processes need to be complemented with design knowledge and evaluated to identify the validity and reliability of creative designs. Additionally, creativity must be incorporated within the bounds or the structure of the design theories, design science frameworks, and design science methodologies.

Motivated by the objective of obtaining better understanding of how creativity unfolds in the design science process, this research addresses the following question:

> *How does creativity proceed in the activities of theorizing and designing in design science research?*

To answer this question, our research first explicates the concept of *bounded creativity* which is analogous to Simon's (1969) idea of *bounded rationality*. We then develop a *framework for incorporating bounded creativity into design science research* to examine and explain the role of creativity in different stages of the design science research process. This framework is applied to a real-world design science research project. The empirical example addresses the practical problem of devising a DSR-oriented method for designing location-specific games for mobile devices. The project results in the development of a general method and is evaluated naturalistically through its use in developing an artifact (a location-specific mobile-device-based game).

The framework for incorporating bounded creativity into design science research is a significant contribution because, although the importance of creativity in design science has been acknowledged, the specific nature of DSR creativity has not been well researched. In particular, the tension between scientific rigor and design creativity presents a unique issue for DSR. Our framework provides explains the nature of this issue and shows *how* to enable or facilitate creativity in design science projects.

This research follows a design science research approach, adopting the (Peffers et al. 2007) DSRM methodology for the development of the framework. The DSRM method consists of the following steps: 1) Identification of the problem, 2) Definition of the solution objectives 3) Design and development 4) Demonstration 5) Evaluation, and, 6) Communication. Following this method, in this introductory section we identify the problem and solution objectives of finding a way to balance creativity with scientific rigor in design science research studies. Next, through our examination of the theoretical background of creativity in design science research, we develop support for the problem definition and solution objectives. We develop the concept of bounded creativity in design science research to lay the foundation for the design of our framework. Following the definition, we describe the development of the framework that defines seven types of bounded creativity and ***how*** they are actualized in different kinds of design science research activities. A design science research project that develops a method for designing a creative location-based educational game as well as the game artifacts, serves as demonstration and a proof-of-concept evaluation of the framework (Nunamaker and Briggs 2012). A discussion is provided on how to incorporate the various aspects of bounded creativity into DSR, the implications of this research, and directions for future research. Finally, this manuscript serves as the communication of our research results.

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[2] Novel or new refers to, but is not limited to something completely original or never seen before. We include all forms of novelty including "original, adapted, and variant" Pahl, G., and Beitz, W. 2013. *Engineering Design: A Systematic Approach*. Springer Science & Business Media.

Theoretical Background

"Creativity" is derived from the Latin "*creare*", which means to create. Since its beginnings in psychology with Guilford (1950) in the fifties, creativity has had a rich history in fields such as psychology, education, clinical research, neuroscience, and sociology (Sternberg 1999). In the organizational literature, creativity has been defined with respect to the novelty of outputs such as product, process, the creative person and the situation, as well as how these different components might interact with other products or ideas (Woodman et al. 1993). It is commonly characterized as a cognitive process that deals at the level of the individual in the generation of creative ideas, and at the process level in the generation of creative artifacts (Greene 2002). Both of these aspects of creativity are intertwined and somewhat difficult to unpack within the context of the design science research process. This is because the outcomes of the design science research process are driven by the knowledge and creativity of the designer(s). Although the presence of creativity has long been recognized in design science research, it is largely taken for granted and rarely described in detail in design science research papers.

Creativity in Design Science Research

The core objective in design science research is to develop novel and innovative artifacts to solve real-world problems, and to yield meaningful contributions to design *and* science. The creative aspects of designing and problem-solving are the very essence of design-science research. Creative problem-solving (Newell et al. 1959) occurs when:

- The problem is vague and ill-defined
- The thinking is unconventional (requires modification or rejection of previous ideas)
- The thinking requires high motivation and persistence
- The product of the thinking has novelty and value

Creative problem-solving can yield a wide spectrum of solutions and knowledge outcomes, ranging from the more abstract (such as theories), to the more concrete (artifacts such as models, methods, and instantiations) (Baskerville et al. 2015). Design science research outputs span multiple levels of abstraction ranging from instantiated artifacts at a local level, to methods, models, and mid-range theories, to grand theories (Baskerville et al. 2015; Gregor and Hevner 2013). Different kinds of knowledge and mental faculties have been found to align with different kinds of activities, such as analytic processes for artifact construction activities and synthetic processes for theorizing form of activities (Owen 1998). Does this mean that creativity may be different in construction of artifacts versus in the development of theories? To address this question we examine the literature on creativity in designing artifacts and creativity in design theorizing.

Creativity in designing artifacts

Although it is widely recognized that creativity is crucial in the design of an artifact (Gregor and Hevner 2015; Hevner and Chatterjee 2010; Hevner 2007; Iivari 2007; Lee et al. 2015), there is little guidance in the information systems literature on how to incorporate creativity (Offermann et al. 2009). Still, it can be argued that artifact development is inherently creative (Hevner et al. 2004; March and Smith 1995). Progressing from an intuitive thought to developing an artifact requires creativity to be applied in the following manner. For any artifact to be designed, there exist criteria that must be met (e.g., principles, practice rules, procedures). Then, the designer must abstract from these criteria by relying on his or her creativity. Creativity involves the ability to produce novel and useful ideas (George and Zhou 2007). A set of principles e.g., Markus et al. (2002) can be followed to create an artifact. The heuristic nature of arriving at the resulting design outcome, however, requires a revisit to the criteria and possible iteration. Iivari (2007) notes that DSR artifacts hold, "more space for creative imagination, since they are not assumed to describe or explain any existing reality".

Creativity in design thinking and theorizing

Based on an in-depth study Johansson ‐ Sköldberg et al. (2013) distinguish between five different types of designerly thinking, that each demands different types of creativity: (1) When design is the creation of artefacts (Simon 1969), the creativity needed is in the construction of the artefact. (2) If design thinking is about reflective practice (Schön 1983), the creativity will be in the depth of the reflection and in choosing different viewpoints for reflection. (3) When design is about problem-solving (Buchanan 1992), the creativity goes into understanding the problem causes and effects. (4) If design is a way of reasoning and making sense of things (Cross 2006; Lawson 2006), or (5) is in the creation of meaning (Krippendorff 2006), then creativity will be in the sense-making.

In the DSR literature, creativity is implied within the context of theorizing , or inventiveness (Gregor and Hevner 2015). The process of design theorizing has been described as operating between an abstract and instance domain (Kuechler and Vaishnavi 2012; Sein et al. 2011). Design theorizing is deemed to be a creative and generative process involving intuition. Creative thinking is often characterized by a serendipitous quality when engaging in the following activities: abstraction, solution search, de-abstraction, and registration (Lee et al. 2011). Creativity can support the induction and abduction necessary for theory building (Gregor 2009) as well as "sense-making" that is essential for theorizing (Weick 1989). Although creativity and imagination are essential to the process of sense-making, Weick (1989) notes that, although success can never by *guaranteed,* the chances for success can be increased through "disciplined imagination". According to him, imagination involves introducing "deliberate diversity" into problem formulation and generation of alternatives and identifying the criteria to select alternatives. Discipline involves consistency in applying rules for evaluating alternatives.

Bounded Creativity

Hoegl et al. (2008) discuss two schools of thought within the creativity literature. The first line of thinking advocates a "thinking outside the box" approach, whereas the second line of thinking advocates an "inside the box" approach to creativity. These two schools of thought have also been described as the *Neo-Darwinian* and the *Neo-Lamarckian* approaches to creativity respectively (Johnson-Laird 1993). The "thinking outside the box" approach exemplifies unbounded randomness and advocates the generation of "hundreds and potentially thousands of unconventional strategic ideas" (Hamel 2001). The multitude of ideas is winnowed down to finally arrive at a few outstanding ideas. The thinking outside the box form of creativity suggests that "quantity breeds quality". This approach to creativity, also referred to as "divergent thinking" (Thompson and Leo 2003), involves the generation of multiple disparate answers to a given problem (Amabile 1988) and can be especially helpful when creating multiple models of options that might not have a single, optimal solution (Hovorka and Auerbach 2010)[3]. Divergent thinking is associated with fluency, flexibility, originality, elaboration, (Guilford 1977) and transformational abilities (Guilford 1983). Divergent thinking is consistent with imagination, provocation, unstructured syntheses, serendipitous discovery, and answers that break with conformity (Müller-Wienbergen et al. 2011). Divergent thinking can be promoted through techniques such as brain-storming (Osborn 1957).

Some of the challenges in thinking outside the box are that one must constantly find ways to increase the number of alternative ideas, and further, find efficient ways of separating the promising ideas from those that may be less promising (Nalebuff and Ayres 2004). It has been found that the very large and unbounded set of ideas generated through open-ended brainstorming, often result in obscuring the ideation process, and that randomness and irregularity impede creativity (Brown et al. 1998; Connolly et al. 1993). These disadvantages have led to the idea of "thinking inside the box." Cognitive psychology and research in creative cognition has shown that thinking within a frame of reference enhances the creation of new ideas (Hoegl et al. 2008; Ward 2004). Building upon established concepts in cognitive psychology (encoding/retrieval, analogical thinking), this school of thought argues that individuals are more creative when limited by constraints than when faced with a 'blank slate' (Finke et al., 1992). The idea of creativity

[3] While "outside the box" thinking is normally associated with divergent thinking, we distinguish our use of "inside the box thinking" from convergent thinking. Convergent thinking is generally associated with deductive generation of a single, concrete, accurate, and effective solution Guilford, J.P. 1967. *The Nature of Human Intelligence*. New York McGraw-Hill.

within constraints was examined within the theory of computational creativity (Johnson-Laird 1988). A similar idea has been termed as *structured ideation* where it was found that unbounded methods led to less successful product innovation than products generated with a more structured thinking approach involving ‘creativity templates’ (Goldenberg and Efroni 2001; Goldenberg et al. 1999). For example, Moreau and Dahl (2005) provide evidence from consumer marketing that input constraints encourage more creative processing.

Runco (2003) and Cropley (2006) provide a good discussion on the joint role of divergent and convergent thinking. We define this notion of thinking inside the box as ***bounded creativity***. This term was first employed by Brown and Cagan (1996) within the context of grammatical design, which, while restricting the design space, did not limit creativity in the resulting design. Support for the idea of bounded creativity can be found in the notion of *creative cognition* (Finke et al. 1992). Finke et al.’s (1992) Geneplore model “proposes a ‘function follows form’ approach in which individuals retrieve from memory existing knowledge frameworks, so-called ‘pre-inventive structures,’ which are then re-combined given the constraints of the task at hand” (Hoegl et al. 2008, p. 1385). Another example of thinking that does not “make a creative leap,” but rather continues to stay within, or close to the box, is the idea of *near analogies* (Ward 2004). An illustration of bounded creativity can also be visualized in theorizing, through Weick’s (1989) idea of *disciplined imagination.* Weick (1989) notes that the discipline in theory development from “consistent application of selection criteria to trial-and-error thinking” working alongside the "imagination" in theorizing through deliberate diversity introduced into the problem statements, thought trials, and selection criteria.

This raises three important considerations for explicitly incorporating creativity in design science research.

- In design science research, a bounded creativity approach will be more conducive to generating novel outcomes.
- Creativity is relevant for both artifact development (designing) and theorizing.
- Different types of constraints may bound creativity in designing artifacts and creativity in design theorizing.

Therefore it is important to identify and explicate: 1) *what* the different types of constraints are that bound creativity; and 2) *how* different forms of bounded creativity are materialized during the design science research process.

Framework for Bounded Creativity in Design Science Research

Figure 1 presents a proposed framework for incorporating bounded creativity into design science research (inspired by Owen 1998). It distinguishes between the realm of theorizing on the right side and the realm of designing on the left side. On each side there is a generating process at the top (generating theory or artifacts), and a consuming process at the bottom (applying artifacts or theory). The framework recognizes that: 1) in design science research there is a (wicked) problem to be solved; and 2) addressing the problem requires artifact development, as well as, a contribution to theorizing (Hevner 2007; March and Smith 1995; Owen 1998). The framework explicitly represents the role of bounded creativity in both of these aspects by: 1) acknowledging that there are different forms of creativity at different stages of design science research; and 2) recognizing that the role of creativity does not diminish the rigor with which the research is conducted.

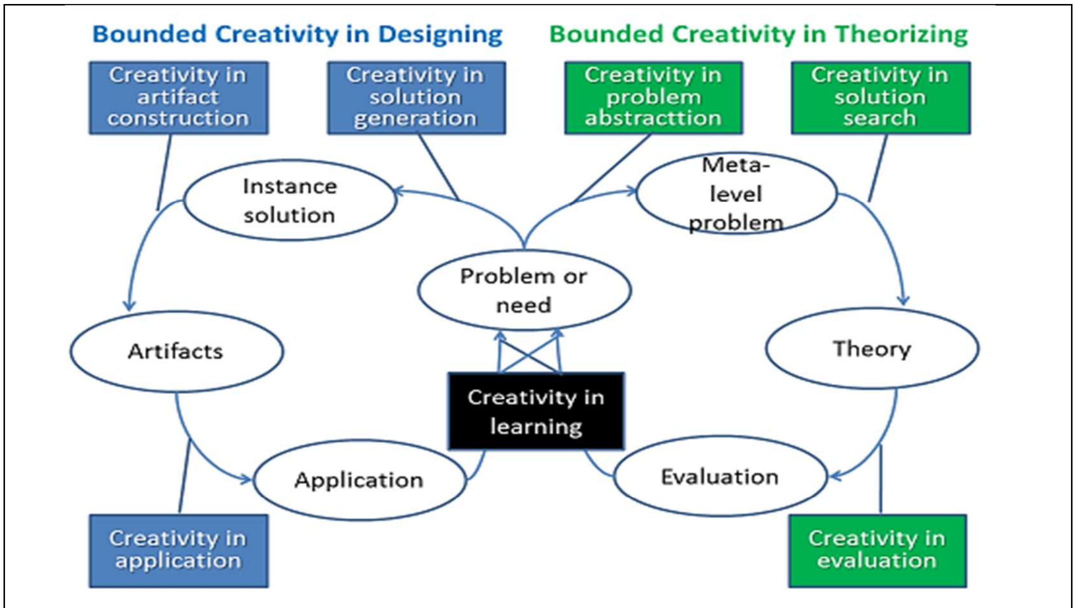

Figure 1: Framework for incorporating bounded creativity into design science research

Bounded Creativity in Designing

From the design science research problem, an instance design solution is generated, resulting in artifacts (the resultant 'Works') that solves the problem. During this process, learning takes place. Only in a rational engineering model could this be seen as a simple waterfall-like process (Brooks 2010). Minimally, the process from problem to making a design that works requires a search "through large combinatorial spaces" (Simon 1969). Identifying a starting point in the problem may not be easy because sometimes the challenge is to identify the exact problem or its boundaries (Clegg 1969). Furthermore, it is sometimes a matter of complexity because "there are more variables … than can be represented in a finite model" (Schön 1983). The process of applying a design to solve the problem or fulfil the need is neither simplistic nor straightforward. It may even require iteration; "both the formulation of the problem and ideas for it solution …" (Dorst and Cross 2001, p. 435). As a result, all activities in designing require explicit kinds of bounded creativity.

- *Creativity in solution generation* requires many ideas but also adherence to the limitations and boundaries of the solution space. For example, Brooks (2010, p. 297-312) shows that even a relatively simple activity such as a kitchen remodeling involves many considerations of the boundaries of the problem as well as the generation of many ideas.
- *Creativity in artifact construction* needs construction and quality within boundaries. This requires designing the attractiveness and affordances of the artifact (Norman 2002) where affordance should be understood as whether the user perceives that some action is possible. For example, a knob on an artifact affords (the perception of) twisting, a cord hanging from the artifact affords pulling, and a button on the artifact affords pushing the button. Thus 'quality within boundaries' is closely related to understanding the perception of users and the conventions respected within the user group[4].
- *Creativity in application* requires consideration of the people, environment and idiosyncrasies of the situation. Applying creativity may also involve a translation to the situation (Czarniawska and Sevón 1996). For example, an artifact that will be used by employees with little technology

[4] Norman's discussion on boundaries and conventions is found at: http://www.jnd.org/dn.mss/affordances_and.html

background might require a different kind of interface than when the artifact is going to be used by an employee that will use it daily for many hours.

Bounded Creativity in Theorizing

Theorizing is the core activity in Design Science Research with either a "Grand Theory" or a "Nascent Theory" as an outcome (Gregor and Hevner 2013). Theorizing encompasses meta-level problem, theory, and evaluation (Lee et al. 2011). For these activities the following types of (bounded) creativity are required.

- *Creativity in problem abstraction* is bounded by what knowledge can be generalized from the problem solution. This generalization can take different forms; from data to description, description to concepts, and description to theory (Lee and Baskerville 2003).
- *Creativity in solution search* is bounded by the abstracted problem and understanding the environment or situation in which the problem is defined and solved. It involves searching for components of a solution. Simon (1969) implemented this search as a "utility function" using declarative logic and "command variables." Note, however, that finding command variables equal to the components of the solution is an activity that Simon left to the creative process of "solution search."
- *Creativity in evaluation* is bounded by the use situation and the abstract problem. The challenge is to identify when the time is right to transition from the design of the idea to the construction of the artifact as well as when to involve the real users, with the real problem, in the real context (Sun and Kantor 2006; Venable et al. 2016).

Bounded Creativity in Learning

The two cycles in Figure 1 come together in learning.

- *Creativity in learning* is bounded by the designer's or the design science researcher's ability to learn. This can be simple, surface learning but still requires creativity when one realizes that it is necessary to change the mental model on which the initial understanding of the problem or need depends. Here, the bounded creativity requires an understanding that is more dynamic. For example, taking into account changes in the environment when evaluating and/or applying the 'Artifact or Works' or the 'Theory'. This critical process of deeper learning has been coined double-loop learning (Argyris 2000; Argyris and Schön 1996).

Next, we describe a design science research project tasked with the problem of designing a creative location-based solution, that underwent three design iterations to yield: a. an artifact which comprised a (set of) location-based educational game(s), b. a general method for creatively developing location-based educational games, and c. an explanatory design theory. Bounded creativity was apparent in the designing, theorizing, and learning aspects of this project.

The Famous Chalk Cliffs Case: DSR Project for the Design of Pervasive Location-Based Educational Games

This section describes a design science research project involving the design, development and evaluation of a novel location-based educational game. The problem was rooted in the failure of a generative design-oriented project that utilized prototyping to develop a location-based educational game. The generative design project, conducted as a series of unstructured, yet creative, design experiments, was unsuccessful in yielding a novel and innovative game. This raised the question of whether the lack of grounding in any form of a structured methodology contributed to the lack of success. It was not clear to what extent the use of a structured scientific approach would allow for creativity in the design process and in the design outcome. The research problem was, *how to incorporate the rigorous aspects of science (such as methodical approach, reliability, and repeatability) to a creative task without diminishing the creativity in a design setting*.

Problem Description

The Famous Chalk Cliffs case is a DSR project that involved multiple iterations of the DSR cycle to develop interactive, location-based mobile games. The design was conducted at the behest of an organization that we will refer to as the National Park Nature Agency and a geological museum at a location henceforth referred to, as the Famous Chalk Cliffs. This geographic location is famous for its chalk cliffs and dense woods leading to the cliffs. The National Park has a museum which engages the community and visitors with exhibitions inside the building, with guided tours of the area, as well as with educational programs for visiting school classes. The practical problem was to design location-aware, mobile games to promote on site learning of the area while engaging in physical exploration of the site in a novel way. The project was based upon the interaction of the visitors with the physical environment of the site using a combination of gaming and information technology.

Initially the design team[5] adopted a creative and generative design science research approach that would allow for the development of innovative and novel ideas without restricting the idea-generation. Since the process of coming up with the design was also a creative endeavor, it lacked a thorough problem understanding. Consequently the design team proceeded with the generative design-oriented project as a series of unstructured experiments using prototyping. The games designed from this initial effort were evaluated in naturalistic settings at the site (around the Famous Chalk Cliffs). The evaluation identified many shortcomings which were related, not only to the performance of the game, but more seriously pointed to deeper, design-related issues. For example, the environment or the physical site was not adequately incorporated into the design of the games, and the hotspots used to engage user players within the games did not align with the storyline of the games. Furthermore, the games were complicated and provided user players too many unstructured choices with few clear directions on how to proceed.

The root cause of the failure of this initial design cycle was the lack of a more methodological approach and suggests the need for balancing the creativity of the design with a more structured approach. This failure points to the need for some deliberation in regards to design science research and creativity, especially since design and creativity are considered as problem-solving activities (Simon 1969). Creativity helps or furthers the generation of a number of ideas or options, some of which may or may not work. If the creative design science research activities are to be evaluated, then bounded rationality becomes relevant in determining: (1) the consequences of the various options, and (2) the stage at which one should stop generating these ideas and options to avoid information overload and simplify design choices. On the contrary, this "logic of design" may have consequences in the repression of free creative thought.

The DSR cycles

Against this backdrop of seemingly oppositional considerations, and spurred by the initial failure of the project while following a more free-form, unstructured approach, the next iteration of the design project created a more structured and methodological design science research approach and undertook three iterations of research (Hevner 2007). In keeping with the duality of design science research regarding rigor and practicality, the project aimed to design a solution to the problem at hand, as well as proving a more generic theoretical approach for broader use. Thus, designing and theorizing took place in parallel; both in iterative cycles as shown in our Figure 1. Hence, there were three different types of contributory outcomes of the Famous Chalk Cliffs DSR project:

1. A design method, "Site-storming[6]", for designing creative, interactional location-based mobile games;

2. A comprehensive location-based game including multiple artifacts and games within the (overall) game; and,

3. An explanatory design theory for designing pervasive, site-based interactive games.

Overall, the design science research project comprised three iterations, that are summarized in Table 1.

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[5] The design team comprised a Steering Committee and a development team that included one of the authors.

[6] The notion of "site-storming" is based on the idea of brain-storming that draws on inspiration from the site or location

Table 1. Summary of the three cycles of design science research activities in the Famous Chalk Cliffs project

	Iteration 1	Iteration 2	Iteration 3
Summary of activities	Two games were designed using research into designing, but without adopting a structured design science research approach	A prototype version of a design method was developed for incorporating creativity into the design method. Using this method, a number of games were designed and evaluated. The game designed in previous iterations were improved and redesigned.	The revised design method was used for re-designing the game from iteration 1. The redesigned game was evaluated. Further, the design method is used to design a number of other games and re-design some previous games
Theoretical background	Design theory of pervasive games	Theories of pervasive game design, theories of site-specific computer games, theories of performance in play and games, embodied design, concepts of space, time, and players, other concepts such as rules, game artifacts, and game culture, and game affordances	Observations and learning from prior background, design science research literature; theories of game performance, performance requirements of site-specific games
Outcomes	Design artifacts comprised two location-based mobile games	Site-storming design method was revised Design artifact of mission-based gaming style of game-cards including mission cards, game cards, prop-cards and site cards Developed model for measuring the success of the performance of the design activity	Learning was abstracted into an explanatory design theory. Other design artifacts included 26 games
Evaluation	Evaluated through testing by 4 participants. Each of the games was evaluated during the development as well as ex-post.	Prototype of design method was used in a workshop by 6 participants to create new games. Cards were used to design scenario-based ideation activities Model was used to evaluate the more complex of the two games designed in iteration 1. Evaluation was conducted on multiple criteria including affordances and constraints of the game and the environment The method was further evaluated through 3 more design sessions, designing a new game, and a comparison of two games, one with, and one without, the use of the game	Evaluation was conducted in two ways: 1) by applying the design method for the redesign of the game and, 2) through the application of the method in workshop on pervasive game design. Further, the redesigned game was intended for a real client and therefore evaluated by two sets of users. First it was evaluated by student participants. Next it was evaluated by potential users.
Learning	Design task was focused more on the use of the technology than the game environment Design activities had a large number of unknown / unclear requirements. Under these circumstances, adopting a more structured approach would be helpful; however, at this stage it was not known, to what extent the structure would impede creativity of the process and the artifact	The design task demonstrated weakness in site-based design. Demonstrated the need for integration between designer and design environment during the process of designing. It also highlighted different types of creativity when designers worked independently and when they worked in groups Another learning was the need for the designer to be more situated within the design environment	When evaluating designs of performance based artifacts such as games, there are two levels of evaluation required: design pervasiveness and performance pervasiveness. Therefore evaluation must include both, evaluating the artifacts for efficiency and utility, and the success of the design science process

Bounded creativity in the Famous Chalk Cliffs project

Although creativity is generally associated with divergent thinking and openness to experience (McCrae 1987), whereas structure is generally considered to confine thinking, we found that unrestrained thinking may inhibit concentration/focus on the problem, produce a large number of unviable ideas and could increase the duration of the design cycle. In the Famous Chalk Cliffs project, the importance of structure was very important to balance the creativity, and in fact, produced a larger number of viable designs. Specifically, the structure provided the following advantages: 1. Structure facilitated knowledge sharing and knowledge transfer. More specific knowledge led to focusing the creativity on more relevant aspects of the design, 2. Structure improved focus which increased the speed with which the more useful ideas could be generated 3. Structure was provided through templates and examples which made it possible to focus on the design requirements. 4. The structure made it easy to transfer knowledge to new-comers to the design and made the requirements clearer for them to understand.

Bounded Creativity in Designing

In the first versions of the game the user-players found it to be boring to play, and not really taking advantage of the location (the Cliff and the surrounding Forest). This points to a lack of a thorough understanding of the problem or need for playing a game; exactly the boundary that was identified in Table 2 for ***solution generation creativity***. Here the first iteration of Theorizing was helpful. The need to accommodate site constraints and affordances and the condition that humans are attracted to something fun was identified as requirements. Furthermore, these requirements helped generating a creative solution where the virtual part of the game fit with the site, where the user-players' locomotion affected the game, and where the site (Cliff and Forest) supported the narrative.

The two last-mentioned characteristics nicely illustrate the ***artifact construction creativity*** that was needed. In the first versions of the game only a simple GPS tracker was used. However, as mobile phones capable of tracking and responding to locomotion became regularly used among 12-15 year olds (the main target group for the game), the creative idea of using this locomotion detection ability in game emerged. This further illustrates the boundary here, namely that of quality. One definition of quality is the fulfilment of expectations (ISO/IEC 25010:2011[7]). In this case, the teenagers to which the game was aimed, clearly had well-developed expectations of mobile devices based on their daily use.

Translating to the situation and adapting to the idiosyncrasies of the situation are the two boundaries in Table 2 for ***application creativity.*** In the case of the Geo-game this was in focus all the time because it was requirement to adapt to the natural environment with Cliffs, Old Trees, Beach, and Hills. There was, for example, a part of the forest said to be a place where Trolls lived. And the very old trees in the same part of the forest looked "ghost-like" and "troll-y". Thus, the adaptation of the game, taking into account this location (situation), were adding a troll-oriented part to the game.

Another example of both artifact construction creativity and application creativity was that it was more fun and rewarding for the user-players to locate the hotspots of the game using sonification (non-speech audio), rather than a physical map.

Bounded Creativity in Theorizing

In parallel with the Geo-game the Site-storming theory and method was developed. In fact, this was the core contribution of a PhD thesis of one of the authors. Before venturing into the PhD study, the researcher had studied computer science and had become interested in performance design. Over the years the researcher developed a number of smaller games some with success and some not. This was done without a structured approach. After the first Geo-game was developed and failed, it was realized that some design theorizing was needed. After consideration of several options, it was decided to use explanatory design theory (Baskerville and Pries-Heje 2010). The explanatory design theory explains why a generalized set of requirements is satisfied by a generalized set of object features. The major challenge that required ***problem abstraction creativity*** was to abstract generic requirements.

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[7] http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=35733, retrieved May 7, 2016

The project ultimately was successful in identifying the following four conditions and capabilities:

- *Human thinks traditionally unless otherwise provoked (condition)*
- *Accommodate site constraints and affordances (capability)*
- *Humans are attracted to fun (condition)*
- *More ideas for the time invested if individual and group work is combined (capability)*

The search for solutions at the more abstract or theoretical level, involves generating ideas for solution of class of problems and ***solution search creativity***. The study identified the general problem as "finding ways to induce creativity within a structured design process". This was a very general problem that could potentially have led to an almost unfettered search for ideas. The bounded aspect of creativity, was to come up with a fairly limited number of ideas for promoting creative thinking while still keeping the problem tractable. The solution search in this study proceeded to use the explanatory design theory suggested by Markus et al. (2002) to bound the solutions by bounding problem. As a result, the following *four solutions* were identified and articulated as the generic site-storming method:

(1) Since humans think traditionally unless specifically challenged, the first solution was to provoke creative thinking using brainstorming. (2) The second requirement was to account for the physical environment. For the generic solution this meant matching the system design to the constraints and affordances that were delivered intrinsically by the physical environment. Therefore location based design was incorporated into the general solution. (3) The third general problem was to make the games engaging and for this, the general solution was to promote fun and pleasure for the designers so that this fun and pleasure could be translated into the design of the actual game. (4) Finally, the fourth general problem was to generate maximum number of viable ideas within the constraints of time. For this the general solution was to combine individual and group design activities to maximize the development of creative ideas within given time constraints.

At another theoretic level (cf. Gregor and Hevner 2013, Table 1, Level 3), a solution was constructed; namely a specific approach, the *site-storming method* that embodies each of the generic principles. This method included an idea-generation method for outdoor computer games (the genre called *pervasive games* or *site-specific games)* and a design process meant to engage and provoke creativity by using the structure of a *design-game* to force divergent thinking. In the concrete it included 32 mission cards, 16 game-type cards and 8 prop cards. Further, the method emphasized physically locating the game designer on and within the site where the instance-game (and thus the IS-artifact) was to be operated. The design process itself was created to be fun because the design approach occurs within a game – it is a playful activity in a game setting. Incorporating creative thinking individually and in groups by the means of competition in play; where the cards are used in turn – resembling a card game.

As soon as the solution search come to an end and some components of a solution – as the four principles mentioned above or the site-storming card game – are in place, the design theory must be evaluated. To do so, ***evaluation creativity*** is needed. Here the creativity is bounded by risks, by the ability to come up with an evaluation strategy (Venable et al. 2016) that for example includes access to real users with real problems in their real context. Another form of evaluation creativity occurs in deciding the evaluation criteria because it is difficult to prove if the artifacts created will be successful. In this case, the success of the developed artifacts was the approval and use by the users or game players.

Both Designing and Theorizing

Both designing and theorizing are cyclical and involves iteration ending with learning. For that ***learning creativity*** is needed. In the first Geo-game – (that was not considered a good game by the 12-15 year old teenagers - that were the main target group), – the learning was, for example, that something more fun and appealing was needed. For the theorizing part, a great deal of creativity went into designing the cards for the card-game. However, the learning, (including questions such as, "Did the cards work? Did they provoke creative thinking? Did they engage the group?"), was very difficult and clearly bounded by the ability to get behind the superficial first-order learning.

Discussion

Our conceptualization of bounded creativity in design science research helps explain how design scientists engage creatively to produce outcomes such as artifacts and theory. This act of creating is somewhere inside that black box we label "designing" or "theorizing". In DSR, creativity is innately different than many other kinds of creative activity because of the scientific rigor that constrains it. Indeed, DSR is widely noted for developing *prescriptive* outcomes, a term that associates the practical outcomes of DSR with the practical outcomes of other science-based professions like medicine. Our framework (Figure 1) elaborates how DSR prescriptions proceed, e.g., prescriptive theories (Gregor 2006; Walls et al. 1992) and prescriptive statements (Gregor 2006; Kuechler and Vaishnavi 2008). Such prescriptions integrate normative and descriptive theories into design paths (Walls et al. 1992), and provide a transition from theoretical statements to specific techniques (Kuechler and Vaishnavi 2008). They provide a recipe that can precipitate a kind of artifact and can form imperative specifications, for example, "A system of type x should include functions a, b and c." (Gregor 2006, p. 621). Our framework explains how the process of prescription depends upon scientific practices (that produce constraints and boundaries on the activities) and on the creativity (that produces new affordances that enable satisfying outcomes).

Bounded creativity reveals how constraints energize and motivate the performance of creativity rather than only inhibiting it. The enactment of this bounded creativity lies in the activity of prescription. In DSR, prescription is the act of transforming a constrained design environment into one with sufficient affordances to satisfy the goals. Such a transformation requires, not only a scientific search of the various possible configurations of the available components, but also a creative search within the designing scientist for the vision that reveals recondite components and configurations. The transformation from a constrained design environment to an affordance-rich environment enables a creative design scientist to discover the design paths (Walls et al. 1992) available in the environment that can lead to satisfactory outcomes. In this way, prescriptive DSR statements meld art and science in producing and employing creative new affordances within the boundaries of a practice that is grounded in science.

The main contribution of this research is the *Framework for Creativity Inclusion in Design Science Research*. The framework is useful for: 1) understanding the importance of bounded creativity with respect to both developing and theorizing; and 2) describing how bounded creativity can be explicitly incorporated and evaluated (and used iteratively). Table 2 summarizes seven types of bounded creativity, and describes restrictions that can bind such creativity. These seven creativity types, along with the guidelines for applying them, should be useful to design science researchers for explicitly incorporating and evaluating creativity in their projects. They should also help in devising more creative general methods for designing.

Table 2: Seven types of bounded creativity in Design Science Research

Creativity Type	Description	Boundedness / restrictions
Bounded Creativity in Designing		
Solution generation creativity	Generate ideas for the solution to a problem or fulfilment of need	Bounded by the understanding of the problem – what the problem *really* is
Artifact construction creativity	Construct with quality, attractiveness and affordances	Bounded by the need for quality by different stakeholders
Application creativity	Apply within the context of people, environment and idiosyncrasies of the situation	Bounded by idiosyncrasies of the situation and the designers' ability to address the situation within these bounds
Bounded Creativity in Theorizing		
Problem abstraction creativity	Abstract the instance problem to a class of problems	Bounded by the ability to abstract and the knowledge of the researcher
Solution search creativity	Generate ideas for solution of class of problems	Bounded by the understanding of the abstract problem
Evaluation creativity	Formative and summative evaluation	Bounded by risks, access to real users with real problems in real context
Both Designing and Theorizing		
Learning creativity	Learn from application or evaluation	Bounded by the ability to learn in depth

Guidelines for Applying the Bounded Creativity Framework

For each element in this framework, a design science researcher can engage their creativity by attending to the fundamental aspects required for prescribing the transformation of their bounded situation to an affordance-rich situation. These activities include four discovery engagements. In this case, the discovery engagements involve a *scientific search* of the various possible configurations of the available components plus a *creative search* within the designing scientist for the vision that reveals recondite components and configurations.

- ***Engage the Aim.*** Prescription is the overarching goal in a creative design science activity. Design scientists aim to discover a set of prescriptive statements.
- ***Engage the Boundaries.*** The boundaries provide the energy that propels creativity in design science. Design scientists discover and understand the constraints in their situation. Some constraints are imposed by science, others imposed by aspects in the design. Value the role of constraints in shaping creativity.
- ***Engage the Vision.*** Vision arises from within the design scientist. It is an invaluable internal trait of the design scientist. Design scientists use it to discover affordances, seen or as-yet-unseen, possible within the boundaries
- ***Engage the Design Path.*** The design paths avoid the constraints and enlist the affordances. Design scientists discover design paths and select the one that most ideally uses the affordances and navigates through the constraints to satisfactory prescriptive statements.

Our research contributes a bounded creativity framework and process that is highly specific to design science research. There is widespread recognition of the importance of creativity in design science research (Gregor and Hevner 2015; Hevner and Chatterjee 2010; Hevner 2007; Iivari 2007; Lee et al. 2015). Nevertheless, most works provide limited guidance on *how to incorporate* creativity in the design science research process. In most of the seminal works on DSR methodology, although the importance of creativity is acknowledged, the primary focus is on scientific rigor. Two books on DSR (Hevner and Chatterjee 2010; Vaishnavi and Kuechler 2015) each devote a chapter reviewing existing creativity techniques available to the design science researcher. These efforts, draw on creativity processes that are similar to creativity in other kinds of design settings. Our research indicates that this assumption might not exactly hold in well-formed design science research settings.

The gap in the current literature is the recognition that the tension between the rigor of science and the leniency of creativity in design demands a different framework and different creativity processes. Most notable in our framework is the distinction between creativity in theorizing and creativity in artifact designing. Our research contributes a framework in which the analytical component leads directly to a process component. The seven types of bounded creativity present in the analytical framework guides four creativity engagements (aim, boundary, vision, and design path). The result is a uniquely consistent framework to both understand and practice creativity in design science research.

This research contributes an exposition that specifically addresses the role that creativity played in an empirical study of the DSR process. We describe how creativity was actually applied in the design science research process. Most of the works dealing with creativity in DSR offer abstract observations based on non-DSR literature. In the few empirical papers that mention creativity, it is a quality that is left to remain implicitly embodied in the outcomes. Much of the discussion focuses on the scientific rigor of the study, or the actual outcome, such as the design theory or the design artifact. Our research is very nearly a unique empirical study of creativity in DSR.

Finally, our research extends the literature on bounded creativity to incorporate its adaptation for design science research by introducing a new, unique boundary on creativity and scientific rigor. Since creativity is most often studied in disciplines of art, scientific rigor has not been noted as a potential boundary condition and its treatment is heretofore unstudied. This research thus extends the literature on creativity, while providing a novel framework to understand, evaluate, and describe the different types of bounded creativity found in design science research.

Conclusion

Recognizing the role of creativity in both artifact development and theorizing, this research has presented a *framework for incorporating bounded creativity into design science research*. The framework identifies seven types of bounded creativity, each of which is defined and illustrated. Four discovery engagements were identified that deal with aim, boundaries, vision, and design path. The results were applied to a game development design science research project. This work contributes to design science research by analyzing and defining the role of bounded creativity in both theorizing and artifact development. The overall significance of bounded creativity is that it juxtapositions creativity and scientific rigor. The framework specifically addresses "how" to incorporate creativity in design science research projects, making explicit an area of design science research that is acknowledged in the literature, but overlooked in reported descriptions of such projects. In a scientific peer reviewed setting where authors are often confronted with reviewers' questions on the methods underlying the decisions for various artifact functionalities, such question leave little room for creativity. Certainly, the pursuit of DSR meta-requirements and the resulting design principles demands rigorous methods, but the implementation of an instantiation of the design principles is still replete with creative possibilities. These include the adaption of the artifact to the usage context, the users and the environment. It is often a process of creativity, or more precisely of bounded creativity. Our framework provides a way for researchers to demonstrate that they have applied rigorous methods while creating an innovative artifact that solves the defined problem. In this research, the framework was applied to a research project that designs creative location-based educational games. Future research will apply the framework to other applications and explore the role of unbounded creativity.

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