Computer Support Tools for Problem Finding

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Introduction

Human creativity as a topic of research and practice has inspired a new understanding of the nature of creativity. Research and exploration has had a democratizing effect, responsible for recasting creativity and innovation as goals for everyone rather than a select few (Shneiderman, Fischer et al. 2006). Organizations and individuals actively seek to enhance their creative output, inspiring creation of better tools to support them. Where creativity was primarily associated to the making of art, now it is explored relative to persons, processes and products, across multiple domains of human knowledge. (Simonton 2003).

In a rapidly changing world, where organizations are challenged to solve large-scale problems efficiently and cost effectively, "innovation" has become a mantra. Organizations seek to foster innovative environments and streamline creative processes in the hope that better solutions are identified more quickly. Internal transformations take place to improve the ability to explore more options, bring more knowledge to bear, collaborate more extensively and experiment with more potential solutions.

Designers, researchers, and managers are challenged to solve problems while keeping up with changes in domain-specific knowledge and tools, and an explosion of digital information. The task of organizing and managing information must be done efficiently if we are to keep up and perform creatively.

With a better understanding of the creative process and the benefits of creative thinking, better tools can be developed. Developers seeking to make tools to support creativity have expanded their scope beyond design tools, and have begun looking to creativity process models as inspiration. In doing so, the activities that precede design tasks have garnered attention.

In this paper, models for the creative process are examined and compared across domains, with particular attention paid to aspects of the creative process known as problem finding or problem structuring. Recently proposed requirements for design of computer support tools and problem solving environments are examined and discussed in this light.

Modeling the Creative Process

Researchers have developed a multitude of process models across domains. These models represent better understanding of cognitive processes, performance processes, and environments that foster creativity.

Creativity models have been developed based upon a variety of methods:

- the study of innovators who broke new ground in their fields
- observation of working designers and artists during their creative process
- observation of business managers during their problem solving process
- experimental study of design and problem solving tasks

For this paper, research literature across the domains of art making, design, research and business are explored, relative to qualities of problem finding.

In an observational study, working artists were observed over time, within their own studio setting, engaged in making a work of art of their own devising.(Mace and Ward 2002) The model resulting from this study can be understood in terms of four sequential phases, but the authors are clear in illustrating that each phase includes evaluation and restructuring before proceeding, and each phase may be revisited. The start of the art making process assumes existence of a body of domain knowledge that is developed in an ongoing fashion.

- Phase 1, Art work conception: an idea is conceived and articulated
- Phase 2, Idea Development: an idea is structured and evaluated
- Phase 3, Making the Artwork & Idea Development: construction of the art work is commenced. The artifact is evaluated, and can affect the idea, causing restructuring of the idea.
- Phase 4, Finishing: the art work is finished and may be exhibited

According to this model, creativity takes place over the entire process of art making and is not identified with a single point in the process(Mace and Ward 2002). This somewhat challenges earlier studies

identifying time spent and experimentation within the problem finding phase as related to higher levels of creative output (Getzels and Csikszentmihalyi 1976).

As a component of a longitudinal study of artists, Getzels and Czikszentmihalyi (1976) conducted an experiment with student artists. Within a single studio setting (as experimental lab), art students were given a set of objects for a still life and some traditional art materials, then given the task of creating an original work of art. The artists were observed during the process, and the final products were judged for their creativity. A positive correlation was identified between tasks and time associated with problem finding, and higher levels of creativity of the final output.

In the design field, a study by Kruger and Cross (2006) examined strategies employed by experienced industrial designers. The creativity and overall success of a design challenge was examined; findings identified a relationship between overall solution quality with data gathering and problem defining activities. Creativity scores, however, were associated with modeling and solution generating activities. Creativity tools, then, should support not only modeling but problem defining and data gathering. This highlights another interesting point - that the overall creativity of a product is not the sole criteria for its success. It must also have value, and in terms of business, it must satisfy the business need.

In science, the area of problem finding and problem solving is compared to the difference between hypothesis formulation and hypothesis testing. While much work has been done in terms of understanding hypothesis testing, not as much has been done to understand or model hypothesis formulation. (Nickerson 1999)

In a model developed by Dubberly (2008), innovation comes about when a business convention decays and requires rethought. Through immersion, insight, prototyping, and demonstration, a new model can be arrived at and eventually adopted. The process includes immersion in the subject, and definition of the problem before full articulation and design or prototyping can begin. The role of people in the process of innovation is highlighted, not only as participants in the process of problem finding and problem solving, but the fact that a problem isn't solved until its implemented, i.e., the new process or product is accepted by the individuals for whom it is designed to aid.

In a study of problem solving in managers, the manager's primary activity was to identify differences between the current state and the desired state, so that the correct action could be taken. The process of problem finding is described is described as follows (Pounds 1969):

- Choose a Model (of the desired problem state)
- Compare to Reality
- Identify the Differences
- Select a Difference

Another important model within business is the definition of design requirements. The cost of designing a new product, building, or software application is expensive, and with rare exception, time based. This means that each phase of the process must be conducted with efficiency. Requirements must be well articulated and well-documented before the design task can begin. Various processes and tools exist for engineering, documentation, validation, communication and review of requirements. Because the design and development process may take place over months or years; the longer the process, the more likely that some requirements will change. Therefore, the design and development process needs to be flexible enough to respond to requirements changes.

Problem Finding within the Creative Process

In an effort to distill a process model by comparison of engineering design models with psychological creativity process models, Howard and Culley (2008) proposed a simple classification of four components. While not presented as a model in itself, the classification does allow for broad categorization of multiple existing models.

▪ Analysis	Associated with exploration of the problem space, fact-finding, problem definition, requirements gathering
▪ Generation	Associated with idea-finding, finding analogies and metaphors, divergent thinking
▪ Evaluation	Associated with evaluation, solution-finding, elaboration, verification, convergent thinking

- Communication/Implementation — Associated with communication, presentation, acceptance, integration

During the Analysis and Generation phases, the problem is structured, modeled and restructured, and it is here that the designer calls up prior experience or examples of analogous design criteria. Problem structuring or problem finding has been cited as a source of creative success in multiple studies (Reiter-Palmon, Mumford et al. 1997), (Getzels and Csikszentmihalyi 1976).

While models tend to be presented as linear and sequential in nature, when observed, designers and artists continually move from one phase to the next in iterations, continually revisiting activities associated with "earlier" phases. Recent studies suggest that the problem structuring process actually takes place in parallel, co-evolving with problem solving. "Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces'—problem space and solution space." (Dorst and Cross 2001) The more possible solution are explored, the more is learned about the nature of the problem.

Based upon the related readings, a general list of tasks associated with problem finding is proposed for consideration in developing criteria for creativity support tools:

Problem Finding

- Identify problem space
- Identify dissatisfactory state or area of improvement
- Identify characteristics of the desired state
- Identify constraints
- Identify / retrieve / research similar conditions
- Identify / retrieve related past experience
- Identify / research similar desired states
- Identify / research similar problem states
- Create model / collection of constraints

- Design
- Incremental review of design, comparison with model / constraints
- Communication of the design
- Completion of the design
- Integration / acceptance of the design

Creativity Support Tools

Recent exploration of the topics of creativity support tools (Shneiderman 2007) and problem solving environments (Hewett 2005) suggests that while different domains have specific design tools, those tools are designed to support the design task, not necessarily to support innovation or creativity as we understand it now. To develop creativity support tools requires casting a wider net and supporting more aspects of the creative process than design alone. Some design criteria for creativity support tools are referenced here.

Design Requirements for a Problem Solving Environment (Hewett 2005)

1. Provide a library of macros and analogs.
2. Make possible multiple alternative representations of domain- based problems.
3. Allow those multiple problem representations to be simultaneous so that they can be compared and tested and evaluated.
4. Allow for flexible and tailorable usage of the working environment.
5. Allow multiple configurations of the working environment and its tools that can be saved and restarted so that having to work on multiple projects does not require a shut down and re-assembly every time the problem solver switches their attention from one problem to another.
6. Support a variety of multiple store and find operations
7. Provide multiple access routes into archives and repositories or relevant data or other information
8. Log processes and intermediate results to enable the user to easily recapture these results.
9. Make it possible for the user to re-configure or re-define the problem domain. Sometimes in working on a problem what one accomplishes first is development of an understanding of what the "real" problem is.

Resulting from a 2005 conference on Creativity Support Tools, some design principles were developed for composition tools, i.e. tools that "can be used to generate, modify, interact and play with, and/or share both logical and/or physical representations." (Shneiderman, Fischer et al. 2006)

1. Support Exploration
2. Low Threshhold (novice support), High Ceiling (expert support), Wide Walls (support wide range of possibilities)
3. Support Many Paths and Many Styles
4. Support Collaboration
5. Support Open Interchange (seamlessly interoperate with other tools)
6. Make It as Simple as Possible
7. Choose Black Boxes Carefully (appropriate complexity of primitive objects)
8. Invent Things That You Would Want to Use Yourself
9. Balance user suggestions with observation and participatory processes
10. Iterate, Iterate
11. Design for Designers
12. Evaluation of Tools

While design tools are prevalent across domains (Photoshop, Visio, AutoCAD, Macromedia Suite) another generation of tools are being created to support learning, ideation and personal knowledge capital. These web-based tools are inherently not domain-specific.

- Britannica Workspace
- Microsoft OneNote
- Evernote
- Zoho Notebook
- Pbwiki.com
- Matchware Mind Mapping

A further exploration of tools to support personal knowledge management:

- With digital files stored in a simple folder structure on an operating system, the operating system folder search and browse mechanisms become the primary tools for organizing files.
    - Windows Explorer, Mac whatever (using keywords and file attributes)
    - Copernic desktop search (using keywords and file attributes; shows file preview, allows navigation to the source folder or file)
- Book collection software such as Librarything.com (allows users to store a record of the books in their library, tagged, social networking)
    - features personal tagging, social tag clouds, communication tools, search tools, browse tools
- Photo album software such as Picasa (desktop software with multiple ways of viewing files including time frame, folder structure, supports search & navigation to source folder or file, preview)
- Music collection software suchas iTunes or Realaudio (desktop software with multiple ways of viewing files including personal album collection, folder structure, by artist, by genre)
- Evernote & Onenote allow tagged collections of representations of files, urls, notes (Onenote supports sharing)
- Twine (social bookmarking, personal knowledge management)

Brainstorming Metaphors for a Workspace to Support Creativity

One of the powers of the digital arena is its plastic ability to create realistic virtual spaces. What, therefore is an appropriate model for development of a creative environment? Hewett suggests a "Workbench" model for problem solving environments (Hewett 2005). This model, while suggesting effective work on a problem, does not extend to the process of problem finding in a fully satisfactory way. Problem finding and creativity are associated with variety, knowledge, personalization, inspiration and investment. What other metaphors might inspire a robust creative environment?

Computers have migrated from stand-alone rooms to components of work rooms and offices, to work stations, to table-top elements, to laptop objects, sitting anywhere within the workspace. As technology

changes, it becomes absorbed into the workspaces we create to support our fundamental activities. Therefore, an examination of existing design and ideation work spaces may yield interesting findings.

In brainstorming various metaphors for creative work spaces, there are two main ideas to define space - the room vs. the workspace. The room might contain a larger collection of information, materials, tools, and objects of inspiration. The room also supports a variety of activities including individual work activities, group work activities, social activities and "down time" activities. The room *contains* a work area; in the work area materials and tools are gathered to support a specific creative task. These components may be a subset of things we keep on hand in the space, or may be introduced to the space for the task at hand.

Room	**Area**	**Tools**	**Objects**	**Functions**
Office	Workbench	Domain specific tools	Domain specific materials	Repository of knowledge
Studio	Office Desk	Computer equipment	Toys	Repository of past work
Atelier	Work Station	Communication Devices	Personal sources of inspiration	Repository of tools
Workshop	Drawing Table	Palette	Furniture	Design space
	Work Table	Office Supplies	Documents, books, publications	Social Space
				Thinking Space
				Work Space

Its interesting to consider not only how we arrange the room, but how we choose which things to gather together to support the task. For each task, we create a pile of materials and tools together in the middle; then we build/create/design it, hand it off, and put the stuff back, or "reset" the room. There is an assumption that there is a desired state for the room.

If extending the metaphor for creativity support tools to encompass ideation, a room metaphor seems to meet the criteria for flexibility, ability to gather and explore. However, when actually building a support

tool, the opportunity to customize the setting may be important. Various themes could be employed, letting the end user choose the work area metaphor that suits them.

A *workbench* is something that a worker approaches with an idea in mind. The workbench implies sitting for the task, the typical workbench includes tools that have been arranged for maximum functionality, i.e. the most used tools are easiest to get to. A workbench includes a surface or work area for assembly of materials or repair. Component materials might be situated near the workbench. Assembly materials (screws, nails) that are extremely similar may be collected in one area, in small, labeled drawers. The workspace is flat, and may have no walls (centered in a space), but is more likely to be flush up to one or more walls. People associated to workbenches are woodworkers, mechanics, artisans, and home owners. Tasks associated to a workbench include creation, assembly and repair. Generally speaking, neither the design task nor the ideation or problem structuring task are associated to a workbench.

An *office* is a somewhat formal space associated with professional environments. The office of an individual may include knowledge repositories and multiple work areas in the form of a desk, bookshelf, document storage, a social space, white boards, art, chairs, and supply storage. The office desk is not only a workspace, and storage space, but is often the social center of the room. The office contains an individual's collection of materials they need to do their job, including reference materials, prior work, supplies and materials relevant to the task at hand, communication devices, objects such as curios or artwork that either have personal meaning or decorate the space. In this sense, it seems an appropriate setting for problem structuring.

A *workstation* brings to mind a more functional or mechanical set of tasks. Workstations are often technical and specialized, including equipment and materials for a very specific set of tasks, populated by individuals with a specific skill set. In this sense a workstation is not be an appropriate metaphor for problem-finding activities, unless the task at hand is maintenance of an existing system. Activities associated to a workstation: monitoring, adjusting, building, assembling.

A *work table* is one component of a larger work space. It implies that a specific task is going to be accomplished, and may be covered with the tools and materials needed to conduct the task. Again, this

type of space generally supports tasks that have already been understood, if not designed, though it may support the idea of experimental assembly of components.

A *drawing table* may be used by an artist, designer, architect or mechanical engineer. It may be a primary work space used for ideation and experimentation, along with design tasks. Again, it implies a central work area situated in a larger work space, upon which or around which materials necessary for completion of the task at hand are gathered and arranged. A drawing table may serve as the designers primary place to sit in the room and therefore may be the position from which a variety of tasks are performed (reading, thinking, assembling, drawing, sketching).

A *studio* is generally used by an individual involved in creative endeavors, including art-making, design, commercial art, performance arts. The artists' studio will differ based upon the art form being made. Sculptors, photographers, painters, dancers, musicians, digital media, mixed media artists have studios that support their art form, though there will be similarities as well. The studio is much like a workshop in that it contains prior works, ongoing projects, collection of knowledge capital in the form of publications and books, favored similar works, memorabilia, tools, materials, a social space, and a primary work space.

An *attelier* is a workshop for the arts, and generally supports several working artisans. It will contain all the things found in a studio, but may also include group work areas, and multiple personal work areas. It may also include a social area for visiting interested parties, including patrons, gallery owners, friends, other artists, collectors.

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