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From generative fit to generative capacity: exploring an emerging dimension of information systems design and task performance

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Abstract. *Information systems (IS) research has been long concerned with improving task-related performance. The concept of fit is often used to explain how system design can improve performance and overall value. So far, the literature has focused mainly on performance evaluation criteria that are based on measures of task efficiency, accuracy, or productivity. However, nowadays, productivity gain is no longer the single evaluation criterion. In many instances, computer systems are expected to enhance our creativity, reveal opportunities and open new vistas of uncharted frontiers.*

To address this void, we introduce the concept of generativity in the context of IS design and develop two corresponding design considerations – 'generative capacity' that refers to one's ability to produce something ingenious or at least new in a particular context, and 'generative fit' that refers to the extent to which an IT artefact is conducive to evoking and enhancing that generative capacity. We offer an extended view of the concept of fit and realign the prevailing approaches to human–computer interaction design with current leading-edge applications and users' expectations. Our findings guide systems designers who aim to enhance creative work, unstructured syntheses, serendipitous discoveries, and any other form of computer-aided tasks that involve unexplored outcomes or aim to enhance our ability to go boldly where no one has gone before.

In this paper, we explore the underpinnings of 'generative capacity' and argue that it should be included in the evaluation of task-related performance. Then, we briefly explore the role of fit in IS research, position 'generative fit' in that context, explain its role and impact on performance, and provide key design considerations that enhance generative fit. Finally, we demonstrate our thesis with an illustrative vignette of good generative fit, and conclude with ideas for further research.

Keywords: systems design, requirements engineering, creativity, generative design, generative capacity, human–computer interaction

INTRODUCTION

In this theory development paper, we offer an extended view of the concept of fit in an attempt to realign the prevailing approaches to human–computer interaction design with current leading edge applications and users' expectations. Specifically, we identify an emerging dimension of task performance relating to creativity and innovativeness and explore how information systems can be fitted to enhance this dimension.

It has been argued that fitting the human–computer interface and, more generally, fitting computing services to a user and an underlying computer-aided task enhances the desired outcome and has a positive effect on overall performance (Vessey & Galletta, 1991; Baecker *et al.*, 1995; Goodhue & Thompson, 1995; Zigurs & Buckland, 1998). Although one's performance is theorized in a generalized fashion as related to any kind of *a priori* objectives associated with an underlying task (Daft, 1991), the literature so far focuses mainly on performance evaluation criteria that are based on measures of task efficiency, accuracy or productivity (Zhang & Na, 2004).

This view of performance was sufficient in the early days of personal computing when computers were seen mainly as productivity tools and the emphasis was on productivity and efficiency of operation. However, productivity gain is nowadays no longer the single evaluation criterion. In many instances, computer systems are expected to be intelligent, communicative and stimulating in order to enhance our creativity, reveal opportunities and open new vistas of uncharted frontiers (Abraham & Boone, 1994; Shneiderman, 2002).

To address this challenge in information systems research, we build on the concept of *generativity* and develop two corresponding design considerations: *generative capacity* and *generative fit*. In bold, broad strokes, *generative capacity* is an attribute of a person, which refers to one's ability to reframe reality and subsequently to produce something ingenious or at least new in a particular context. And *generative fit* is an attribute of a system, which refers to the extent in which a particular information technology artefact, or part thereof, is conducive to evoking and enhancing that generative capacity in people. We submit that systems with high generative fit help people to realize their generative capacity. In other words, a system with higher generative fit is more conducive to innovative results. We suggest that a thorough study of the two interrelated concepts and subsequent operationalizations can guide systems designers who aim to enhance creative work, unstructured syntheses, serendipitous discoveries, and any other forms of computer-aided tasks that involve unexplored outcomes, expect fresh design alternatives, or aim at boundary spanning results. The concept of generative fit extends the current understanding of the fit–performance relationship in the context of information systems research and helps to update our body of knowledge with the requirements of contemporary computing.

In the next section, we explore the notion of generativity, review its theoretical background in the context of the social sciences and provide a working definition of generative capacity. Then, in the subsequent section, we briefly examine the role of fit in information systems research, position 'generative fit' in that context, explain its role and impact on performance, and provide key design considerations that enhance generative fit. Moving on, we review briefly the research on creativity and position generative capacity and generative fit in that context. Finally, we demonstrate our thesis with an illustrative vignette of good generative fit, and conclude with ideas for further research and final thoughts.

THE CONCEPT OF GENERATIVITY

Generativity is defined generally as an ability or capacity to generate or produce something (Webster, 2005). It refers to an evocative power or aptitude that can result in producing or creating something (Weick, 2007). In natural language, to generate is to bring into existence. According to Webster's Dictionary, to *generate* means to produce something concrete (e.g. to generate electricity), to originate abstract concepts (e.g. to generate ideas), to be a source or cause inspiration (e.g. to generate enthusiasm), or to reproduce (e.g. to give birth to a new generation). Generativity emphasizes a productive capacity that focuses on creating something that is beneficial and desirable. Cook & Brown (1999) used the generative dance metaphor to portray how knowledge is produced and reproduced: 'the generative dance entails productive inquiry in a substantial and robust sense: it is not only productive as a team is productive when it meets a preset quota; it is truly generative. By this we mean that it is a source of innovation, of productive change as when a team invents new ways of working more effectively' (p. 393). We examine several formative instances from various disciplines in which the term 'generative' was used in conjunction with theory development (see summary in Table 1) and then develop its application to information systems.

The concept of generativity has been applied time and again in the context of the social sciences. Erikson (1950) examined *psychosocial generativity* as a psychological concern and

Table 1. Formative theories that apply the generativity concept in various disciplines

Discipline	Theory	Generative facet
Psychology (Erik Erikson)	Psychosocial generativity	The drive to rejuvenate; to reproduce; to nurture and guide the next generation.
Linguistics (Noam Chomsky)	Generative grammar	A finite set of rules that generates infinite syntactical configurations.
Organization science (Donald Schön)	Generative metaphor	Figurative descriptions of social events that shape the attitudes and behaviors toward them.
Social psychology (Kenneth Gergen)	Generative capacity	The ability to challenge the status quo and to transform social reality and social action.
Architecture (Christopher Alexander)	Generative schemes	A simple recipe that allows creating a well-built artifact that is adjusted to its unique context.
Computer science (John Frazer)	Generative evolutionary design	Generating multiple disparate sets of design alternatives that may be inspiring to designers.
Social studies (Danielle Zandee)	Generative inquiry	A recurring hermeneutic process that generates theoretical quantum leaps.

a vital aspect of adulthood. The psychosocial stream treats generativity not as mechanical reproduction but rather as regeneration. Psychosocial generativity is a human need for continuity and rejuvenation through the next and hopefully further refined generation.

Chomsky (1972) introduced generativity to linguistics with *generative grammar* that refers to the deep structure of language underlying the richness of any natural language and its infinite expressive capacity. Just as the four building blocks of DNA can produce infinite configurations of life forms, for linguists a finite set of rules that define the deep structure of a language can generate infinite syntactical configurations. Generative grammar implies infinite and ever-growing possibilities.

Schön (1979) discussed the role of *generative metaphor* as a mechanism in which one changes perspectives on the world and gains new insight. In a similar fashion, Morgan (1986) with *Images of Organization* applied the principles of generative metaphor to the study of organization and organizational forms. The metaphors we use are fateful. Through our pre-suppositions and metaphoric language we largely create the world we later discover. Generative metaphors have a transformative power because they shape the images we envision, and in turn, the images of the future guide our present artefact and actions. A generative metaphor has the power to reconstruct our social reality and consequent action.

Gergen (1994) introduced *generative capacity* as a characteristic of a radical boundary-spanning theory that can provoke and transform social reality and social action. Generative capacity, he argues, is 'the capacity to challenge the guiding assumptions . . . to raise fundamental questions . . . to foster reconsideration of that which is taken for granted, and thereby to generate fresh alternatives for social action'. Generative capacity refers to the ability of a theory or idea to challenge the status quo and to help people think out-of-the-box and to imagine the unimaginable.

Alexander (1996) identified and classified *generative schemes* as DNA-like building blocks of architectural design. Generative schemes are sets of simple recipes that allow anyone with basic skills to create or put together successfully a well-built artefact or building object, such as a four-legged table, an arched door or a barn. The simple instructions always generate infinite variations because the 'generative scheme, always generates structure that starts with the existing context, and creates things which relate directly and specifically to that context' (Alexander, 1996). Their ability to rejuvenate and readjust to the changing environments and needs makes generative schemes timeless patterns in the deep structure of the human experience.

Frazer (2002) presented *generative evolutionary design* for computer-assisted generation of possible solutions for ill-defined (Simon, 1969) or wicked (Buchanan, 1992) problems. Contrary to the common problem-solving practice in computer science in which a computer-assisted-design target is specified by predefined parameters, 'generative evolutionary design' is focused on the generation or discovery of multiple new design alternatives that evolve from one another into unique and unexpected solutions. The generative design algorithm may be tuned for either triggering possible design alternatives that are potentially inspiring to designers or alternatives whose main purpose is to challenge an *a priori* given design (Janssen, 2006).

Zandee (2004) proposed *generative inquiry* as a transformative process that offers an alternative to the rationally-structured theory development that is commonly used in social studies. Generative inquiry is a recurring hermeneutic process in which we reflect on experiences, and in turn, experience the effect of that reflection. This cyclical and self-perpetuated process gravitates between reflection and experience, thereby shifting our attention from the socially constructed logical rationalism into a space grounded in visceral experiences and a paradigmatically loose reflection. This, in turn, can help us to overcome the gravity of the dominating paradigmatic thinking, which eases the way for the emergence of theoretical quantum leaps. Generative inquiry offers a revitalization process of our epistemic stance that can redefine our personal, professional, collective and social existence.

The above review reveals a multitude of closely related conceptualizations of generativity that were applied in various branches of the sciences. In sum, *generativity* refers to a capacity for rejuvenation, a capacity to produce infinite possibilities or configurations, a capacity to challenge the status quo and think out-of-the-box, a capacity to reconstruct social reality and consequent action and a capacity to revitalize our epistemic stance (Table 1).

In this study we explore the notion of generativity, or more particularly, the concept of generative capacity in the context of human–computer interaction and systems design. Building on the various conceptualizations above, we submit that **generative capacity comprises the ability to rejuvenate, to produce new configurations and possibilities, to reframe the way we see and understand the world and to challenge the normative status quo in a particular task-driven context.** Although in this paper we refer to generative capacity exclusively as an attribute of people, the concept can be adapted also to non-humans (e.g. artificial intelligence or smart agents, as per the work of John Frazer and his associates on Generative Evolutionary Design).

In this paper, we focus on theorizing how information technology-based systems can support generative capacity in people. We offer the term *generative fit* to denote the extent to which an information technology-based system is designed to complement, bolster and enhance the inherent generative capacity of its users. Next, we discuss the idea of generative fit and position it in the context of human–computer interaction and systems design.

GENERATIVE FIT IN THE CONTEXT OF INFORMATION SYSTEMS

This link between fit and performance is explored below by examining three types of fit: physical, cognitive and affective. Given an understanding of the three types of fit and their interdependence, we add a fourth type of fit, namely generative fit, which is the focus of this paper.

Rooted in population ecology and the contingency theory tradition (Van de Ven, 1979), the idea of 'fit' plays a central role in theories that focus on the interaction between humans and computers. Differences aside, the ubiquitously held concept of fit maintains that matching (i.e. fitting) the human–computer interface to the attributes of a user and an underlying task at hand enhances performance, whereas user and task characteristics are commonly assumed to be relatively fixed or stable. Human Computer Interaction research focuses on investigating fit, its relationship to attributes of information technology, and how fine-tuning fit can enhance task performance. Thus, the effect of fit on performance is the fundamental cause–effect relationship under investigation.

So far, fit has been conceptualized mainly as physical fit, cognitive fit and recently affective fit, too (Te'eni, 2006). To provide a context in which we can position generative fit, we describe these three types of fit in broad strokes, as follows: *Physical fit*, such as ergonomic designs, allows for comfortable operation and ensures minimal physical effort to accomplish a task while tending to a user's overall well-being (Buxton, 1986). Similarly, *cognitive fit* minimizes the cognitive effort needed to understand the requirements of a given task and subsequently to perform it. Cognitive fit seeks to match the information representation displayed to the user's mental model of the task demands. Assuming that users are guided by their particular mental model, it is theorized that a consistency between their mental models and the computer representation of task-related information reduces the propensity for error and reduces the effort and time required to complete the task (Vessey & Galletta, 1991). Parallel research efforts that do not use explicitly the term cognitive fit have also shown that incongruence between task demands and display hinders performance (e.g. Jarvenpaa, 1989). Lastly, *affective fit* can be conceptualized as the interface design considerations that promote the user's positive affect, or in a more generalized form, the fit between a system interface and a user's desired affective state (Isen, 1993; Fredrickson, 1998). Whereas affective fit per se is still an unexplored territory, its significance is becoming apparent. Recent work emphasizes the role of emotions in computing (Norman, 2004) and the importance of positive affect as an integral part of HCI research and teaching (Picard & Klein, 2002). Indeed, elements of affective fit are considered in people-oriented systems design methodologies such as participative design (Ehn, 1989), value sensitive design (Friedman *et al.*, 2006) and the like. Furthermore, there is growing evidence of the significant and substantial negative effect of stress and strain on performance of software developers (Chilton *et al.*, 2005). In conclusion, physical, cognitive and affective fit are complementary views of systems design that are geared primarily towards the enhancement of task performance and, in some cases, out of care for the well-being of the users.

So far, task performance, the outcome of good fit, has been conceptualized and operationalized in the literature mainly with task-related efficiency-based criteria (e.g. measures of task efficiency, accuracy or productivity). Other kinds of performance criteria such as user's overall well-being, minimizing health hazards or enhancing positive affect have been examined, but the lion's share of the relevant research focuses on task-related efficiency-based criteria. In this study, we too concentrate on task-related performance and argue that the prevailing efficiency-based criteria alone do not provide sufficient understanding of the design requirements in today's wide array of information systems.

We focus on task-related performance and submit that it has two unique components. One component of performance is *operational efficiency*, and the other is *generative capacity* (see Table 2). Operational efficiency is the kind of task performance that is usually observed in the literature. It relates to well-articulated tasks with low ambiguity, finite in nature and in which one

Table 2. Juxtaposing two task-related performance types

Dimension	Operational efficiency	Generative capacity
Cognitive process	Convergent	Divergent
Nature of task	Low ambiguity	High ambiguity
Boundary of task	Restricted	Open-ended
Nature of outcome	Known in advance	Unknown, at least in part
Desired Action/process	Follow procedure	Be creative, innovate
Orientation of outcome	Close gaps	Open gaps
Success criterion	Efficiency, accuracy, punctuality	Making a difference, rejuvenating

is expected to be efficient, accurate and on time. Generative capacity, however, relates to one's ability to deal with unclear tasks with high ambiguity, open-ended in nature and in which one is expected to be innovative, expansive and make a difference.

Whereas for some tasks operational efficiency is critical and generative capacity is counterproductive (e.g. tasks related to manufacturing control systems), for other tasks operational efficiency is not relevant and generative capacity is critical (e.g. tasks related to scenario planning). However, other than in some extreme cases, most tasks require a certain blend of both operational efficiency and generative capacity, as described in the following section.

These two extreme instances can be articulated using J. P. Guilford's (1967) schema of convergent thinking and divergent thinking as the fundamental typology of a human approach to problem solving. Whereas convergent thinking refers to an analytic mode focusing on deductive generation of a single optimal solution to a set problem, divergent thinking refers to a fluid synthetic mode focusing on creative generation of multiple disparate answers to a set problem (Guilford, 1967; Guilford & Hoepfner, 1971). Therefore, the first instance represents a fundamental need for *convergent action* that requires users to be concrete, accurate, effective, fast and with little or no deviation from standard operating procedures. The other instance represents a fundamental case of *divergent action* that requires users to be imaginative, creative, innovative, provocative and with little or no conformism (see Figure 1).

The extent of each component, i.e. the extent of desired *operational efficiency* and *generative capacity*, may differ according to the characteristics of the underlying task. In extreme instances, only one component is desirable and the other is not relevant and may be even counterproductive (Points 1 and 5 in Figure 1). However, in most cases, the underlying task requires a blend of both operational efficiency and generative capacity, as described in Figure 1. Whereas Points 1 and 5 in Figure 1 represent the two extremes, Point 3 represents special cases in which both operational efficiency and generative capacity are critical for performance (e.g. tasks related to computer-assisted design of a building as described by the illustrative case in the following section). In the same fashion, Point 2 represents cases in which the blend should emphasize generative capacity (e.g. tasks related to Decision Support Systems (DSS) or Executive Support Systems (ESS)); and respectively, Point 4 represents cases in which the blend should emphasize operational efficiency (e.g. tasks related to a keyword search as in the case of a product search in online shopping or a reference search in

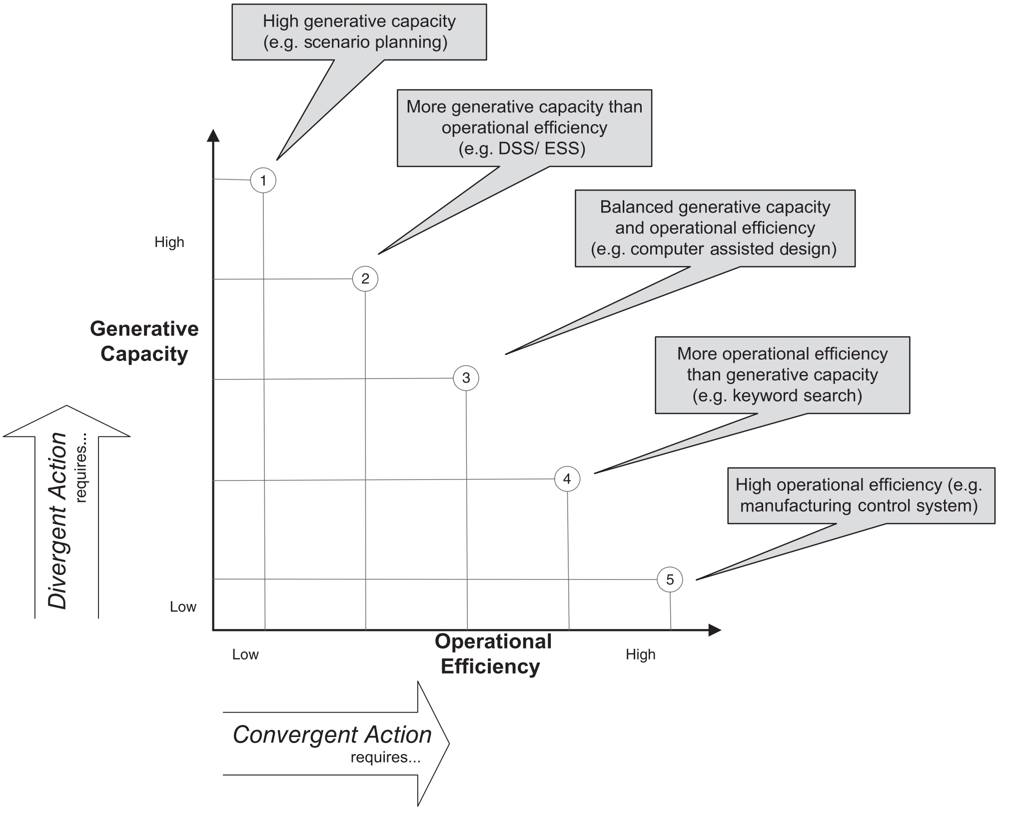

Figure 1. Balancing between the need for operational efficiency and generative capacity based on task characteristics.

a research database). The main concern here is fine-tuning the blend of operational efficiency and generative capacity for the particular task characteristics. Complex systems or systems with many variants such as knowledge management systems or data mining systems should be assessed for the right blend on a case-by-case basis.

We have already discussed the effect of fit on performance and explored the role of generative capacity vis-à-vis operational efficiency in various types of desired outcome. The final building block that requires further elaboration is the kind of fit that enhances generative capacity. Thus and for simplicity and consistency's sake, **we define generative fit as the extent to which the functionality and process support of a (computer) system are designed to complement and enhance one's innate generative capacity in a particular task-driven context. Therefore, generative fit enhances the human resources needed in the production of new, ingenious, task-driven output configurations.**

In the next section, we discuss the differences between generative capacity and creativity to provide further insight into the richness of generativity and its potential added value in systems design. The discussion highlights the advantages of generative capacity and generative fit in providing superior foundations for designing systems that are conducive to innovative work.

CREATIVITY AND GENERATIVE CAPACITY

Although both generative capacity and creativity are associated with innovation, the two concepts are different in nature. In the following section, we position the concept of generative capacity in the context of creativity research and review the merits of considering generative capacity and generative fit for designing information systems.

There is a broad range of studies and views on creativity in the social and cognitive sciences, but so far a clear holistic framework has not emerged to unite them (Sternberg, 2002; Kaufman & Sternberg, 2006). Nonetheless, it has been generally agreed that research on creativity can be classified into four main domains: creativity as a human trait or dispositional characteristic of a person, creative environments or climates, creative processes and tools and creativity as a trait of outputs of all sorts and degrees of abstraction from a concrete product to an idea (Rhodes, 1961; Sternberg, 1988). Each of these domains represents a different interpretation of the notion of creativity.

Creativity research in the information systems field is built mainly on the social and cognitive sciences as reference disciplines and consequently has inherited their fragmented theoretical underpinnings, as demonstrated for example in MacCrimmon & Wagner (1994); Fagan (2004). Research on creativity in the information systems field falls generally into the following four sub-areas: (1) creativity during the system analysis, design and development processes and creative attributes of information technology employees (e.g. Couger *et al.*, 1993; Nambisan *et al.*, 1999; Cooper, 2000; Tiwana & McLean, 2005); (2) The effect of DSS and Creativity Support Systems on creative decision-making of individuals (e.g. Elam & Mead, 1990; Abraham & Boone, 1994; Massetti, 1996); (3) The effect of Group Support Systems (GSS) and Group Decision Support Systems (GDSS) on creative problem solving in conventional groups (e.g. Dennis *et al.*, 1996; Garfield *et al.*, 2001; Hender *et al.*, 2002); and (4) The effect of computer-mediated collaborative technologies on the production of creative outputs by members of distributed groups or virtual teams (e.g. Boland *et al.*, 1994; Ocker *et al.*, 1996; Majchrzak *et al.*, 2000; 2004; Malhotra *et al.*, 2001).

Problems with the current conceptualization of creativity in information systems research

Although there is a general understanding about the main building block of creativity as a phenomenon of study (i.e. person, environment, process/tools and output), there is no consensus about the exact relationships among them (Santanen *et al.*, 2002), let alone their relationships with other key constructs in information systems (Couger *et al.*, 1993). This can turn sometimes into a misconception of fundamental relationships leading to research design flaws and ambiguous or invalid conclusions about creativity acts (Wierenga & Bruggen, 1998).

In the basic model that assumes a creative person (or group) producing a creative output, human traits are modelled as the antecedents (i.e. independent variables) of a creative output (i.e. dependent variables). The role of information technology in this basic relationship is the focal point of creativity research in the information systems field. However, with no clear overall understanding of the mechanics of creativity, the exact role of information technology in that context has been left ambiguous too. Information technology may be modelled as a moderator if it is seen as having an impact on a creative process of a person or a group. It may be modelled as a mediator if it is seen as a medium that transforms and transmits the creative act of a person or a group to the output. Moreover, in the case of artificial intelligence and other types of smart agents, information technology can be also modelled as an antecedent or source of a creative output.

With no general theory of creativity and given the complexity of the underlying domain, most studies focus on a partial subset of interest and leave the rest in the shadow, subject to speculation or arbitrary assumptions. For example, Wierenga & Bruggen (1998) urge scholars to make a clear distinction between creativity as a human trait and creativity as an output trait. Their plea is still relevant, although they too take a narrow view of creativity and disregard the influence of both environmental factors and process-related factors in that context.

Finally, the bulk of creativity research in the information systems field focuses on the effect of creativity support via information systems upon work in organizational settings. However, in spite of the vast variety of possible tasks and desired creative outputs in organizations, their operationalization in information systems studies, irrespective of methodology, has been often a certain decision-making task. Reducing all creative acts to decision-making tasks is problematic for two reasons. There are other kinds of tasks that require creativity in the organizational context, let alone outside the organizational realm (e.g. design-oriented tasks). Furthermore, analytical decision-making is merely one part of a manager's job; the other part involves idea generation, form-giving and innovation design (Boland & Collopy, 2004). Ironically, the creativity support systems that one might believe to be built primarily to enhance syntactical processes that resemble design thinking and attitude, have been treated in information systems research as decision support systems that inherently focus on analytical processes.

The relationship between creativity and generative capacity

Based on an exhaustive review of published definitions of creativity, Couger (1996) identified two recurring characteristics: 'newness and uniqueness' and 'value or utility'. The focal point of that notion of creativity is *the* creative *output*. In contrast, generative capacity refers to the potential or ability of a person (or a group) to produce new configurations and the like as defined earlier. The focal point of that notion of generative capacity is the *potential to produce* creative output. Therefore, the discussion of creativity, or even the conditions conducive to creativity, is inherently constructed around an anticipated outcome. In contrast, reframing the discussion around generative capacity shifts the attention to the underlying source or origin of innovation and provides unequivocal insight into its root cause. This is more than a shift in language; it is a shift in focus – for while the discussion of creativity is geared toward a finite end-result, the discussion of generative capacity is focused on the perpetual and life-giving sources of innovation. As the discourse drives action and consequent innovation into a respective path, this is a shift in standpoint that can revitalize the study of innovation and the practice of designing systems that support creative acts.

Another indication of the alignment between generative capacity and the notion of creativity is the practice of using idea count, and to some degree, idea quality assessment as surrogates of creative output. Idea count is the most common operationalization of creative output in the creativity support literature, especially in studies that examine the effect of DSS, GSS or GDSS on decision-making and problem solving tasks, as demonstrated by MacCrimmon & Wagner (1994). Idea quality assessment is also common but less frequently measured in comparison to idea count. If it is generally agreed that ideas are the indicators of creative outcome, then generative capacity should be acceptable as the source of such outcome by default.

Moreover, making the implicit explicit by directly examining generative capacity instead of various other alternative operationalizations, may help in reducing the complexity and ambiguity that is currently built into the concept of creativity and its measurement. Given that generative capacity encapsulates the source of creativity both as a human trait and as an output product trait, it can be standardized and utilized across various research environments.

Adopting the concept of generative capacity will build close links to unexplored reference disciplines. The divergent mode of generative capacity aligns it with Design Theory and ‘design attitude’ (Boland & Collopy, 2004), which have close ties and a long history with creativity and its environment. In addition, building on the concept of generativity enables related information systems research to tap into a rich tradition of formative works that also employ the concept in other disciplines, as explored earlier in the paper. Broadening the range of reference disciplines available for information systems research on creativity is likely to inspire new ideas and have a transformative impact on the field.

Moreover, the assessment of generative fit, the information technology-related counterpart of generative capacity, can provide a distinctive test of the potential contribution of products or processes to creative activity. Consider the following two innovations:

> The iPod is a brand of portable media players that was launched by Apple in 2001. Most of the iPod devices are designed mainly for playing audio. The iPod’s unique user interface and its ease of use together with a seamless infrastructure of complementary services have made it the world’s best-selling digital media player and its worldwide mainstream adoption made it one of the most popular consumer brands. Just as with Sony’s Walkman in 1979 (Sony History, 2007), the iPod has revolutionized the way music is distributed and consumed both on individual and industrial levels.

The iPod is a platform that enables users to store and replay digital media files; it has a low generative fit because it does not allow users to create anything new, other than perhaps to organize the files in unique play lists.

> Second Life (http://www.secondlife.com) is a 3-D virtual world entirely built and owned by its residents, currently over 5 million individuals from around the globe. In Second Life one can

> create anything imaginable with powerful, highly flexible building tools and a simple, intuitive interface. Creating new artefacts is easy to learn, yet robust enough to allow one to reach the limits of his/her inspiration without curtailing creativity. No separate tools or applications to buy or learn are necessary. Since its debut in 2003 and building on a fully integrated economy designed to reward risk, innovation and entrepreneurship, Second Life grows exponentially on every parameter from economic indicators of growth to the extent of institutional investments and volume of social interactions.

Second Life is an adaptive platform that enables users to keep building upon it new ingenious configurations in pursuit of their objectives – every object in Second Life (e.g. person, tool, place) can be easily transformed if desired and new objects are envisioned and built routinely by users. Thus, it has high generative fit.

At first glance, both the iPod and Second Life appear as similarly innovative platforms that can be characterized as disruptive and radical innovations (Dewar & Dutton, 1986). However, while the iPod enables merely a passive consumption of produced media, Second Life encourages the creation and recreation of new personalized configurations that extend its own boundaries. The creative design of the iPod is a boon for music fans who want to listen to music, but not for those who want to generate new tunes. In contrast, the generative design of Second Life inspires and empowers involved users across the board to get engaged and build something new. Both are creative, but only Second Life is a generative platform.

SYSTEMS DESIGN CONSIDERATIONS

We have argued that people's generative capacity is a source of innovation and that generative fit encapsulates characteristics of (computer-based) systems that enhance and complement that capability. In this section, we take a step further and share insights regarding generative design considerations, that is, the design considerations in developing systems or platforms for high generative fit.

The lion's share of the literature that discusses the conditions conducive to innovative processes emphasizes features of a work environment or a personality that promote one's creativity. For example, motivation, autonomy, work settings, climate, workload and personal characteristics (Amabile, 1983), (Amabile *et al.*, 1996a,b), (Stenmark, 2005). Considerations also include wider scope determinants of innovation such as organizational vision (Swanson & Ramiller, 1997), technological infrastructure (Broadbent *et al.*, 1999) or institutional factors (King *et al.*, 1994). However, there is not much attention to the desirable features of information technology-based systems in that context and particularly to requirements for systems that fit them for innovative processes.

Some studies have examined how information technology can support creativity. For example, Greene (2002) suggests that creative outputs may benefit from computer applications that support the following: easy exploration and experimentation, engagement with content to promote active learning, functionality for knowledge processing, collaboration,

Table 3. Generative design directives and features with illustrative examples based on a 3-D CAD system.

Generative design directive	System feature	Illustrative contribution to generative fit
System should be evocative	Visualization	Digital 3-D representations of building construction plans allows vivid views of any architectural or structural objects from any angle or point of view.
	Simulation	Simulation of smoke spread in case of fire; simulation of snow accumulation on various roof shapes; simulation of temperature build up.
	Abstraction	Zoom in/out – from the widget level to complete building view.
	Integration	Integrated Virtual Prototyping system allows overlay of cross-domain drawings with no regard to craftsmanship boundaries.
	Communication	Support of cross-domain exchange and sharing; everybody has access to all drawings.
System should be adaptive	Customization	Customized interfaces for various work types, work environments and personal preferences.
	Automation	System recalls last view; system provides selective set of screen tools.
System should be open-ended	Peer-production	Extensible system – partners in engineering companies can build their own extensions.
	Rejuvenation	Open development standards; easy upgrade path.

iterative work, trial and error and domain-specific actions. These seven characteristics overlap with similar features that were recommended later by Shneiderman *et al.* (2006). Given the inherent relationship between generative capacity and creativity our conclusions have some overlap with the above literature. However, these studies differ markedly from our work because they refer specifically to creativity while we build our thesis in reference to generative capacity. Moreover, they provide loose sets of criteria while we provide an integrated framework based on top-level directives.

Building on our thesis on generative capacity and its potential contribution to information systems design, with support of studies on the effect of knowledge sharing in communities of practice, the impact of information technology on socio-technical systems and current experience with building technology-intensive computer-based innovative design environments (Brandon, 2004), we offer three broad design directives for generative designs: they should be evocative, adaptive and open-ended. For each of the three design directives we propose several operable features that contribute to generative fit, as summarized in Table 3.

Generative design is evocative

A system with high generative fit inspires people to create something unique. It evokes new thinking and enables them to translate their ideas into a new context. information technology can help toward creating the environment or conditions that are prone to those insights by generating and juxtaposing *diverse frames* that are not commonly associated with one another within an underlying context (Sternberg, 1988). There are several ways to generate or elicit diverse frames using information technology, as demonstrated below:

Visualization

Systems should incorporate human-centred visualization tools that enable seeing multiple dimensions (Shneiderman, 2002). That is, 3-D digital images of physical objects and visual representations of various facets of less tangible parameters such as the characteristics of networks, hierarchies, processes and the like. Visualization provides the ability to see an object from multiple perspectives and to search for new insightful points of view.

Simulation

Systems should incorporate human-centred simulation tools that enable testing an object or a process or part thereof in multiple situations. This refers to the underlying process or object's behaviour, its dynamic capabilities or response to particular stimuli in different contexts (Gokhale, 1996).

Abstraction

Systems should incorporate human-centred abstraction tools that enable examining objects or processes at multiple degrees of granularity. Increasing or decreasing granularity enables one to distinguish between the situated features of a task or object and the fundamental characteristics that define it. The ability to move swiftly between levels of granularity is essential for identifying emergent patterns, commonalities and anomalies (Srinivasan & Te'eni, 1995).

Integration

Systems should incorporate human-centred integration tools that enable aligning exclusive yet related domains, objects or processes in multiple overlay configurations. Integration refers to one's ability to overlay or merge views of various parallel subsystems or crosscuts of objects that are associated with different core domains, disciplines, practices or organizational units which are traditionally or institutionally unrelated. Supporting the ability to overlay traditionally unrelated subsystems or objects through integrated platforms provides much insight about interoperability between heterogeneous systems and promotes system-wide boundary crossing, across-the-board sharing and cross-fertilization (Boland *et al.*, 1994).

Communication

Systems should incorporate human-centred communication tools that enable sharing of multiple points of view. In this case, communication refers to one's ability to talk and share information with other actors and stakeholders with no regard to institutionally imposed boundaries. Communication tools enable cross-fertilization through sharing of information, participative action, ad hoc and ongoing cooperation and collaborative work practices (Wasko & Faraj, 2000). An extended notion of communication tools includes ubiquitous access and fast connectivity to shared knowledge-based repositories.

Generative design is adaptive

A system with high generative fit can be used by a diverse set of people in their own respective environments and for various tasks within an intended scope. It is adaptive with respect to the type of users or groups it serves in diverse problem spaces. It is also simple to understand and easy for anyone to master. Information technology can help by creating adaptive systems or platforms that are flexible yet powerful, to enable the generation of new configurations. Two main IT-enabled features drive the systemic flexibility and adaptivity that are required for generative fit, as follows:

Customization

Systems should incorporate tailorable facilities and customization tools that enable user-induced adaptation (Mackay, 1991; Tam & Ho, 2006; Germonprez *et al.*, 2007). As it is impossible to design systems that fit all users and all situations, the incorporation of tailorable facilities affords systems where one's actions are not dictated through narrowly defined rules of engagement or training on how the technology ought to be used. In contrast, using built-in customization tools allows users to play an integral role in the modification of the technology in the context of its use. Technology tailoring should be a native concept in generative design to allow users to redefine continually the services they need and to customize them according to the use patterns of their choice.

Automation

Systems should incorporate artificial intelligence that enables system-induced adaptation (Weiser, 1993). Although customization tools provide much value, they also require users' attention in response to change in use pattern, environment and the like. Designing adaptive systems that incorporate continuous learning and improvement based on codified use patterns and other performance measures allows users to shift resources from system operations to generating the desired outputs.

Generative design is open-ended

A system with high generative fit can generate a virtually infinite number of configurations. It is inherently open-ended because it is evocative and because it is adaptive. That is, by design, high generative fit already provides the foundations for generating endless configurations by many. Information technology can help to enhance regeneration and future configurations, and thus contribute further to the long-term vitality and sustainable generative fit of the underlying systems. Two information technology-enabled features enhance open-endedness and subsequently the generative fit, as follows:

Peer-production

Systems should incorporate peer-production facilities, that is, the means that enable any individual or group to produce and share at their own volition new and useful extensions of products or services (Schultze *et al.*, 2007). Peer-production promotes innovation through collective action that yields chains of uncoordinated successive evolutionary changes in response to market demands and emerging opportunities. Peer-production becomes possible only in a technological environment that is designed *a priori* with an extensible architecture and a social environment that affords the necessary incentives and normative support. For example, the architecture of internet browsers encourages the development of plug-ins or add-ons by unaffiliated third parties, and the architecture of Wikipedia encourages contributions of knowledge objects and a stream of continuous updates and refinements. Both platforms are examples of an extensible architecture and a design strategy that counts on peer-production for continuous development and growth.

Rejuvenation

Systems should incorporate a modular architecture in support of renewal processes. Renewal refers to building an integrative path for continuous fine-tuning as well as radical innovation. The degree of modularity pertains to the embedded reconfigurable flexibility of its components and corresponds to the inherent coupling among them. For example, open source applications are designed with a modular architecture that affords easy reconfiguration and upgrade path.

In summary, systems that are evocative, adaptive and open-ended can be characterized as systems with high generative fit. We have also described operable system features that can contribute to generative fit. These design considerations are summarized in Table 3 and illustrated in the next section with a vignette on information technology-enabled 3-D digital representation that enhances the generative capacity of architects, engineers and construction professionals associated with the office of architect Frank O. Gehry.

AN ILLUSTRATIVE VIGNETTE OF GENERATIVE FIT

The unparalleled successful adoption of information technology-enabled 3-D digital representation in the office of architect Frank O. Gehry is a good illustration that demonstrates the concepts of generative capacity and generative fit. The vignette is based on interviews (with various internal and external stakeholders) that were conducted in the course of a study about networks of innovation in architectural design and construction firms. An elaborated description of the study is available in Boland *et al.* (2007). We sought to illustrate our theoretical conceptualization of generative capacity and generative fit using their account. Considering the exploratory nature of this paper, we only highlight key points from their study to make a concrete illustration of our thesis and not to provide evidence for verification.

The vignette is based on 66 interviews that aimed to reveal how the various actors related to Gehry Partners experienced the newly implemented digital 3-D representation; how it affected their information-sharing practices; how they adapted to the changes that resulted; how it made a difference in their work practices; and how their associates and affiliates (e.g. contractors, regulators, clients) adopted and appropriated the new digital 3-D representations.

In comparison to the traditional 2-D blueprint drawings, the widely used 2-D computer drawing applications such as AutoCAD contribute to enhanced operational efficiency through improved drafting productivity, decreased errors, reduced communication cost and employment of de-skilled workforce. The productivity gain of these applications is attributed mainly to its ability to reuse design objects. With 2-D computer drawing applications, architects tend to recycle design objects from a previous project in order to save time. These applications are also limited in their capacity to handle complex objects. Consequently, in large-scale buildings, architects using 2-D CAD systems tend to use simple design elements that repeat in a monotonic fashion, as illustrated in Figure 2. Therefore, the more they rely on 2-D computer drawing applications (as opposed to hand drawing), the less they create original design content in a given project (Mitchell, 2004). Thus, whereas 2-D computer drawing applications are designed with efficiency-based criteria in mind and are geared toward convergent action, they also inhibit generative capacity.

The utilization of software packages such as CATIA and Rhino for digital 3-D representation in the Architecture, Engineering and Construction (AEC) industries constitutes a dramatic departure from the frequently used 2-D computer drawing applications. In contrast to drawings, the 3-D CAD applications allow full visualization of the building designs in any scale and any level of details. Architects can move quickly back and forth between images of the entire building from different perspectives, its sub-sections and particular details of electrical, mechanical and other design elements. This added flexibility allows the architect or any other user to make iterative changes or just try new configurations quickly and with a fraction of the effort that would have been required to do the same with 2-D CAD applications. In this case, we identify both high operational efficiency and high generative capacity. The latter is largely achieved by the high generative fit that stems from tight integration and superb visualization. The combined operational efficiency and high generative capacity allows for large-scale projects with complex designs, as illustrated in Figure 3.

The 3-D CAD is based on Integrated Virtual Prototyping which means that everyone works on the same model and the same set of plans, as opposed to the old way in which each contractor or stakeholder would have only their own custom-designed subset. Having to work together with the integrated virtual prototyping stimulates cross-fertilization and exchange of ideas which turns into a more creative, more innovative and more efficient design.

Furthermore, in the 2-D CAD, the measurement of each construction object is done relative to other nearby objects within a grid of points that is pre-specified by the architect and marked

Figure 2. A product of 2-D CAD.[1]

Figure 3. A product of 3-D CAD.[1]

on site by a surveyor. However, with 3-D CAD representations the measurement of each construction element is specified by the Euclidean coordinates <x, y, z> of its spatial location relative to one absolute point. Moving from a relative to absolute measurement model reduces significantly the possibility of propagating measurement errors, thereby increasing the project's operational efficiency.

Finally, the complex design elements and continuous change at all fronts motivate constructors to experiment with new materials, new construction techniques, and new work practices, which in turn leads to further innovation.

We define generative capacity as the ability to rejuvenate, to produce new configurations and possibilities, to reframe the way we see and understand the world, to think out-of-the-box and to challenge the normative status quo. As illustrated in Table 3, the implementation of digital 3-D CAD application has without doubt enhanced every aspect of generative capacity at Gehry's office, and at the same time also reinforced its operational efficiency.

IMPLICATIONS FOR FURTHER RESEARCH

While the conceptual definitions of fit in the context of information systems are intuitively agreeable, behaviour fit and defining it operationally are highly contentious issues. Most researchers do not explicitly model the role of fit, although most diagrams present 'fit' as an intermediary variable leading to improved performance. The best-known conceptualizations of fit in information systems are cognitive fit (Vessey & Galletta, 1991), organizational task–technology fit (Goodhue & Thompson, 1995) and particular task–technology fit (Zigurs & Buckland, 1998). Although all three treat fit as an intermediary variable affecting performance, the specific mechanism by which fit intermediates the effect on performance remains a black

1 Both buildings were designed by architect Frank Gehry using different CAD tools. Fig. 2 is Loyola Law School (1981) and Fig. 3 is Weatherhead School of Management in Case Western Reserve University (2002).

box. Further work is required to shed light on that point in various instances. Explaining how a particular fit variable changes an outcome by intervening in the process leading on to the outcome can provide much insight into effective design.

The proposed conceptualizations of fit in the literature have treated the underlying phenomenon as isolated cause–effect snapshots, as demonstrated in a sample of 37 studies that were examined by Zigurs *et al.* (1999). A single time-point for data collection may work well in simple instances (such as in our previous examples or a controlled laboratory experiment), but it fails to provide a faithful picture of the role of fit in the overall relationship between users, tasks and information technology. Fit, and particularly generative fit, has a clear temporal dimension and a long-term effect on modifying users' behaviour through learning and through its impact on work practices. Thus, contrary to the prevalent practice in information systems research that often relies solely on cross-sectional studies (Avital, 2000), we suggest that the effect of fit is conceptualized and tested in ways that account for its long-term effect on a user's adaptive behaviour.

So far, task performance, the outcome of good fit, has been conceptualized and operationalized in the literature mainly with *task-related* efficiency-based criteria (e.g. measures of task efficiency, accuracy or productivity) and to a lesser degree with *user-related* affective-based criteria (e.g. user's overall well-being, health hazards or positive affect). This study has concentrated solely on task-related performance and, like most of the literature, does not cover user-related criteria. Regardless of the unequal coverage in our study and in the literature at large, we firmly believe that both task-related criteria and user-related criteria are equally important measures of task performance. Building on Csikszentmihalyi's work on creativity as a cultural medium (Csikszentmihalyi, 1996) and the experience of flow (Csikszentmihalyi, 1990), we believe that generative fit has a critical impact on user-related affective-based performance criteria and particularly on the user's well-being. Future work should examine the relationship between user-related criteria and generative fit and generative capacity, and how generative fit can be fine-tuned to enhance user-related criteria such as user's well-being and positive affect.

CONCLUSION

Building on the conceptualization of generativity in social sciences at large, we have contextualized it in the information systems milieu and suggest the two corresponding constructs – generative capacity and generative fit. We submit that generative fit enhances generative capacity, that is, it produces or assists users in the production of new configurations and possibilities, fresh and innovative ideas and out-of-the-box thinking that challenges the normative status quo. Using the vignette on the impact of 3-D representation technologies in the AEC sector, we have illustrated the possible contributions of generative fit and the resulting implications of elevated generative capacity to collective learning, work practices and overall performance.

We have set the foundations for further research of generative information systems and proposed top-level considerations in reference to generative design. Further work should develop measures of generative fit and benchmarks of generative capacity; refine our understanding of generative design; seek ways to enhance generative fit and identify technologies that are conducive to generative capacity; extend the concept of generativity to other interrelated areas of information systems; investigate further the determinants of generative capacity and study its systemic and long-term impacts.

Imagine a technological frontier where people's wildest dreams are about to unfold in a world unlike anything we could have ever imagined. The study of generativity sets course to the development of platforms that enhance creativity, unleash unconventional design, promote innovation and are instrumental in revitalizing our epistemic stance. With generative design, ordinary people can achieve extraordinary results.

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