Creativity in HCI: Exploration of the Research

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Introduction

Over approximately the last 50 years, creativity research has abounded from such diverse fields as psychology, education, engineering, design, cognitive science, and computer science. More recently, the importance of creativity in the field of human-computer interaction has come to light. In the last 15 years or so, there has been an influx of research and resources dedicated to understanding the creative process in general, the impact of creativity on the design of user-centered systems, the outcomes of their use for various groups, and tools which foster creativity. Indeed, one may infer from the appearance of a recent special topics issue of *Communications of the ACM* (October, 2002) on "Creativity and Interface" as well emergence of an ACM-sponsored conference entitled "Creativity & Cognition"[1], that the subject is of increasing interest to human-computer interaction (HCI) researchers and practitioners alike.

Many themes branch out from the broader domains of HCI, creativity, and design of information spaces. Some specific topics frequently examined include artificial intelligence and creative systems, how to study creativity in design, creativity support tools, aesthetics, affective computing, the effect of creativity on teaching, and cognition underlying creativity, among others. This paper reviews the current state of the research in areas pertaining to HCI as related to the domain of creativity and technology and

[1] http://research.it.uts.edu.au/creative/ccrs/

touches upon the following topics: aspects of creativity support tools, art practice, organizational creativity, and creative cognition.

Current Research

Creativity Support Tools

A substantial portion of the recent investigations into the intersections among creativity, design, and HCI has centered on unraveling the ways that technology can support the creative process (Mamykina, Candy, & Edmonds, 2002). Connection of the creative process to such traditional areas of HCI has included forays into such closely-related areas as collaboration in interdisciplinary teams (Mamykina, Candy & Edmonds, 2002), development of tools to enhance creative design (Thomas, Lee & Danis, 2002; Shneiderman, 2002b; Candy & Edmonds, 2000), research into the characteristics of applications that support creativity (Greene, 2002), and studies of agents and creativity in the realm of artificial intelligence (Boden, 1994).

Genex Framework

One prominent HCI researcher to delve into this arena is Ben Shneiderman, who first indicated awareness of the increasing amount of computer-based activity dedicated to "supporting human intellectual and creative enterprises" (p. 17) in *Designing the User Interface* (1998a). Shneiderman proceeds based upon his philosophy that creative environments have in common the characteristic that the users may be experts in their domain of work, but novices in the underlying computer technology necessary for the creative activity. He sees creative environments as those which may include exploration enablers, decision-support tools, and cooperative systems which allow two or more people to work together even if separated by space and time. In light of this vision, Shneiderman has proposed a framework of activities for creative work (2002b). To begin with, he addresses the core issues underlying general HCI research: who are the users and what do they do? He describes potential users of creativity software tools as those who, like any population of knowledge workers, must bypass the so-called domain "gatekeepers"[2] in order to publish or disseminate their artifacts, which are then accepted based upon quality standards. To this end, Shneiderman envisions creativity support tools which will allow users to be more creative more often, and ultimately "straddle domains".

To define user activities that need support, Shneiderman draws from work by Csikszentmihalyi (1996), who stresses the social nature of creativity, as well as the premise that implementable software is a necessity, and finally his previous work on the "genex" (generating excellence) framework (1998b). His framework for creative work, then, encompasses four non-linear activities: collect, relate, create, and donate. The donate portion of this framework is especially interesting as it rests on the notion that creativity artifacts are designed and disseminated in consultation with others, rather than in isolation, a historically popular representation of creative activity. As an aside, Shneiderman also mentions that the World Wide Web is a creativity enabling medium since by its very nature it provides much more efficient access to resources and experts than has ever been possible. This sentiment echoes Siau's (1999) beliefs that information seeking and retrieval is crucial to creativity, and that therefore the Internet, and especially

[2] Domain gate keepers are discussed in Csikszentmihalyi's systems theory approach to creativity. See Csikszentmihalyi (1999) for an extended discussion of this theory.

the WWW is full of possibility for the realization of creative potential via its unique technologies and services.

Shneiderman continues with his framework, proposing methods by which creativity support tools can be integrated effectively into a user's already constructed working environment. Three methods discussed include ease of data sharing via compatible file types and formats, compatibility of action patterns and consistent terminology, and smooth coordination across windows. Data sharing might involve importing particular data from a service site and then manipulating or varying it to fit personal tastes. An example of a fairly low-level action pattern is a word processing sequence such as "cut-copy-paste". Building on this idea, Shneiderman suggests that creativity tools should support higher level sequences such "annotate-consult-revise" or "collect-explore-visualize", even though they will require users to adjust their working styles until these action patterns become standard in applications and interfaces. Shneiderman continues on to propose eight tasks that should "help more people become more creative more of the time". Each task should be considered in light of the domain of work of which it may be a part. The tasks are searching, visualization, relate, thinking, exploring, composition, reviewing, and disseminating. Supposedly, this checklist of tasks should help software designers to develop tools which enable users to be more creative. Finally, Shneiderman addresses the critics who may posit that technology should not attempt to augment creativity, but rather that creativity is a human process that needs no help from computers. To combat this, he stresses that any technology could potentially be used in a manner for which it was unintended, whether that be in a negative or positive way.

Systems he envisions will bring benefits to society at large, although issues of costs and cultural acceptance may slow the progress.

Related to Shneiderman's vision is work by Vass, Carroll and Shaffer (2002), who attempt to provide a theoretical basis for the development of computational problem-solving environments (PSE's) which support creativity. This theory combines classic creativity research in flow theory (Csikszentmihalyi, 1996) and the systems model approach (Csikszentmihalyi, 1999) with the authors' own conception of the creativity workspace which they designate "WorkFlow". Their WorkFlow model supports the Genex (collect, create, relate, donate) framework established by Shneiderman (2000). In particular, the authors are concerned with extending the scope of usability within the realm of PSE's by broadening the concept of usability from one which moves past user satisfaction and reduction of error rates to one which promotes also improvement of a user's end work product.

Collaboration & Knowledge Sharing

Collaborative creativity proponents (Mamykina, Candy & Edmonds, 2002) have put forth their notion of the question that HCI research must answer: "What tools, methodologies, and practices can support creativity of individuals in interdisciplinary teams?" This question is in response to the authors' belief that the past focus in HCI on creativity has been too weighted on an individual's creativity and cognitive processes. Instead, these authors posit that creative activity takes place in a social context that includes "interactions, mentoring, and collaboration in creative work" (p. 96). They cite well-known creativity researchers Amabile (1983) and Csikszentmihalyi (1999) who have, respectively, researched the role of social context in creativity and advocated the systems theory approach to creativity[3]. Characteristics of creative tools the authors believe will enhance collaborative teamwork include provision of support for shared languages, encouragement of communication that will aid understanding of a common vision (e.g. artistic or design vision), engagement in "what-if" sessions, and sharing of knowledge resources. They conclude that tools should support "articulation of creative ideas" and support interdisciplinary exchange (p. 99). As well, they believe that barriers inherent in interdisciplinary collaboration may be also well-addressed by organizational behavior and management researchers and that formation of any creative culture should encompass trust, encouragement, and allow for risk-free exploration and creative investigation.

Creative Process in Context

Candy and Edmonds (2000) also emphasize the larger creative environment and feel that an understanding of the evolution of the creative process is crucial for effective system design. They see the role of HCI in development of technical systems as one which will foster creativity by going beyond the traditional "surface" aspects of HCI such as interface design and programming. Instead, they suggest that researchers must incorporate premises from "creativity in action in the real world" within a two-component "holistic" strategy that develops technology in conjunction with creativity in action. The strategy contains two main ideas: multiple input and outputs, and boundary or special case studies. The inputs and outputs portion dictates that technologies should draw from expertise from key disciplines to generate multiple perspectives and then

[3] The systems theory approach to creativity deemphasizes the mental process of the lone individual. Instead, the theory also accounts for a cultural or symbolic aspect, termed the "domain" as well as a societal aspect called the "field". The system is the intersection of the domain, the field, and the individual. See Csikszentmihalyi (1999b) for an extended discussion of this theory.

widely disseminate artifacts, or outputs. Boundary studies should examine examples of creativity found in unusual work practices. [such as what?]

Greene (2002) also concurs with the idea that the environment in which creative activity is expected to take place is crucial. As in the discussion of collaborative creativity (Mamykina, Candy & Edmonds, 2002), Csikszentmihalyi's (1996) work on the systems approach to creativity is discussed in relation to the broader understanding of creative work. Greene purports that creative activity is judged by some "novel change to a symbolic domain and the production of some artifact judged by domain experts, in some manner, to be creative." (p. 100). An enabling creativity environment should allow access to knowledge that can be easily examined and discussed. According to the author, creativity may be best enabled by computer tools that facilitate the following two levels of creative activity: knowledge gathering, sharing and integration, which in turn leads to idea generation; and provisions of direction and functionality which allow creation of artifacts in a particular domain. The author describes previous work with a system called Explore Modern Art (Jones & Green, 2000), created in collaboration with IBM and the Museum of Modern Art (MoMA). This work led to the generation of a list of computer tool characteristics which are necessary to support creative thinking and generation of creative artifacts.

The author and colleagues ran several user studies over a four-month period of time in which they observed users interacting with the system and kept system logs to refine the list of application characteristics which encourage learning and creative activity. An iterative design process allowed evaluation of the current system and led to redesign and improvements based on user input. Seven characteristics of successful creativity-enabling systems were generated, including notions of risk-free exploration and experimentation, promotion of learning and discovery via engaging content, support for search, retrieval, and classification, support for iteration and collaboration, use of instructive mistakes, and support for required domain-specific actions. In conclusion, the author again suggests that creative acts take place within a larger knowledge environment and that tools that support these activities should allow for learning of and experimentation with that knowledge in order to facilitate the creative process.

Tool Examples

A plethora of tools have been designed or prototyped which are intended to support various creative processes. These tools enable various functions such as designing, sketching and generating ideas, viewing and exploring materials, composing music, creating art, etc. Just a few recent examples of these types of tools are QSketcher (Abrams, Bellofatto, Fuhrer, Oppenheim, Wright, Boulanger, et. al., 2002), C-Sketch (Shah, Vargas-Hernandez, Summers, & Kulkarni, 2001), Side-Views (Terry & Mynatt, 2002a), MACSS (Amitani & Hori, 2002), and EVIDII (Nakakoji, Yamamoto, & Ohira, 1999). QSketcher is an environment for composing music for film; C-Sketch is a collaborative idea generation tool for engineers; Side-Views supports experimentation and exploration of compound solutions by storing multiple versions of data in concurrence with research by Terry & Mynatt (2002b) pertaining to Schön's reflection-in-action theory; MACSS stands for "MAcroscopic Composition Supporting System" which "offers a spatial representation of music to a composer to support his/her composition process" (p. 165); and EVIDII which allows designers to collaborate via association of affective words and images which are transformed into visual representations of the relationships among designers, images and words.

Cautions

Despite the promise of creativity support tools, some research unconnected to HCI in particular has emitted caution about the role of technology in creative environments. Edwards (2000), for example, refers to literature which has investigated the effects of computers on creativity and drawn both positive and negative conclusions. In particular, he cites research from education, including work by Papert (1990), who believes that we should look at the opportunities computers can offer rather than studying the effects computers will have on society (i.e. move away from technocentrism). Other researchers see potential for enhanced creativity via technology, particularly because computers facilitate the generation and exploration of new ideas (Boden, 1994). Still other educators who have investigated the effects of computer-aided instruction (e.g. Bruce, 1989) believe that technology will not have an impact on creativity at all. Edwards (2000) emphasizes the importance of designing the proper human-computer interfaces, referring to applications that "facilitate thought and exploration" (p. 225). If this is accomplished, then through these types of programs, individuals will indeed realize that they are able to control their activities and ultimately expand thought. [WHAT?!]

Technology & Art Practice

One of the major areas in which technology is joined with creativity is that of digital art, a field which has been actively pursued since the mid-1960's (Edmonds & Candy, 2002).

In this domain, expert artists use digital technology in pursuit of their creative endeavors. Increasingly, the trend has been to conduct this activity in collaboration with other artists rather than solo, a shift which is proving beneficial in several facets. Not only are artists now classified as "computer experts" but, according to Edmonds and Candy (2002), along with collaboration arises opportunity for more ambitious creative projects as well as motivation due to increased funding for shared projects. The context in which these artists work is described by the authors as "knowledge work" (p. 91). That is, outstanding creativity[4] arising from serious creative activities is dependent on significant knowledge. The authors make the point that the creative process has been studied extensively (especially in the realm of design), and that it is likely that processes in design practice are likely similar to those in art. Studies of designers in various fields have revealed commonalities across domains in both thinking and working. Apparently, most are "'holistic thinkers,' in the sense they look for an overall broad scope before moving into specific detail" (p. 92). Another important finding is that designers often are solution-led and impose constraints in given design situations to reduce the number of possible solutions. The consensus is that outstandingly creative people appear to be able to shift the constraints in a design situation in order to create the ideal conditions for design. Computer systems designed to enhance creativity should therefore take this into account. Perhaps summing up the entirety of the union, the authors state that, "The use of complex tools, such as computers, forms a significant part of the context in which the conditions for creativity exist" (p. 93). Going further, they claim that computer systems should

[4] Arising from Boden's (1990) work concerning the 'P' (psychological) and 'H' (historical) creative. The authors divide 'H' into levels of 'exceptional' and 'outstanding' creativity. Exceptional creativity is recognized as such only within a domain group. On the other hand, outstanding creativity transcends the domain and becomes recognized beyond the expert community.

enhance the development of an artist's knowledge by facilitating "exploration of ideas, knowledge, and options" (p. 93). Typical important exploration activities elicited from empirical research include: breaking with convention, immersion, holistic view, and parallel channels. These activities in combination should theoretically lead to ideal idea generation for digital artists. Examples of influential digital technology systems are discussed, including Harold Cohen's system AARON, a system that creates drawings and paintings autonomously. As well, Manfred Mohr is an artist who has contributed to the field by way of exploration of visualization techniques, particularly multi-dimensional geometrical displays. In closing, models that attempt to replicate the creative process are discussed, along with their three common threads: exploration, generation, and evaluation.[5]

Organizational Creativity

Much of the HCI-related creativity research pertaining to tools which support creativity has foundations in classic organizational culture literature as well as organizational creativity literature (e.g. Williams & Yang, 1999). According to Puccio, Talbot, and Joniak (2000), creative productivity in the workplace has been an important topic for researchers for many years. As such, the literature on organizational creativity is immense and beyond the scope of this paper. Suffice it to say that investigations into this area have been responsible for generation of much of the theory on the models of creative process which may be applied further to HCI. Amabile (1983) and Csikszentmihalyi (1988) are two prominent creativity researchers often mentioned in HCI creativity

[5] It should be noted that research pertaining to this topic makes up [encompasses?] a large percentage of the research presented at the ACM-sponsored Creativity & Cognition conferences.

research with regard to theories that concern social contexts of creativity and their application in organizations. Most of these theories stem from research on individual creativity. Qualities of creative individuals are applied to analyze creativity at various organizational levels including individual productivity (e.g. Puccio, Talbot, & Joniak, 2000), the workplace environment as a whole (e.g. Stokols, Clitheroe, & Zmuidzinas, 2002) and at the team-level of output (e.g. Kurtzberg & Amabile, 2000-2001). All of this research may be related to HCI investigations, most likely in the contexts of work process with various information systems, and as such lends itself aptly to the contextual design approach introduced by Holtzblatt and Beyer (1997) which introduces various models of work process including representations of sequence, flow and culture.

Use of software tools to enhance creative organizational design [what is organizational design?] is also addressed by Thomas, Lee and Danis (2002), who believe that design processes are often ill-defined problems that "require creativity quintessentially". The authors take a rather pessimistic view of people's evolving ability to design creatively, acknowledging that organizations increasingly need to be innovative, yet the degree of flexibility allowed employees to pursue creative endeavors is often inhibitive. Some of the barriers to innovation they cite include: inefficient and ineffective processes for innovative design; lack of appropriate knowledge sources; and lack of appropriate motivations. They go on to describe the typical errors made by people during innovation attempts.

In light of these errors, they further describe software tools that combine the power of computing and knowledge of how to impact creativity. The main feature of these types of tools is their ability to organize the creative process by providing people with a larger palette of appropriate problem-solving strategies, relevant knowledge sources, and representations (e.g. Pattern Languages), and appropriate levels of motivation for task completion. In addition, they address the issue of improving creativity over time, which they theorize is a goal that may be possible to attain with systems which provide feedback about creativity at various stages of the innovation process. This feedback might occur in teamwork self-reflection sessions or via analysis of results of creativity assessment run during particular use modes.

Creative Cognition

Much of the early research into creativity was conducted by cognitive and behavioral psychologists. Their findings have also continued to have an impact on present-day studies concerning the creative process. In particular, work in creative cognition (e.g. Finke, 1995; Finke, Ward, & Smith, 1992; Ward, Finke, & Smith, 1995) has provided the foundation for scales and dimensions by which creative output can be measured, such as the two-dimensionality creativity scale described by Smith, Paradice, and Smith (2000). In this scale, creativity is measured in terms of four categories of creative output: creative and conservative idealism, and creative and conservative realism. These authors attempt to apply this scale to individual creativity in organizations and describe additional cognitive psychologist terms which may impede an individual's creativity in an organizational environment, including fixation, structured imagination, and functional fixedness. Fixation is the problem of not being able to switch from an inappropriate solution to a more correct path, while structured imagination refers to the inability to deviate from what is already known. Functional fixedness, a state whereby individuals cannot use objects in a way they are not intended to be used, may also cause fixation. Several classic experiments in creativity are described to show how individual creativity may be inhibited in particular situations, such as learning a new programming language or coming up with alternative networking solutions. A suggested way to overcome creative “blockage” includes procrastination or altered context (time spent “away” from the problem) with the end result of insight via incubation. Ultimately, the authors conclude that cognitive barriers, including prior knowledge, can prevent organizational progress in areas such as implementation of information systems. They believe that “awareness of impediments to creativity and the use of creativity-enhancing techniques” can help individuals and organizations better utilize creative outputs (p. 116).

Creative cognition in general creative output has also been extended to the realm of design process. In a study by Nigel Cross (2002), the approach to design of three exceptional designers was studied across three differing design projects. He found that strategies for design were quite similar across domains, and concluded that there may be basis for a model of creative design process able to be extracted from these findings. The similar strategies included use of “first principles” in terms of knowledge and skills, exploration of the problem space by “framing” it in such a way that stimulates emergence of design concepts, and arrival at design solutions when there is a conflict to be resolved between high-level design goals and acceptable design criteria.

In contrast to Cross's focus on the larger contextual process (2002), researchers such as Liane Gabora have also investigated the cognitive mechanisms underlying the creative process (2002). This work is focused on the specific processes that occur at the biological level. She theorizes about the mechanisms involved in the cognitive change that occurs as an idea transforms from inspiration to the finished product. Relevant terms mentioned include memory, distributed representation, associative network, and defocused attention, among others. As well, various stages of the creative process are outlined, including preparation, incubation, illumination, and verification[6]. Much of the similar literature in this area draws from the domains of neurological sciences and biological psychology although it is related to creativity cognitive processes, e.g. recent work by Martindale (1999) and earlier work by Mendelssohn (1976). As well, Boden's (1994) work on agents, artificial intelligence and creativity is based upon the question of whether agent systems may help to further human creativity. Her research is deeply entrenched in the understanding of psychological processes involved in creativity, including combinational and exploratory-transformational thinking. In addition, she strives to understand the scientific bases of creativity as they are able to be embodied in computational resources (e.g. Boden, 1999).

Conclusions & Future Research

Although in the field of HCI there is optimism about the future role and development of creativity-enhancing technology, there is also much speculation. Research into this area is generally void of grounding in actual HCI-related theory, although there have been a few

[6] These stages draw from Poincaré's plan for problem-solving discussed in Couger's (1996) review of 22 creative problem-solving methodologies.

notable attempts to correct this in the HCI literature. Shneiderman appears to be the most prominent mainstream HCI researcher concerned with creative process, although his notions of creative activity seem to better fit into the realm of personal interactivity and exploration, rather than his initial conjecture that creative output must be accepted by gatekeepers of a domain. The role of knowledge sharing and collaboration appear to be rising areas of interest, particularly in relation to exploration and visualization of knowledge and in the role of innovation in organizations. One strikingly common element within much of the above research is the notion that the foundation of creative output is the creative environment, or context within which people work. This is evidenced by the frequent references to work of creativity researchers Amabile (1983) and Csikszentmihalyi (1988; 1996; 1999), who both stress the importance of social interaction in the creative process.

In conclusion, future empirical research may best be geared toward dissection of the creative process which both individuals and teams undertake in any given design or innovation process. Mapping of these processes in different contexts will be crucial as will provision of a toolbox of methods for assessing the crucial points of creative output. In particular, the issue of creativity in usability has largely been unaddressed. Research into the processes inherent in usability testing including design of test sessions, methodology, and evaluation techniques may prove useful. It is likely that there will continue to be a division between those groups studying creativity in a social context versus those who believe that the heart of creative activity is centered on the individual (much like the typical division in HCI between founding cognitive psychologists and programmers and social/contextual, or qualitative, researchers). As with this argument, the ideal result will likely include aspects from both factions, such that creativity support tools are designed both with a user's cognitive processes as well as his/her creative environment in mind.

Finally, a creativity research area not discussed at length in this paper and that probably warrants future investigation is assessment of creativity (e.g. Abedi, 2002). HCI literature is fairly devoid of assessment literature; therefore, investigation into classic creativity as well as education literatures will likely provide more information on this topic and provide guidance for future investigations into evaluation of creativity in HCI-related contexts.

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