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Abstract

Creativity is fostered by distributed cognitive activity as individuals interact with artifacts and with each other, often with the aid of artifacts. In this design science research-in-progress, we describe a software artifact known as Theory Garden that was developed to facilitate distributed cognitive activity. We detail an experimental process through which we are assessing the potential for this artifact to facilitate creative outcomes in the context of problem formulation. The experiment involves two different phases: one that addresses managerial problem definition, and one that deals with the requirements processes of software development teams. We conclude with potential implications of this research, should we find evidence that Theory Garden software does support more creative outcomes.

Keywords: Creativity support systems, design science, distributed cognition

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IT FOR CREATIVITY IN PROBLEM FORMULATION

Introduction

In our daily lives, we interact with the world through the aid of a myriad of inchoate theories about things that concern us and the consequences of our action. However, we rarely subject such common sense theories to focused analysis. As a result, one might say that our half-formed theories "take us only so far." This observation leads to a simple but profound question – what might be gained if we could subject our theories about the world to some formal exploration with a small measure of cognitive effort? In recent years, a range of information technology (IT) innovations have emerged to support just such an investigation into the ideas that drive the day-to-day behavior of individuals and groups. One promising avenue in this regard is the emergence of visualization as a resource for insight and idea generation (e.g., Cleveland 1993; Shneiderman et al. 1999; Tufte 1997), complex argument visualization in the computer supported cooperative learning (Kirschner et al 2003; Weinberger & Fischer 2006) and also in decision support systems (Zhang et al 2005; Yearwood & Stranieri 2006). Visualizing ideas in an interactive IT environment enables individuals to iteratively refine their beliefs and test them against others' ideas (Boland, Tenkasi, and Te'eni, 1994). Such efforts at reflection and conceptual exploration support the development of creative processes for both individuals and groups.

In the present research-in-progress essay, we report on experiments we are conducting in the design and application of a creativity-enhancing visualization tool. Specifically, the research question we pose is: do the design principles reflected in the mental modeling software that we have developed enhance the creativity of initial problem formulation and the generation of the design space in a system development project? To date design science has produced no design theory relating to creativity. There is work on emerging knowledge processes (Markus et al 2002), collaboration (Boland et al 1994), generative processes (Avital & Te'eni 2008), learning (Kali 2006), process design (Lee et al 2008), and knowledge creating design networks (Berente et al 2008). But none of these capture that particular aspect of creativity that involves novel combinations - particularly with respect to more or less creativity as a dependent variable. Previous studies essentially hold the level of creativity, inventiveness and innovativeness constant and focus on the process itself.

This design research-in-progress is motivated by a vision of creating tools for distributed cognition in a world that values the ability of each individual to generate knowledge by proposing and testing theories. We envision the emergence of a public community that engages in developing theories about the arts and sciences as well as everyday personal theories about how the world works in its political, financial, social, and cultural aspects. By graphically depicting the basic elements of their personal perspectives, individuals can discover new connections among familiar elements (Boland and Tenkasi, 1995) as they construct representations of their tacit understandings and conduct a learning dialogue with others. Visualizing ideas in an interactive IT environment enables individuals to iteratively refine their beliefs and test them against others' ideas (Boland, Tenkasi and Te'eni, 1994).

The software tools we are developing support the creation of theories in the form of directed graphs, showing the elements and relationships that comprise a given theory. The software enables individuals and community members to articulate and animate a theory – revealing its patterns of action and cycles of interrelationship – and to simulate the logical consequences of a theory, given only a few qualitative descriptors of its elements and relationships. In our vision, social actors who could benefit from the application of this tool range from primary school students (i.e., K-6) to senior citizens, from rank and file workers to corporate executives, and across a wide range of industries and professions. As an on-line, publicly accessibly environment, this software suite could foster the formation of diverse communities of shared exploration and engender creativity across a variety of domains as it encourages the continuous, iterative combination and re-combination of cognitive elements. The remainder of this essay will present the underlying research and theory used in the construction of the software environment we are using in our experiments, and the research-in-progress that we will be reporting at ICIS 2009.

Creativity

Although the concept of creativity remains veiled in a degree of mystery, researchers inevitably emphasize its recombinant essence (Boden, 1994; Johnson-Laird, 1988). That is, creativity often entails the generation of new ideas or artifacts through the novel combination of familiar elements. As such, creativity is largely about looking at existing factors in new ways, applying multiple lenses to that which we believe we already understand, seeing new relationships, and opening new ideas.

Creativity necessarily involves the minds of individual actors, and the bulk of research on creativity addresses the ways in which creativity occurs from an individual perspective. Research in organizational creativity, for example, focuses primarily on the structures that support individual creativity (Amabile, 1998; Woodman et al., 1993; Stacey, 2002). This prevailing, individualistic view of creativity, however, does not capture the inherently social context within which individual creativity is rooted. In our current research, we capture both individual cognition and the interplay of social and technological activity that is reflected in micro-level creation of novel cognitive combinations.

The software environment we will employ has been in continuous development and enhancement over the last 15 years, and is known as *Theory Garden*. Drawing on theories of distributed cognition (Boland et al., 1994), the systems approach (Churchman, 1971), and the hermeneutic tradition of social theory (Gadamer, 1976), the software enables individuals to refine their own perspectives by making them explicit, and to communicate these perspectives to others. The tool proved especially useful in contexts where collaboration was needed (Boland et al., 1994) and where innovative thinking was encouraged (Boland & Tenkasi, 1995; Majchrzak et al., 2005). In our current project, we extend this research stream and apply the newly expanded capabilities of *Theory Garden* software to the cognitive domain of creativity. In the spirit of design science research (Hevner et al., 2004) we propose a series of tests that will further inform the design of this software environment with respect to creative outcomes. The long-term goal of the project is the creation of an on-line Web 2.0 (Parameswaran and Whinston, 2007) community for the nurturing of creative ideas.

Creativity and Distributed Cognition

Treatments of creativity from a cognitive perspective tend to embrace an evolutionary understanding of individual cognition (e.g., Johnson-Laird 1988; Boden 1990). In such views, existing cognitive elements are combined, often at random, and these re-combinations can represent new cognitive elements. Similarly, much of the research on design-oriented creativity focuses on the cognitive activity of recombination (Simon, 1996; Churchman, 1971; Alexander, 1979; Cross, 1989; Altshuller, 1984; Schön & Wiggins, 1992).

In this research, we explore the importance of creative exchange and recombination of ideas, which frequently takes place within an intensely social and technologically rich milieu. In contemporary design contexts, for example, the importance of social interaction and the application of technological resources could hardly be overstated. Accordingly, we employ an understanding of creativity that embraces the full range of socio-technical factors within a creative process. To support such an understanding, we adopt the theoretical lens of distributed cognition (Boland et al., 1994, Hutchins, 1995; Norman, 1994; Salomon, 1993).

Distributed cognition posits that cognitive processes are not limited to the mind of an individual thinker (Hutchins, 1995; Hutchins and Klausen, 2000). Rather, cognition is distributed socially and technically across individuals and artifacts within the external environment (Hutchins, 2000). Socially, cognitive processes may be distributed across members of a group in that each member may play a specific role with respect to the collection and processing of information and the initiation of action by the group.

Several researchers and theorists in the design discourse have begun to recognize the social dimension of design and organizational creativity (Clark & Fujimoto, 1991; Henderson, 1991; Bucciarelli, 1994; Dougherty, 1992; Ancona & Caldwell, 1992). In this view, creative ideas are not only portrayed as individual combinations of cognitive elements, but rather as new elements that are iteratively generated through a series of negotiations among actors who have diverse perspectives of a given design domain.

Technical distribution can be seen in the ways in which individuals and groups incorporate physical artifacts into design processes. These technical structures are used to support the limited internal cognitive capacities of a group, providing what Clark (1997) has referred to as “external scaffolding.” The use of external structure is also reflected in the acknowledgement by design theorists of the importance of representational artifacts (Simon, 1996; Churchman, 1971; Alexander, 1979; Cross, 1989; Altshuller, 1984; Schön & Wiggins, 1992). In our research in progress, technological artifacts are understood to be essential for distributed cognitive processes, as they support the visualization, dialog, and interpretation required for creativity (Boland et al., 1994). From this distributed cognitive perspective, artifacts can be said to have at least three fundamental facets: (1) communication support, (2) computation, and (3) transmitting knowledge across time (Hutchins, 1995, 2000). Boland et al. (1994) identified six principles for designing technologies to support such distributed cognitive activity: *ownership, easy travel, multiplicity, indeterminacy, emergence,* and *mixed forms.* Majchrzak et al. (2005) found support for the importance of their role in providing contextual information/cues in learning environments.

A fundamental way in we wish to foster creativity and novel combinations is by bringing contextual elements into the purview of analysis and adding contextual elements to the representations that designers encounter. When viewing the world as a nested web of interconnected, hierarchical systems, designers must be selective about the salient system components they wish to address as "context". System theorists often prescribe "models" as "a way in which thought processes can be amplified" (Churchman, 1984, p.61). An important aspect of system modeling is to understand that every model reflects a designer's assumptions, and that these assumptions can always be questioned on some grounds (Churchman, 1971). Hence, models can aid dramatically in a designer's thinking. However, designers must also guard against complacency. There must never be a "final" model, since new elements can always be "swept in" to a systems model and defensible alternative system models inevitably exist (Churchman, 1971). The *Theory Garden* software helps to illustrate this point and enables members of a design team to expand the range of concepts that they integrate in their deign process.

Theory Garden – An IT Environment for Nurturing Creativity

The *Theory Garden* tools support a distributed cognitive approach to creativity through multiple mechanisms. First, *Theory Garden* creates a mechanism for exchange around individual beliefs and perceptions. The tools within the suite enable individual designers and other stakeholders to make explicit many of the inchoate beliefs that underlie their initial perspective on the design domain. By rendering these ideas in the form of a directed model of elements and relations, an individual can explore the practical implications of their assumptions, and share these perceptual models with others within the design effort.

Secondly, the artifacts can be used to support the exploration of ideas in a collaborative design setting. Thus, rather than developing and exchanging individual models of the design environment, a group of individuals can collectively generate and revise their understanding of the domain, enhancing their model through real-time assessment of the relationships between factors within the domain.

Finally, *Theory Garden* supports the exploration of design options by shifting some of the cognitive burden to the external structure of the artifact itself. One of the key reasons that individuals need support in generating elaborate and explicit models of a design domain is the inherent cognitive limitations of the human mind. At any given time, we are incapable of attending equally to a large number of factors and expressing the relationships that we expect to prevail between them. By employing the causal-modeling functionality of the *Theory Garden* platform, designers are able to incorporate a broad range of factors and focus on the ways in which they relate to one another. Thus, *Theory Garden* provides the "external scaffolding" that enables design teams to engage in a higher-level exploration of the design domain (Clark, 1997).

Within the context of information systems design, the *Theory Garden* artifacts are especially relevant for supporting the generation of an initial design vision. While the prevailing term for such early-stage system design work is the "requirements phase," we characterize this stage as the generation of the design space. The distinction is significant. The term 'requirements' implies the pre-existence of an appropriate solution set. In such a context, a designer's objective is the identification and capture of this 'hidden' solution of a self-evident problem. However, a key capability associated with creativity involves framing the problem in novel ways and in formulating new problems entirely (Selzer & Bentley 1999). Thus, in the design domain, our conception is one in which the opportunities for creativity and the associated innovativeness are manifold. Truly creative design activity cannot be characterized simply as a search for an appropriate solution to a clearly specified problem; rather, for creative designs the problem itself must be formulated creatively.

Our research question is: Do the design principles reflected in the *Theory Garden* software tools enhance the creativity of initial problem formulation and the generation of the design space in a system development project?

Theory Garden enables the development of conceptual models across all of the stakeholder groups involved in a design effort. Through the exchange and review of these diverse models, designers and other stakeholders experience a wide range of perspectives on the design domain. This perspective exchange will enable greater potential for novel combination and recombination of relevant design factors. This approach contrasts starkly with the focus on requirements aggregation and consistency checking that prevails in most contemporary information systems design. For example, within the *Theory Garden* model, the identification of ostensibly conflicting statements of need or perception is an opportunity for perspective taking (Boland & Tenkasi, 1995) and the exploration of designs factors. In the traditional requirements process, conflicting requirements are an indication of a design impediment and the necessity of negotiation. Perhaps even more important is the ability of *Theory Garden* to simulate the logical consequence of a change in value of one or more elements on other elements in the model by tracing their causal relationships. This adds a dynamic aspect to the visualization of the model and an expanded opportunity for seeing patterns in the relationships among elements in the model and for considering novel combinations, which should lead to an increase in the creativity of potential solutions being explored.

Theory Garden Software

The core functionality of the *Theory Garden* software is intended to capture qualitative theory models through graphical representations of relationships between elements in a person's causal model of a situation. In visually capturing these models, *Theory Garden* software is intended to help individuals develop, articulate, and share understandings about particular phenomena (Boland et al., 1994). This implementation of a visual thinking tool is intended to aid a user in surfacing and working through the assumptions that are brought to situations (often not explicitly) and guide that individual's understanding of situations. Figure 1 illustrates a model created in *Theory Garden* by one of the authors showing a cause model of the September 8, 2008 *New York Times* op-ed column by Paul Krugman entitled "The Power of De". It shows how elements of the current financial situation in the United States could be modeled and create new insights by putting elements that are familiar by themselves into a larger systems context.

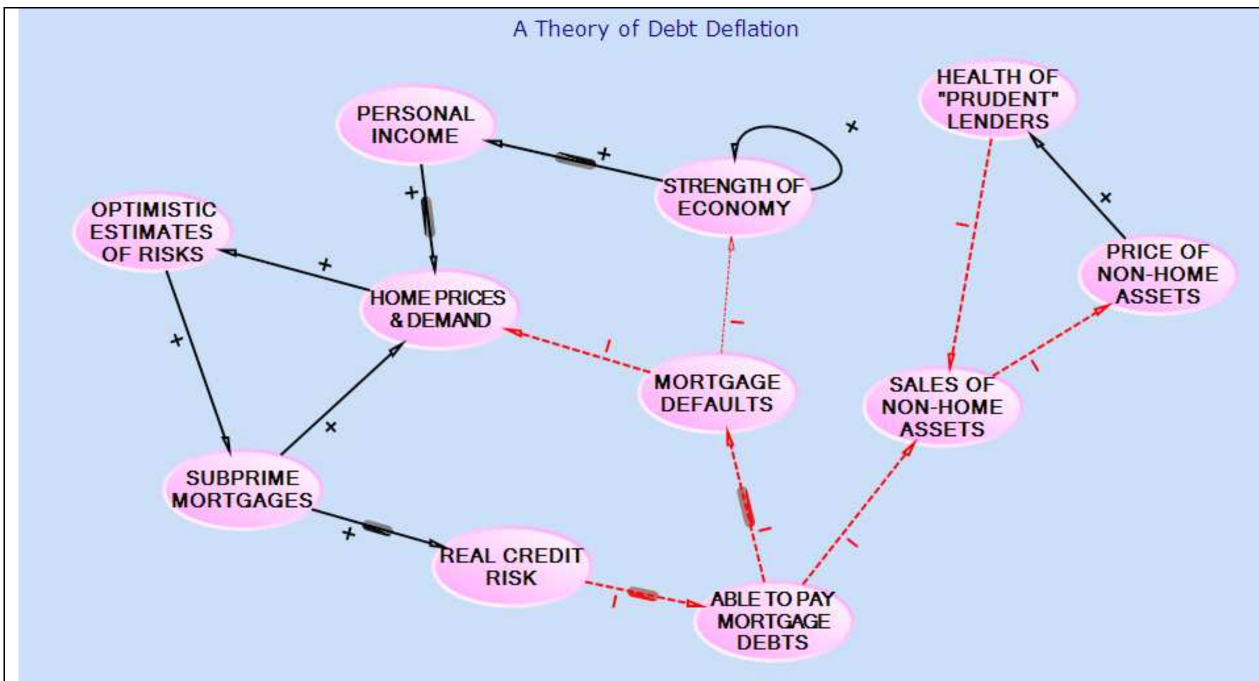

Figure 1. Krugman Financial Model

A simulation of the cause loop model made from Krugman's article is shown below as figure 2. It demonstrates how a cause loop model of Krugman's theory reformulated the problem of sub-prime mortgages to reveal the upcoming, larger financial crisis in the USA several weeks in advance. The cause loop model shows how the "sub-prime mortgage" crisis was about to create a second crisis as the value of non real estate assets deflated and the dire implications for otherwise "prudent" financial institutions (yellow line) that did not become overexposed by holding mortgage backed securities. That is, the financial crisis of sub-prime loans is portrayed as a much broader phenomenon that we beings discussed in the media at the time. Simulating Krugman's model suggests that even after the sub-prime crisis has begun to recede, the larger economic problems continue to grow. This is a dramatic example of the ways that causal modeling from multiple perspectives can shift a problem definition and thereby the design space being addressed.

The graphical representation of figure 1 is simulated in an advanced qualitative system-theoretic post processor, the TG-Engine (patent pending). This simulation engine relies on a hybrid set of techniques including statistics, genetic algorithms, and neural network logic to mathematically iterate through cycles of a given model, based on the qualitative relationships established by the user. This quickly becomes an NP-hard problem with only a few elements, and the TG-Engine can simulate dozens of cycles through the model in seconds. It is not the purpose of this work to explicate on TG-Engine – for more information, see Goraya (2001).

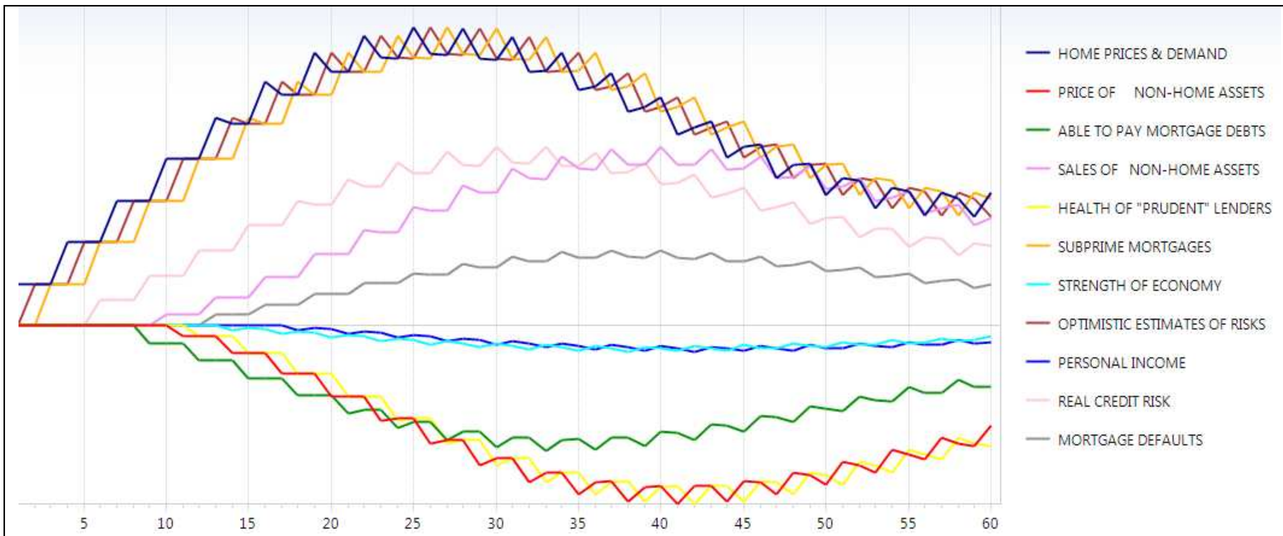

Figure 1. Simulation of Krugman Financial Model

Research Approach

A goal of design science research (Hevner et al., 2004) is to develop artifacts based on solid theoretical foundations, then to test these artifacts in relation to their foundational theories, which inform further development of the artifact. The *Theory Garden* software is now being rigorously tested specifically with respect to improved creativity and innovation as dependent variables in a controlled environment. This research looks to inform both the research on creativity and distributed cognition, as well as the further development of the artifact, with the end-goal of an on-line community that fosters creativity across a wide range of applications.

The domain of the group processes we are studying is problem formulation, or the creative generation of a problem space (Simon, 1996) for a given set of design tasks. As design projects are highly impacted by the initial articulation of the problem space, following theorists such as Simon (1996) and Churchman (1971), we hold that much of the creativity of any innovative effort can be found in the way in which the problem is stated. Creative definition of a problem space can therefore be expected to increase overall innovativeness of a project (Selzer & Bentley 1999).

We are conducting experiments to test the impact of the artifact's use on creative definitions of problem spaces for a design task. Within the context of information systems design, we hypothesize that the *Theory Garden* software will be especially relevant for supporting the initial vision generation efforts of design teams. While the prevailing term for such early-stage development work is requirements determination or requirements engineering (Davis, 1982; Loucopoulos & Karakostas, 1995; Sommerville & Sawyer, 1997), we characterize this stage as the generation of the design space.

We are testing for enhanced creativity among the members of a design team through three mechanisms: (1) models are iteratively made more comprehensive as individuals make their perspectives explicit; (2) by making perspectives explicit, models can be questioned and leveraged socially; and (3) through animation and simulation, individuals and groups will question assumptions and sweep contextual considerations into their models. This perspective exchange will support greater potential for novel combination and recombination of relevant design factors (Boland & Tenkasi, 1995; Majchrzak et al., 2004) and increased contextualization (Majchrzak et al., 2005).

Research Method

This project will be conducted in two phases. Phase one is intended to address a "generic" creativity in defining problem spaces via a field experiment with experienced managers, and the second phase addresses a particular application domain – software development teams – and the way the software might enhance creativity in the requirements phase. Next we address each in turn.

Phase 1 – Creativity in Defining Problem Spaces

Before attempting to understand the implications of the Theory Garden tools on creativity in any specific design domain, we look to understand the ways in which these tools can support creative definition in a problem space for a variety of design tasks. The research methodology for this first stage will involve experimentation with experienced managers on familiar design tasks that require limited specific technical or domain knowledge. We plan to conduct a total of five experiments during over the next two years. Each experiment should involve at least 40 subjects who will be randomly assigned to four groups. For each design task we will have one control group and three conditions, and each group will be interviewed after the task. Following will describe each group:

Group A: The control group will be asked to simply define the detail the requirements associated with the given design task, and to list and prioritize these requirements. They will be asked to follow the popular "Force Field Technique" (Lewin, 1943) to devise these requirements.

Group B: This group will be asked to together devise a theory map within Theory Garden that describes the domain of the problem and contextual elements. Then they will be asked to both simulate and animate the map a number of times, changing the map as they deem appropriate. Through this animation and simulation, we expect assumptions to be questioned and additional contextual elements to be swept into the theory map. This group will submit the final group map as well as a list of prioritized requirements.

Group C: This group will follow the traditional "nominal group technique" (Van de Ven & Delbecq, 1971) where each individual privately devises a set of requirements, then the group comes together to create the group requirements. As with Group A, the "Force Field Technique" (Lewin, 1943) will be leveraged. No Theory Garden tools will be used for this.

Group D: This group will combine the "Nominal Group Technique" (Van de Ven & Delbecq,1971) with use of the Theory Garden tools. Each individual will be asked to privately devise a theory map about the task domain. Then the group will come together to create a single group map. The group will then simulate and animate the maps a number of times, changing the map as they deem appropriate. Again, we expect assumptions to be questioned and context to be swept in to result in a more innovative problem definition. This group will submit all individual maps and the final group map as well as a final list of prioritized requirements.

All lists of prioritized requirements will be scored on measures of thoroughness, practicability, and creativity by a panel of independent raters.

Phase 2 - Creative Requirements in Software Design Teams

To test our assertions regarding the benefits of the capabilities of the Theory Garden suite in the generation of the design space in a field experiment setting, we propose to conduct a study of active design teams. For the purposes of this study, we will identify existing information systems design teams with between 8 and 10 members. Since contemporary IS development projects frequently entail the creation of project teams on an ad hoc basis to ensure the presence of project-specific skills and application domain knowledge (Curtis et al., 1988), we will identify teams that have been working together on a given project for one month or longer.

Teams will be randomly assigned t one of three conditions – those who will be asked to use the Theory Garden tools on an individual basis (Group A), those using Theory Garden in a collective effort (Group B), and a control group for whom Theory Garden will not be used (Group C). All teams will be asked to complete a common task – the development of an initial requirements specification for the development of a transaction processing system. After a short introduction to the proposed task domain, the following activities will be engaged for each group:

Group A– The control group will not use Theory Garden tools will be used. Team members will be asked to discuss the proposed design domain, and proceed with the generation of the specification in accordance with their established decision making process. However, the same specification template/format will be required across all groups.

Group B – Teams will proceed directly to the development of a common theory map of the design domain (i.e., individual models will not be created before the team collectively employs the Theory Garden software). The team will be permitted to iterate through multiple versions of the model until they arrive at a collective model with which most of the team is satisfied. Finally, as with the other groups, each Group B team will be asked to develop a preliminary specification document using a standard format.

Group C – In the tradition of the "Nominal Group Technique" (Van de Ven & Delbecq, 1971), team members will be asked to create individual theory maps of the proposed design effort including the documentation of all factors that they believe to be relevant for the project. After the individual maps have been created, the maps will be exchanged with the group. The project team will discuss the various maps that have emerged and will engage in the development of single collective map for the group. Finally, the team will be asked to develop the preliminary specification document using a standard format.

After the design teams have generated their preliminary specification documents, participants will be interviewed and the specifications will be independently scored on measures of completeness, consistency, practicability, and creativity. Panels of independent system analysts will conduct all evaluations of team-generated documents.

Anticipated Significance of this Research-in-Progress

This research will be significant in several ways. First, through careful documentation of the experiments and analysis of the effect of such technology on creative processes, the study can have a direct impact on our understanding of creativity in management decisions and in software development processes. Further, in demonstrating creativity enhancement through IT-mediated creation, analysis and exchange of theory models will open the door for new approaches to education from K-12 and onto universities. It will also open new avenues for knowledge management in industries, services and the not for profit sectors. Finally, it will stimulate further development of the vision presented at the beginning of this proposal - the vision of a dynamic web 2.0 community based on the creation, exchange, critique and elaboration of theory models.

The fruits of this research are expected to benefit three broad communities: the management profession, software development, and the academic / educational community. For the management profession, we plan to develop extensions to *Theory Garden* that involve default templates for creating, combining, and extending theory maps that can directly encourage creative managerial thinking (Boland & Collopy 2004). Management research now has more than half a century of theorization that can be codified and readily leveraged and adapted to specific organizational domains. While the best organizational theories are highly relevant to practice (Van de Ven 1989) oftentimes managers do not explicitly attend to these theories in everyday practice (Christensen & Raynor 2003) because they are dense, deemed unapproachable, and managers may not know where to start. Theory Garden offers a medium for making the vast organizational literature more tractable and applicable.

For software development projects, requirements are critical for setting the stage for the entire project, and the creativity of those requirements directly impact the innovativeness of the resulting artifact. However, creativity is difficult to measure, so developers generally focus on improving elements that they can measure – such as cost, security, and reliability. Creativity can be problematic, however, since it is difficult to articulate what is meant by creativity *a priori*. We argue that Theory Garden might complement requirements processes as a "generative" artifact (Avital & Te'eni 2008) thus accommodating creativity not through specific requirements or soft goals (Chung et al. 2000), but through a method whereby designers can intentionally negotiate concerns relating to creativity, make applicable tradeoffs explicit, and recursively monitor creative outcomes throughout the design process.

Finally, for academic and educational purposes, Theory Garden as a tool to foster creativity has innumerable applications. With researchers, for example, Theory Garden offers a ready medium for recombining components of existing and novel theoretical views and extensions of these views. For educational purposes, Theory Garden tools would aid children through senior in reasoning through their perspectives and thus iteratively forging novel, creative perspectives. The Web 2.0 on-line community alluded to in the introduction will also be informed by this research and will be available to the public.

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