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INDUCING CREATIVITY IN DESIGN SCIENCE RESEARCH

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Abstract. The importance of creativity is widely acknowledged in design science research, yet there is a lack of understanding of *how* this creativity is manifested throughout the design science lifecycle. This research examines the effects of the boundaries that are placed on creativity by the particular design science research method used throughout the design cycles and iterations. The progressive and methodical nature of design science research imposes structure comprising rational and creative, boundaries on the problem-solving process. These boundaries determine *when* and *where* to iterate to a specific previous stage. A set of iteration indicators, derived from the literature on creativity and bounded rationality, provide the design researcher with guidance on how to recognize that the time for iteration is nigh. These indicators are evaluated using a case study for the design of creative, pervasive games.

Keywords: Creativity, Design Science Research, Rigor, Bounded Rationality, Bounded Creativity, Designing, Theorizing, Site-Storming, Iteration Indicators.

1 Introduction

Design Science Research strives for both scientific rigor and practical relevance. Scientific rigor implies careful attention to a design science method, which is a key aspect of the science of design [1]. The most prominent design science methods incorporate cycles or iterations within their stages, with a widely held assumption that deciding *when* and *where* such iteration should be decided is intuitive: reasonably obvious and simple. At most, the decision is anchored to the "nature of the research venue" [2, p.

56]. Research into imposing boundaries on creativity by design science research methods triggers interest in this issue. But how do we preserve the creativity that is so key to invention and innovation, while maintaining scientific rigor?

There is a widespread assumption that imposing method and rigor in designing generally diminishes the creativity and innovation of the designs produced, thereby reducing their relevance ([3] [4] [5]). Because these assumptions overlook the iterative and progressive way that rationality and creativity unfold under the rigor of design science research, they incorrectly assume creativity and scientific rigor cannot co-exist. The need to obtain a better understanding of the role creativity plays leads to the question:

How does creativity affect the activities of theorizing and designing in design science research?

The objective of this research is to explain the distinct nature of creativity in design science research and explicate its most obvious characteristics. Although creativity is generally associated with the researcher's intuitiveness, we propose that a design science research method progressively narrows the boundaries on both design rationality and design creativity. When these boundaries become so narrow that the creative aspects are left tedious and uninteresting, the design search must retreat to a previous stage to reopen the boundaries. Iteration is then partly a consequence of bounded creativity in design science research.

2 Theoretical Background

Creativity is a companion to rigor and utility. It is important to incorporate creativity into the research process so that the analytical processes supporting rigor and practicality do not impede the novelty of the solutions. But what of the possibility that creativity impedes the rigor or practicality? Creativity is necessary for designs to be robust, practical, useful and effective. But to preserve rigor, the creative processes must interact with design knowledge and satisfy evaluations that identify the validity and reliability of the results. Creativity must also be incorporated within the bounds or the structure of design theories, frameworks, and methodologies.

2.1 Bounded Rationality and Bounded Creativity

Bounded rationality recognizes that individuals and organizations are limited by constraints, such as knowledge of a problem, inability to fully conceptualize complex systems, and resources [12]. Decisions must be both satisfactory and sufficient; not necessarily optimal. Decisions only satisfice; they satisfy the aspirations represented by a problem [13, p. 30]. But design differs from decisions. Decision theory focuses on a choice among alternatives; design focuses on "the discovery and elaboration of alternatives." [12, p. 172]. The search aspect of design involves a series of incremental and progressive decisions, each of which sets a direction. Designers evaluate and compare possible design directions. From bounded rationality theory, it is not possible to consider all design directions and choose the optimal. Rather, each progressive decision narrows the boundaries placed on future decisions. It is a selective search through a "maze of possibilities" [13, p. 54]. Each decision selects a satisfactory solution. The search then proceeds to the next dimension, and so on. In design science, bounded creativity (the amalgamation of Simon's bounded rationality in design and bounded creativity in engineering) means that humans are limited in their ability to make perfectly creative designs. The design discovery process is a search through a limited range of progressively creative designs, so designs are satisfactorily creative rather than optimal.

2.2 Creativity

How is bounded creativity akin to or different from any other notion of creativity? The topic of creativity has had a rich history in many fields. Creativity is a cognitive process that operates at the level of the individual[1] in the generation of ideas, and at the process level in the generation of creative artifacts [7]. Both aspects of creativity are intertwined, and difficult to discern for design science research, because the outcomes are driven by the knowledge and creativity of the designer(s). Although the presence of creativity is well recognized, its process is largely taken for granted. At the core of the creative design process are iterations.

There are two schools of thought regarding creativity. *Thinking outside the box* exemplifies randomness and advocates the generation of many ideas, so that some good ones will appear [8]. *Thinking inside the box* is restrained by pragmatics, and similar to *structured ideation* [9, 10]. Creativity research also distinguishes *divergent* from *convergent thinking. Divergent thinking* is associated with fluency, flexibility, originality, elaboration, and transformational abilities [11]. Convergent thinking is generally associated with deductive generation of a single, concrete, accurate, and effective solution [12]. Divergent and convergent thinking may both be present in creative episodes, whether outside- or inside-the-box, but neither is analogous to bounded creativity. Thinking within a frame of reference actually enhances the creation of new ideas [13, 14]. That is, individuals are *more* creative when given operating limits [15]. This explains why creativity must increase as design decisions progress. Moreover, ideas or solutions must be effective [16]. Bounded creativity specifically addresses the operating limits of effectiveness in creativity.

3 Bounded Creativity in Design Science Research

A distinguishing attribute of science is its dependence on a scientific method. This means that design science research must also be characterized by its methodical approach to design, making the methodological approach one of the most distinctive operating limits in design science research. There are a variety of well-known methods.

[1] Although the terms creativity and innovation are often used as synonyms, creativity is usually attributed to individuals or groups, whereas innovation is attributed to organizations. Wang, C.-J., *Does leader-member exchange enhance performance in the hospitality industry? The mediating roles of task motivation and creativity.* International Journal of Contemporary Hospitality Management, 2016. **28**(5): p. 969-987.

E.g. Nunamaker et al. [17] framed a multi-methodological approach that centers system development within theory building, experimentation and observation. Walls, et al. [18] propose using a design method and a meta-design. Design science frameworks add further scientific structure to the design process (e.g., [2], [19]) For our purpose of illustrating how methods progressively create boundaries on rationality and creativity, we use a generalized model that contains the most common process steps. Figure 1 illustrates these steps, which, like most design science methods, are fully iterative. The general process involves steps that flow downward (large arrows). Any step can stop the downward progress and iterate back to previous steps instead (small arrows).

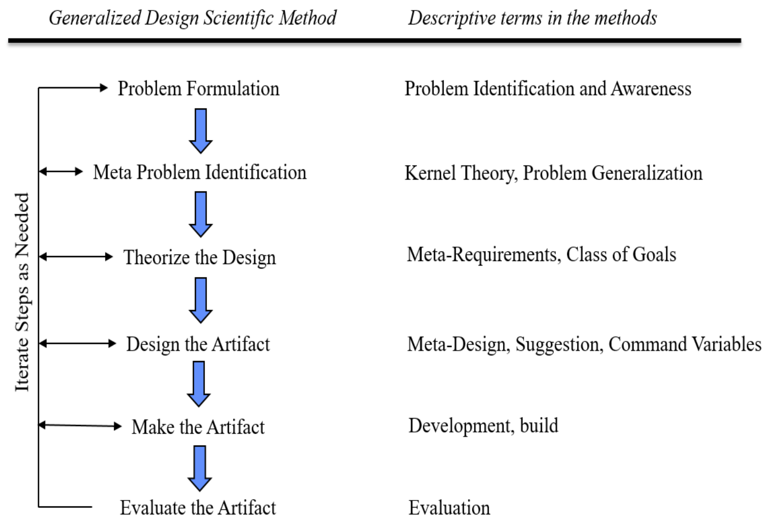

Figure 1. Generalized design scientific method

In addition to narrowing the progressive rationality and creativity boundaries on any unstructured design process, a design science method adds further structure and further boundaries to the design process. We are accustomed to considering such boundaries from the more functional perspective of satisfying requirements and achieving practical utility. Each step of the design process limits the range of possible design components or assemblies that can be invoked in the solution artifact from this point forward.

An important consideration is when to stop and when to continue iterating. From the perspective of bounded rationality, progress in a step can break down if there are no available design decisions that satisfice the design aspirations. In this situation, the functional requirements and practical utility have been made impossible by previous design decisions. The breakdown is an indication to iterate to a previous stage.

Bounded creativity exists to some extent in any design setting. Why is design science research any different? Because design science research aspires to the rigor of a scientific method. While such a methodical approach improves the reliability and the validity of the knowledge resulting from the design process, the methodical process introduces structural boundaries on the progression of the design decisions.

3.1 How problem formulation develops subsequent creativity boundaries and iteration indicators

Problem formulation can be creative in the sense that the available evidence about the problem is characterized by uncertainty. At this step, this uncertainty arises from evidence that is incomplete or inadequately understood [20]. Identifying a starting point in the problem may not be easy because sometimes it is difficult to identify the exact problem or its boundaries [21]. Such incomplete diagnostic evidence makes a completely deductive problem diagnostic process difficult at best. An abductive, creative leap may be required to move from this incomplete evidence to a diagnosis. As a design decision, the creativity boundaries can be wide at this step. In other words, the leap can be quite a big one.

Identifying the problem narrows the creativity boundaries moving forward. Note that each design decision within the current stage develops conditions that bound creativity at the next step. This thread helps in understanding how the creativity boundaries narrow from this design decision. The medical concept of misdiagnosis is an appropriate analogy; in business it aligns with fads and fashions [22]. Misdiagnosing a problem narrows the boundaries for the identification of the meta-problem, i.e., the class of problems to which the problem-at-hand relates. For example, if there has been an increase in the number of intrusions into the system, we might focus on evidence that our users are being careless. If instead we might focus on the evidence that the access control system is inadequate. Depending on how this evidence is interpreted, the design creativity boundaries at the next step (meta-problem) will narrow. If the users are careless, the meta-problem (at issue for the next step) will be bound to other human and social kinds of problems. If, instead, the access control system is diagnosed as inadequate, the meta-problem will be bound to software, hardware and technical systems kinds of problems. In the former, creativity will become bound to ideas about human resources. In the latter, creativity will become bound to ideas about technologies.

3.2 How meta-problem identification develops subsequent creativity boundaries and iteration indicators

This research deals with creativity. We are not identifying a new class of problems, but, rather, addressing a new class of solutions. In a design science research problem, creativity is involved in classifying a problem that has been formulated in the previous step. This task is complicated because “there are more variables … than can be represented in a finite model” [23, p. 79]. Because the boundaries are still quite broad at this stage (there are myriad problem sources), the limits of the designer’s knowledge about similar kinds of problems, or limitations of the designers’ domain knowledge may impose a rational boundary. If the designer has experience with similar problems, an inductive classification might follow, with a tinge of creativity in inventing a new class of problems. If the designer is familiar with classifications that cover the identified problems, a deductive classification might follow. However, if neither is the case, we need a creative leap to abductively classify the problem within some range that is within the designer’s field of knowledge. For example, if the problem is diagnosed as an issue of access control technology, and the designer's expertise is anchored to intrusion detection systems, there may be a creative leap to classify the technology problem as belonging to the class of intrusion detection problems.

Classifying the problem as one kind or another means it will have shared characteristics with other problems of its kind. The shared characteristics should encompass the aspirations the design will seek to satisfy. These characteristics, and their implied aspirations, will narrow the creativity boundaries for the step that follows: design theorizing. The design decision to classify the problem among a category of similar problems predefines the aspirations that will become the main constructs in the design theory. For example, if our security intrusion problem is identified as user carelessness, then creativity becomes bound to solutions for human and social problems. But do we classify the problem at hand as a cognitive problem or an affective problem? Are the users ignorant or indifferent? Do they not know or not care? If it is a cognitive problem, the aspirations might include changes in user behavior and new user experiences that change their knowledge and understanding. For an affective problem, aspirations might include aspiration changes in user behavior and new user attitudes that change their motivation. Deciding which class of problems is at hand is a design decision that will narrow the boundaries on the creativity that can be exercised in the next step, design theorizing.

3.3 How design theorizing develops subsequent creativity boundaries and iteration indicators

Theorizing is itself a creative act. For Weick [24], imagination is essential for sensemaking. Theorizing is improved through disciplined imagination, a bounded form of creativity in which creativity is bound to a consistent process. The 'discipline' in theorizing comes from the consistent application of selection criteria to 'trial and error' thinking and the 'imagination' comes from "deliberate diversity introduced into the problem statements, thought trials, and selection criteria that comprise that thinking" (p.516). Within the design science process, Weick's notion of a consistent process of disciplined imagination invokes a series of thought experiments. These experiments take the designer from the defined class of problems to the class of solutions and to the potential instance of an ultimate solution. Unlike some other forms of theorizing, design theorizing operates between an abstract and instance domain [25, 26]. For design theorizing, creativity can support the induction and abduction necessary for theory building [27], its inventiveness [28] and its "intuitive, blind, wasteful, serendipitous, creative quality" [24, p. 519].

Settling on a design theory further narrows the creativity boundaries for the next step, artifact design. It sets up the conceptual framework under which, and the vocabulary with which, the designers will make the main design decisions for the solution artifact. The framework will provide the kinds of components, features, functions, interfaces, protocols, etc. Because these are the meta-requirements for the ultimate artifact, the design theory determines the language and the grammar of the final artifact design. The boundaries constitute the criteria, such as principles, practice rules, or procedures that must be met by the artifact design [29].

For example, if we have decided that user carelessness is caused by indifference, perhaps protection motivation theory [30] would offer good grounds as a kernel for the design. Consistent with this theory, we might decide that a training program could provide the solution. The goal of this training program would involve motivating users to protect themselves from the losses. Based on this theory, the features would include building their appraisals of severe noxiousness the loss, their expectation of its likely occurrence, and their belief that the prescribed coping response is effective. These are the major constructs of the kernel theory. The design theory would involve translating this language and these concepts into an artifact (e.g., an educational program). Such a design theory now narrows the boundaries of creativity to a range that includes the use of training to build protection motivation in employees.

Creativity problems may arise at this step if the designer is unable to satisfactorily generate a design theory that addresses all the aspirations present in the given class of problems using the constructs implied by the shared characteristics in the class given in the previous step. A creative theory may be missing from those that satisfice the aspirations. For example, the possible theories may all seem commonplace and unsatisfying from a creative standpoint: the usual approach to problems of this sort. Where no interesting design theories are at hand, it might be assumed that the problem has been misclassified into the wrong kind of problem. Then the design process retreats to iterate the meta-problem identification stage in search of a less usual set of constructs and aspirations on which to begin the design.

3.4 How artifact design develops subsequent creativity boundaries and iteration indicators

Creativity in the design step becomes more narrowly focused on the specification of the ultimate artifact. It is crucial in the design of an artifact. The creative challenge is the production of both novel and useful ideas [31]. The design decisions at this step must be increasingly creative to fit the solution, the problem, and the design theory to one another. The step further invokes creativity and abduction because the focus is growing more practical. The designed solution must work to solve the practical problem. Still the design decisions must be made in a climate where the theory has narrowed the boundaries for consideration, even though there are myriad variables [23], yet uncertain evidence about the practical setting This uncertain evidence has not only involved incomplete or misunderstood information about the problem as formulated earlier, but also the difficulty in differentiating between the design alternatives at this step in designing [20]. Aspects of alternative designs can inhabit each other. Creativity is important in this step to ensure that the design fits within the theory's boundaries, operates within the practical criteria of the problem setting, and incorporates those aspects of the alternative designs necessary to solve the problem, all under the uncertainty of evidence about the problem and its solutions. The designer must be particularly creative because the design theory is anchored to constructs shared among similar problems. Not only must the designed artifact fit the theory, the practical criteria and the setting, but it should be distinctive. It should be different -- somehow better than previous designs that regard similar problems. It should be inventive, novel, and interesting.

The design decisions taken in this step impose narrower creativity boundaries on the next step, artifact making or building. The specifications for the artifact will necessarily limit any further design decisions to relatively low-level, details. Such issues often arise from imprecision or provisionality in the design and ambiguity in the communication of the design between designers and builders [32]. Where these issues exist, the builders have some latitude to interpret the design specification. But their ability to develop any major design decisions is quite bounded.

3.5 How making artifacts develops subsequent creativity boundaries and iteration indicators

Creativity in the 'make' step is further narrowed by the design specifications. But it would be naïve to assume that there are no further design decisions left for the make/build activity. As previously mentioned, there is uncertainty in the communication of the design, and imprecision and provisionality in the design itself. There may also be errors that arise from the design or the theory behind the design. The components or assemblies applied to the design may operate differently from that expected by the designer. Considerable creativity can be required to make the artifact work, both practically and as intended by the designer, yet without departing in essential ways from the design as developed in the previous step.

The design decisions in this step complete the imposition of the narrowest boundaries on the next step, evaluation. The typical evaluation step compares the characteristics of the artifact with the specifications in the design. While there is still a limited range of creativity in evaluation, the characteristics of the artifact are most often unchangeable physically or logically (at least in terms of the evaluation). The results of the evaluation may be used formatively or summatively [33], but these results must pertain to the artifact as produced. Creativity is bounded by the immutability of the artifact during the evaluation step.

3.6 How artifact evaluation develops iteration indicators

Boundaries on creativity in the artifact evaluation step are further narrowed by the presence of a constructed artifact. Although evaluators may creatively tinker with an artifact, evaluation is usually focused on examinations and experiments with the artifact designed. Still, there is room for creativity in the environment into which the artifact is positioned for evaluation. There is also creativity needed for choosing the parameters under which the evaluation takes place. While evaluations sometimes aim to break the artifact, such as with extreme or out-of-specification conditions, creativity is sometimes needed to make the artifact work successfully in normal operating conditions. An example is creative experimentation with an artifact in search for a situation in which the artifact satisfies all the aspirations in its design.

4 Indicators for Iteration in Design Science Research

Based on the analysis of bounded creativity, we can now compile a set of indicators that prescribe when iteration is appropriate. These are summarized in Table 1. Although some design science research methods suggest that iteration can retreat to any previous step, we suggest that such retreats be incremental. Iterative retreats step back only one stage at a time. For example, if during the make/build step, it is not possible to make the artifact operate, the process should iterate back to the design step. This would allow the designer to search for another satisfactory design within the existing design theory. If the designer cannot, then we can assume the design theory is faulty and retreat iteratively back to the design theorizing step.

Table 1. Indicators for iteration

Iterate from	Iterate to	Bounded Creativity
Meta problem identification	Problem formulation	No problem class can be created: the problem has been misdiagnosed.
Problem formulation	Meta-problem identification	The designer cannot find any similar problems and cannot classify the problem
Design theorizing	Meta-problem identification	The designer is unable to satisfactorily generate a design theory that addresses all the aspirations present in the meta-problem using its constructs.
Artifact design	Design theorizing	The designer cannot translate the given design theory into a set of design specifications that deliver a promising, practical artifact design. The design theory is leading to designs that are unimaginative, mundane, and imitative.
Making artifacts	Artifact design	The builders cannot invent a way to make the artifact operate as designed.
Evaluation	Making artifacts	The evaluators cannot invent a situation in which the artifact satisfies the aspirations of its design.

The use of bounded creativity indicators for determining when to iterate also makes creativity a specific companion to the scientific aspect of design science research.

5 Unfolding Iteration in the Case of "Craggy Cliffs"

To evaluate the iteration indicators, a case study is appropriate [33]. The indicators are evaluated within the context of a research project involving the design, development and evaluation of a novel location-based educational game. The design problem in the Craggy Cliffs Case (anonymized) was rooted in the failure of a creative project that was tasked to develop the location-based game. The project comprised a series of unstructured, yet creative, design experiments. However, initial work on the project was unsuccessful in yielding a novel and innovative game. This failure created the conundrum of whether the failure of the creative project resulted from the lack of grounding in a structured methodology or, whether the use of a structured scientific approach such as design science research would stem creativity in the design process and in the design outcome. The meta-problem within this case study 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.

5.1 Problem Description

After the initial failure of the creative design project, the Craggy Cliffs Case used a design science research approach to solve the problem of designing a creative location-based solution for engaging and educating youth visiting a national park. This project underwent three further design iterations to yield: (2) a novel artifact instantiated in the form of a site-specific location-based educational game; (3) a general method for creatively developing site-specific location-based games; and (4) an explanatory design theory for the design of creative location-based games [34, 35].

5.2 Iterations 1 and 2: Design Cycle

The Craggy Cliffs Nature Center was having trouble attracting young people to engage in outdoor nature appreciation and was interested in using smart mobile phone technology to engage young visitors. With this objective, the project proceeded. The first iteration proceeded without using a design science research methodology. The physical site was explored, and the topography, cliffs, and specific and interesting trees in the forest were identified. "We explored the affordances" of the site, states the main designer. Then several iterations followed where prototypes were built and tried at the site. For example, GPS technology was relatively new at the time. Therefore, the designers built a prototype of a mobile phone using GPS which displayed a map with a dot pointing to one's location. This prototype was tested, and two problems identified. First, the mobile coverage was not very good at the Craggy Cliffs site. Hence, what worked in the laboratory did not work at the site. Second, using a mobile phone with a map led the young people to look more at the phone than the nature around them. Third, the Craggy Cliffs Center wanted to increase engagement through a multi-player game, which required a network that could not be established in the forest and around the cliffs.

Thus, fulfilling the main purpose of appreciating nature through a site-specific multi-player game failed at first. In a second iteration the boundary posed by the bad mobile phone and GPS connection led to the creative exploration of different design decisions within the boundaries of the technology given at the site. Here we see an indication that evaluators could not invent a satisfying situation, and an iteration from *Evaluation* back to *Making Artifacts* ensued (see Table 1). The final decision was made to not give everyone a mobile phone, but rather, provide each team with one. A further iteration of creatively addressing the problem of having the game-players spend too much time looking at the phone led to a decision not to use the screen of the mobile phone but just play the sound of a narrative that a group of game-players could gather around and listen to together. Here we see an iteration from *Making Artifacts* back to *Artifact Design* (see Table 1).

During the iterations mentioned above, it became clear that the design process was a series of unstructured experiments using prototyping but lacked any well-defined methodology. The key objective of the site-specific game was to engage the visitors with the location. However, there were, at the time, few methods to incorporate the special characteristics of the physical site into the development of the game. Thus, in the iterations 1 and 2 the design work was focused more on the use of the technology than the game environment with the design activities having many unknown / unclear requirements. Therefore, a more structured approach was needed.

5.3 Iteration 3: Meta-level design

The problem that initiated the design of a general method for site-specific game design was a realization that no specific method existed for developing site-specific games. Furthermore, there was a need for a more structured way of working. Here we find indications that, first, that the builders could not invent a way to make the artifact operate. Then that the design was too unimaginative. There was a stepwise series of iterations from *Making Artifacts* back to *Design Theorizing*; thence to *Problem Formulation* (see Table 1): To develop this general method, the designers drew on several kernel theories. These included: 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, as well as game affordances.

The method that was developed was named "site-storming" (reference left out to preserve author anonymity), which combined the idea of brainstorming for site-specific ideas, and was developed in several iterations. At first it was just a structured approach; "we need to analyze the site first before we have a creative phase coming up with ideas for how to use the site and so on." In the second iteration of the development of the site-storming method, it was found that different creative outcomes were elicited when designers worked independently than when they brainstormed in groups. Therefore, the method came to include an individual brainstorming phase followed by a group-oriented phase. A third iteration tried the idea of using cards. This was inspired by cards published by the design company IDEO [36]. Thus, the design artifact was of mission-based gaming style game-cards including mission cards, game cards, prop-cards and site cards. The iterations continued. When to continue iterating and when to stop was determined by either the rational boundaries or the creative boundaries in the situation. Gradually and progressively more severe design boundaries become imposed on the designer and the iterations were planned an enacted accordingly. Each design decision involved selecting a satisfactory solution to one of the aspirations in the design problem. e.g. deciding what type of cards were needed in the site-storming method.

5.4 Iteration 4: Meta-level design

Learning from the previous iterations helped develop a meta-level explanatory design theory. Here we find indications that the designers could not imagine similar problems within the design theory. There was an iteration from *Problem Formulation* back to *Meta Problem Identification* (see Table 1): Developing a generic approach was intended to provide the grounding for finding ways to induce creativity within the structured design process described above, so better ideas could be generated in the time spent iterating. This approach helped to define a balance between structure and creativity where the structure enabled creativity, rather than inhibiting it. Observations and learning from prior iterations, consideration of design science research, theories of game performance, and performance requirements of site-specific games were all abstracted into an explanatory design theory. From this, the game from prior iterations was redesigned and evaluated, and twenty-six additional games designed. The redesigned games were evaluated by student participants and potential users for design pervasiveness and performance pervasiveness. The general requirements and solution components are shown in Figure 2.

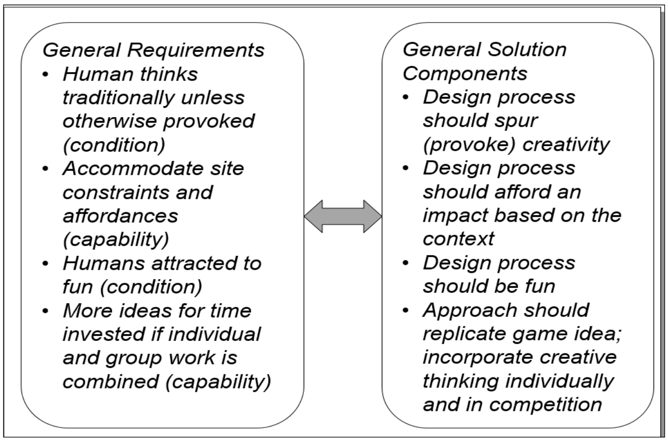

Figure 2: Requirements and Solution Components

Figure 2 is presented as an explanatory design theory [37]. The abstraction of a design theory expressed as general requirements and general solution components required several iterations. The notation chosen determined some boundaries, e.g. one must express requirements as either conditions or capabilities in accordance with an ISO standard for requirements.

6 Discussion and Conclusion

This research has proposed bounded creativity as a mechanism for achieving novelty in design science research. Bounded creativity, in conjunction with bounded rationality, provides iteration indicators to achieve creative outcomes. As demonstrated in the case, the design science research process is iterative and incremental providing opportunities for feedback, improvement, and refinement. Design science research methodologies involve cycles and iterations. It is a common assumption that the decision to iterate is somehow obvious and simple, but this assumption overlooks two difficult problems. First, how does a design researcher know when it is an appropriate time to iterate and which previous stage is an appropriate choice? Second, when is the design science process sufficiently complete so further iteration is unnecessary? We posit that the problem of *when and where* to iterate is scoped by the rational and creativity boundaries imposed by the progressive and methodical nature of design science research.

There are extremely significant implications for the role and application of creativity within design science research. First, the structure and rigor of this research approach induces the need for creativity despite given constraints. This challenges the designer to draw on skills, curiosity, observation, and imagination to combine experience, style, other domains, patterns, or other creativity generating mechanisms, to find a new and innovative solution to a given problem. Second, bounded creativity iterations will drive outcomes that are more robust and reliable, by weaning out creative ideas that may be unable to stand the test of evaluation, through the progression of ever narrowing bounds of rationality and creativity.

Although the importance of creativity within information systems has been widely acknowledged, we lack an understanding of the effects of the boundaries placed on creativity by design science research. The structure of scientific rigor marshals the principled search for an artifact that demonstrates utility. However, this progressively narrows the boundaries of both rationality and creativity as the research process proceeds. Identifying when the narrowing of the boundaries has brought the rational or creative search to failure, will indicate that the current stage of the design search should be terminated. Then, iteration to a specific previous stage is suggested.

This research provides a perspective of bounded creativity in design science research, demonstrating how boundaries are placed on creativity at different stages of iteration. Bounded creativity scopes or narrows the range of options through the methodological lifecycle, often forcing the designer to retreat and rework a design. The forward iterations are much narrower in scope than earlier stages, with the designers' decision significant in determining the extent and bounds of the creative space and creative processes. Bounded creativity can help achieve a "creative enough" outcome. Furthermore, the notion of bounded creativity works at any level of outcome ranging from instantiates artifacts, to mid-level methods, to abstract level theoretical outcomes. This work contributes to design science research by analyzing and defining the role of bounded creativity in both theorizing and artifact development. Certainly, the pursuit of design science research meta-requirements and resulting design principles demands rigorous methods, but the implementation of an instantiation of the design principles is still replete with creative possibilities. It is often a process of creativity, or more precisely, of bounded creativity. Future research should examine how bounded creativity, as analyzed in this paper, can be applied within other contexts; for example, creating a health app for individuals with a specific disease condition.

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