Ernest Edmonds and Linda Candy

Creativity, Art Practice, AND Knowledge

Achieving a balance of control and freedom by supporting a mix of strategies.

Creativity can be characterized as a process toward achieving an outcome recognized as innovative. This definition goes beyond everyday creativity, which is personal to the individual concerned and does not necessarily lead to publicly evaluated outcomes. Conceiving new ideas and making artifacts by any individual may indeed be creative to that person, but the outcomes from personal creative acts are not usually valued as such by others. Boden's distinction between 'P' (psychological) and 'H' (historical) creative is relevant here [1]. A further distinction is needed within 'H' creative between exceptional and outstanding creativity.

The outcomes of creative work that are exceptional may be evaluated (and valued) by others, usually the domain experts, but they not necessarily recognized as such outside that knowledgeable group. Outstanding creativity is that which has stood the test of time and has become recognized beyond the specialist community. This is what artists are finally judged by. Further descriptions of the creative process and creative outcomes are found in [1, 5, 11]. One aspect that is important here is stressed by Boden. Creativity does not come out of a vacuum in a sudden and mysterious flash. Typically, the creative step is based upon significant knowledge and serious creative activities, including art practice, can best be understood in the context of knowledge work.

Since the mid-1960s, artists have been actively and successfully using digital technology in their practice, with many of these artists classified as "computer experts." Bringing the expertise of art and technology together has usually been the achievement of one person working alone. As we consider more recent digital art, increasing collaboration occurs between people from different disciplines with different skills. The paradigm for digital art seems to be shifting toward collaborative practice as a norm. Whether this pattern of collaborative practice continues to grow or not will, perhaps, change as education develops and responds to the art and technology developments presented here. We may see a growth in the number of artists who are expert in computer technology to a similar level as those in painting, sculpture, or print making. On the other hand, the advantages of collaboration extend beyond the acquisition of technical skills. Collaboration provides opportunities for more ambitious creative projects [4] and furthermore, the funding initiatives that explicitly encourage joint activities also contribute to this growing trend.

The artists' reflections in the second part of the authors' book, *Explorations in Art and Technology*, raise issues about digital technology in relation to creative practice [2]. The book records a set of studies of the process of making new art using digital technology (see

Figure 1). Many of the artist contributors noted how working with computers has stimulated them to move their thinking forward. One discusses the importance that digital technology has had in encouraging him to shift the very idea of what he considered to be art. Others found that using computers caused them to reformulate the boundaries of their artistic vision, for example, by adding time as a dimension of the work. Many artists have been encouraged to break with established conventions, a core element of truly innovative practice.

Figure 1. Collaborators study an artistic problem.

For most artists, the importance of using and having access to expert technological knowledge cannot be overemphasized. As a study of collaboration revealed, some find it vital for each member of the team to have a clear and well-defined role. On the other hand, by their own account, some artists have been struck by the way digital art collaboration leads to the blurring of the distinction between artist and technologist. In both situations, access to expert knowledge and opportunities for the collaboration needed in order to acquire that expertise prove to be essential in enabling the realization of successful digital projects. An interesting aspect of collaboration is the way in which it provides participants with more than one viewpoint about the nature of the creative process. One artist notes how the process of collaboration with a technologist, and the kind of discussion that it requires, encouraged her to reflect on different views about how to proceed with the work and what method to use to produce it. Collaboration helps the participants to address tasks via a number of parallel channels of thinking that draw upon different types of knowledge. From this process, entirely new understandings emerge that transform the outcomes of the creative work.

Studies of Creative Process

Understanding the ways the creative process has been influenced by the growth of computer use is a key research issue. Studies of the creative process, as distinct from studies of the outcomes of this process, have been much more extensive in the field of design than in art. Although there are differences between the fields of design and art, they have similar characteristics with regard to the creative process. It is therefore useful to broaden the discussion to examine the issues surrounding creativity in general, but particularly in design practice.

There has been considerable research into how designers carry out design activities. In product and software design, common characteristics have been identified [9, 12]. Maccoby [10] studied prominent designers and engineers whose contribution to their fields was unquestioned by their peers and the world at large. Although they represent a spectrum of different fields and cultures, they exhibit similar ways of thinking and working. Most are "holistic thinkers," in the sense they look for an overall broad scope before moving into specific detail. Other studies indicate that design is often solution-led, in that the designer often proposes several candidate solutions early on in order to better examine the problem. Designers impose constraints that reduce the number of solutions and help generate new concepts, changing their goals and adding constraints during the design process. Boden makes a good case for the claim that changing a constraint might be at the core of creative thinking [1].

Taking account of these studies and our own investigations into innovative designers, various characteristics of the creative process have been identified with a view to identifying the kind of computer system that could be supportive to the designers' creative practice [3, 6]. New ideas do not just come out of thin air. The conditions for creativity are very important and outstandingly creative people seem to be able to arrange

for the right conditions to be available. The use of complex tools, such as computers, forms a significant part of the context in which the conditions for creativity exist. The studies referred to previously identified aspects of the creative process relevant to art and technology practice. Most interestingly, they relate to artists' observations on working with computer technology that were discussed earlier.

A key activity in the process is the exploration of ideas, knowledge, and options. Some examples of aspects of exploration that were identified from empirical studies are summarized here:

Figure 2. E601 by AARON 2002 (image courtesy of Harold Cohen).

- *Breaking with convention.* Breaking away from conventional expectations, whether visual, structural, or conceptual, is a key characteristic of creative thought. Events that hinder such breaking with convention are avoided, whereas positive influences are embraced.
- *Immersion.* The complexity of the creative process is served well by total immersion in the activity. Distractions are to be avoided.
- *Holistic view.* The full scope of a design problem is only fully embraced by taking a holistic, or systems, view. The designer needs to be able to take an overview position at any point and, in particular, to find multiple viewpoints of the data or emerging design important.
- *Parallel channels.* Keeping a number of different approaches and viewpoints active at the same time is a necessary part of generating new ideas.

The creative person needs to work in parallel channels. The creative process also includes idea generation and the evaluation of those ideas. All three activities frequently involve acquiring new methods or skills and using expert knowledge. Much of the collaboration that we observe in the artist's discussions is concerned with new skills and expert knowledge. Digital artists are concerned with finding and creating the environments in which they can work productively. The early digital artists had little choice but to acquire the necessary computer expertise themselves if they were to be able to achieve anything at all. Their experiences were rarely collaborative in the sense we mean today where people of different skills and backgrounds combine their efforts to make the technology accessible for art practice.

As an example of the role of digital technology in the development of an artist's expert knowledge, it is interesting to consider two artists whose contributions to computers in art has been very significant over many years.

Digital Technology and Creative Knowledge

Harold Cohen's computer system, AARON, is the most successful example of a computer program that creates drawings and paintings autonomously [7], as illustrated by an example of its output in Figure 2. Cohen's artistic knowledge about creating drawings and paintings was captured in the form of a computer program that could then create new works itself. In the process of developing the program, the artist's process involved evaluating AARON's drawings and reexamining the knowledge in the programs in light of his judgment. He then modified the program many times to include the new insights in the program. The creative process was one of externalizing his existing drawing and painting knowledge and then, once it was made visible by the computer, evaluating the outcomes and making further changes for which he often needed to acquire new knowledge. Thus, the evolution of Cohen's own knowledge about painting was at the center of the process.

When he began this work, the drawings were concerned with strictly organizational issues in the sense they were basically abstract. Cohen has since moved into expressing knowledge about color in the computer program, which has been generating figurative art works. The figurative knowledge in the computer system required more knowledge about the world.

For Cohen, creativity is something that is a process of continuous change, as distinct from single events. That change, as his work exemplifies, is in the mind

and actions of the human and the process is essentially a directed one. It is a process of engineered knowledge development. His work is unique and the basic concept of developing an autonomous creative computer has rarely been taken as far as this. Cohen explores the implications of his work for art practice and the changes it has brought about in concepts of art and who owns it in a recent essay [2].

Another artist who has made pioneering contributions to art and technology in quite different ways is Manfred Mohr, whose work has been transformed by the visualization possibilities of technology. Mohr's work involves the construction of two-dimensional views of six-dimensional cubes (hypercubes) as seen in Figure 3. His goal is to express geometric knowledge about the cube that is encoded in the computer system using a programming language. The computer program then generates graphical entities from which he makes artworks using conventional media such as canvas and laser cutting and special computer output devices to implement his intentions. The goals of two parties to the process—the artist and the computer—are clearly differentiated: the computer program generates purely geometric objects while the artist makes aesthetic choices from which he goes on to make artworks. The artist cannot do the bi-dimensional geometry in his head and the computer requires the artist to specify the geometric knowledge in a computationally tractable form. Only with the aid of the computer is he able to take an holistic view of the objects with which he is concerned. For Mohr, the interactive process with the computer is one with which he extends his capability as an artist: *"what fascinates me about a machine is the experience of a physical and intellectual extension of myself"* [8].

A productive relationship with the computer is dependent upon both the power of the programming language used by the artist and his own ability to develop its capability to achieve his goals. Mohr's approach is to retain ultimate aesthetic control over the final outcomes rather than leaving the final choice to the computer. This symbiotic interaction differs from that of Harold Cohen's, whose primary goal is to have the computer system make the artworks. The role he chooses for himself is to specify to the computer the critical underpinning knowledge about art from which the computer generates the drawings and paintings. In using a computer language to make a computer create works, rather than a software application to create the drawings and paintings himself, he is expressing a fundamental premise on which his whole approach is based, exemplified in the statement: *"I inevitably get nervous about the notion that somebody could make art without a profound grasp of the underlying disciplines involved"* [7].

> The use of complex tools, such as computers, forms a significant part of the context in which the conditions for creativity exist.

Cohen's artistic vision places high value on expert knowledge about art and its role in computer-generated art. Mohr's vision involves exploring generative processes that are not accessible to human perception but are, nevertheless, able to be specified using the method he has chosen. The final artworks remain the province of his artistic decisions. For each artist, the particular points in the creative process when it is desirable to interact with the computer language and the outcomes it generates are different.

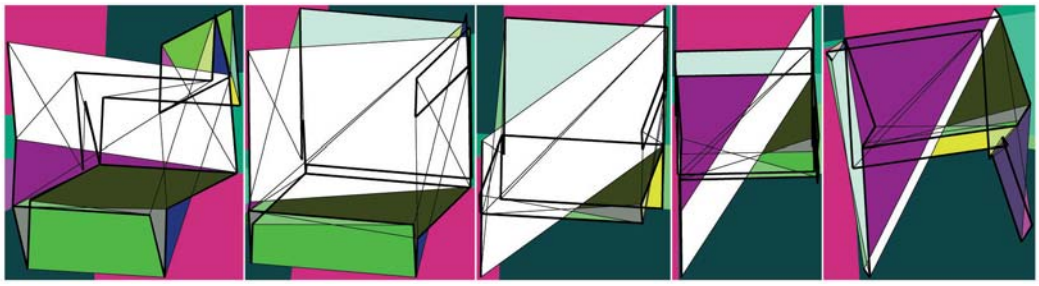

Figure 3. P-709/A—five parts (image courtesy of Manfred Mohr).

Creative Knowledge Work

Case study results provided different kinds of evidence about creativity, from which models, one modeling creative process and the other modeling creative cognition, were derived. These highcognitive models informed the requirements for a creativity support system in which knowledge and visualization are essential ingredients of creative work [5]. Visualization activities are to be found in most examples of creative work although the degree of emphasis varies considerably from domain to domain. In our preceding discussion, we noted how important the computer was in enabling Mohr to investigate and consider his multidimensional cubes. Knowledge, on the other hand, is central to Cohen's work: it might even be said to be about knowledge.

A number of models that aim to represent the creative process include the highly important activities of exploration, generation, and evaluation. The characterization of each of these activities is drawn from a number of studies including those of the authors and is described in brief here.

Exploration involves accessing source data, comprising different types of knowledge that may be examined, assessed and interpreted in terms of the primary goals of the creative knowledge worker: for example, addressing customer requirements, problem specifications, design briefs, and so forth. This is an open process, possibly without observable directions, However, the thoroughness and selectivity of the activity is critical to the quality of the generative stage that follows immediately and to the subsequent iterations that take place between those stages. Having a comprehensive set of knowledge sources readily available is extremely advantageous. Knowing where to look and how to select the knowledge is even more important. There is often rapid iteration between the exploration and generation activities depending on the domain or problem area.

The *generation* of possible solutions or approaches to the brief or problem definition draws upon the results of the initial exploration. Problem formulation, as distinct from problem solving, is critical to the effectiveness of the solution space that is defined. It draws upon a wide range of analogous cases often outside the immediate domain. This has been characterized as an ability to make remote associations. Creativity is demonstrated by the generation of many potential solutions instead of gravitating quickly toward a single and (usually) familiar solution that is not necessarily the optimal one. The ability to consider parallel lines of thought and to select and transform the results to meet the demands of a different situation is a critically important aspect of solution generation.

Evaluation involves taking the results of the generative activity and testing the candidate solutions against a set of constraints. This leads to modifying, reformulating, or discarding solutions depending on the feedback. Selection of the optimal solution may involve a number of trade-offs against the constraints that are applied especially where, as is usually the case, the product is a complex one. The application of tight constraints may be considered conducive to creative solution finding and thus evaluation is a vital part of the creative process [1]. Evaluation may be viewed as a pervasive activity that takes place from the exploration phase onward. The use of expert knowledge in evaluation has been identified as an important aspect of successful solution finding.

Conclusion

Creativity does not always involve knowledge work and knowledge work does not have to involve creativity. Knowledge work involves the assimilation of existing knowledge and its interpretation for the benefit of others. The knowledge worker's knowledge is a continually evolving body of expertise but this is not necessarily creative in itself. However, where the knowledge work involves the generation and evaluation of new ideas, solutions, and artifacts, this can be described as creative knowledge work—art practice can frequently be seen as exactly this kind of process. Space limitations preclude a comprehensive discussion of the implications of this work for software design. However, the studies of creative practice discussed here help us understand the challenges to human-computer interaction in providing positive support for human creativity by artists and, more widely, by all creative knowledge workers. C

References

1. Boden, M.A. *The Creative Mind: Myths and Mechanisms.* Weidenfeld and Nicolson, London, 1997.
2. Candy, L. and Edmonds, E.A. *Explorations in Art and Technology*. Springer-Verlag, London, 2002.
3. Candy, L. and Edmonds, E.A. Creativity enhancement with emerging technologies. *Commun. ACM 43,* 8 (Aug. 2000), 62–65.
4. Candy, L. Cognitive modeling of creative knowledge work for interaction design criteria. In *Proceedings of the 4th International Roundtable Conference on Computational Models of Creative Design*. J.Gero and M-L Maher, Eds., (Dec. 1999), 57–79.
5. Candy, L. Computers and creativity support: Knowledge, visualisation and collaboration. *Knowledge-Based Systems 10*, 1 (Jan. 1997), 3–13.
6. Candy, L. and Edmonds, E.A. Creative design of the Lotus bicycle: Implications for knowledge support systems research. *Design Studies 17*, 1 (Jan. 1996), 71–90.
7. Cohen, H. *The Robotic Artist: Aaron in Living Color.* The Computer Museum, Boston, 1995.
8. Gomringer, E. *Manfred Mohr—Cubist in the Computer Age.* Algorithmic Works (Manfred Mohr), Josef Albers Museum, 1998, 5–7.
9. Guindon, R., Krasner, H. and Curtis, B. Cognitive processes in software design. In *Proceedings of INTERACT'87*, North-Holland, 1987, 383–388.
10. Maccoby, M. The innovative mind at work. *IEEE Spectrum*, 1991, 23–35.
11. Partridge, D. and Rowe, J. *Computers and Creativity*. Intellect, Oxford, 1994.
12. Ullman, D.G., Dietterich, T.G. and Stauffer, L. A model of the mechanical design process based on empirical data. *AI EDAM 2*, 1 (Jan. 1988), 33–52.

Ernest Edmonds (ernest@ernestedmonds.com) is a professor in the Department of Information Technology at the University of Technology, Sydney, Australia.

Linda Candy (linda@lindacandy.com) is a senior research fellow in the Department of Computer Science at Loughborough University, U.K.

Funding for part of this work was provided by the EPSRC.