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ABSTRACT

The new medium of computer-aided design requires changes to the creative problem-solving methodologies typically employed in the development of new visual designs. Most theoretical models of creative problem-solving suggest a linear progression from preparation and incubation to some type of evaluative study of the "inspiration." These models give a communicable structure to infinitely variable creative experiences, but that perspective may need to be altered in the integration of computer applications into design education. In its infancy, computer-aided design merely saved engineering students the tedium of computation. Later on, computers were used to assist in drafting. Currently the computer can help with many aspects of visual design, including allowing for three-dimensional study models and providing access to helpful newsgroups and remote resources through the Internet. As long as students have the advantages of some previous knowledge of the programs and of appropriate hardware, computer applications can help them represent their ideas graphically. The computer-aided design environment is characterized by several qualities that require a move away from the linear problem-solving paradigm: (1) interactivity with programs, or even with the Internet, provides a cycle of immediate feedback which does not lend itself to assembly-line design or learning; (2) the visually mediated form of thinking is more holistic than linear; (3) the open-ended, discovery-oriented dynamic seems to operate without strict rules of causation; and (4) its ability to empower individual designers to make decisions conflicts with older views of the designer as a detached observer. The new model for creative problem solving is a feedback loop, an ongoing cyclical process of discovery and evaluation. Three separate studies of computer-aided design studios from fall 1993 to summer 1995 found these qualities at work with varying degrees of success; in some cases, interactivity was slow to develop, while in others, lack of personal empowerment or too much concentration on product over process was a problem. In some situations, moreover, the technology was not being used to its full potential. Future research is recommended. (Contains 13 figures and 19 references.) (BEW)

Tying Theory To Practice: Cognitive Aspects Of Computer Interaction In The Design Process

Amy E. Mikovec
Dennis M. Dake

Marshall McLuhan in his 1965 book, Understanding Media coined the evocative phrase, "The medium is the message." According to McLuhan, the medium is the thing that affects changes in everyone who comes in contact with it. This transformation of human interaction with the environment is caused because, "it is the medium that shapes and controls the scale and form of human association and action" (McLuhan, 1965).

McLuhan suggests that any extension of the senses (new medium) effects the whole psychic and social complex in which the individual lives. In the second half of the 20th century it is the computer and its worldwide interlinking of networks that pose the greatest challenge to the human nervous systems of users. For visual designers the challenge is pervasive. The medium of computer -aided design is a dramatic departure from older and more traditional visual design media. This new medium requires changes to the creative problem -solving methodologies employed in the development of new visual designs. This paper proposes a new pattern for creative problem solving, responsive to the medium of computer aided visual design.

Linear Descriptions of Creative Problem-Solving

Descriptions of the creative problem solving process have changed little, in structure, since the late nineteenth century when the German physiologist and physicist Herman Helmholtz described the stages in his own scientific discoveries as saturation, incubation, and illumination. In the 20th century, theoretical statements on creative problem-solving have proliferated. One of the most influential was formulated in 1926 by George Wallas who defined the creative problem-solving process as consisting of four successive stages:

1. preparation (collection of preliminary work searches, and researches);
2. incubation (a period of vary-

ing length between external prepa ration and illumination where the prepared material undergoes sub conscious organization and elabo ration);
3. illumination (sudden, clear insight that comes unbidden); and
4. verification (critical study and evaluation to confirm the illumination) (Wallas, 1926).

Preparation	Incubation	Illumination	Verification

Figure 1. Creative Problem-Solving Process
Wallas 1926

Since Wallas, traditional definitions of creative problem-solving processes have added some stages, subtracted some, or shifted them in order of presentation. In 1953, Osborn formulated one of the best known modern theories of problem-solving that included seven stages.

Orientation
Preparation
Analysis
Ideation
Incubation
Synthesis
Evaluation

Figure 2. Creative Problem-Solving Process
Osborn 1953

These traditional models have one thing in common, a linear pattern. From initiation of the process to refinement of a successful product the pattern is linear, as if moving along train tracks. Such linear processes have been confirmed by many reports from creative individuals and through psychological studies. These models give to productive and infinitely variable human creative experiences an orderly pattern and communicable structure.

One such current model within design education has been developed by Iowa State University professor Fred Malven (Malven,1989). Designed to help beginning visual designers develop a research orientation, prior to formulating possible solutions, this current reincarnation of the linear creative problem -solving process has been dubbed the PATHWAYS model. This acronym stands for:

Problem Definition - Recording the problems that currently exist and stating general goals for improving conditions.

Analysis - Listing specific minimum (and optimum) requirements which a successful solution must satisfy.

Theory - A set of beliefs as to how the environment potentially influences the desired outcome (cause-effect relationships- "If I do X the result will beY").

Ways -Concepts (ideas) for using the stated theory to satisfy stated requirements.

Solution - Based on the most promising concept(s), a single solution that does the best job of solving the stated problem.

As the 21st century approaches, new visual design media, such as computer graphics, are drastically altering the environment in which visual design is conducted. It is our contention that, in order to understand generative processes in the computer environment, designers need to substantially alter their visual design methods to take into account and maximize the unique strengths of the computer as a medium.

The Strengths And Challenges Of Computer Applications

There is little debate over the necessary integration of computer applications into design education. If college graduates are to be viable candidates for employment, they must possess a minimum understanding of computer technology.
The Foundation of Interior Design Education Research, the national accrediting body for interior design programs, requires students reach minimum levels of awareness, understanding, or competency for each established area of the interior design curriculum.

2.12 Communication Skills
Visual presentation skills are essential for the communication of design concepts. Exposure to a variety of media allows experimentation with new ideas, broadens the scope of creative expression, and allows discovery of the best means of portraying the individual's thought processes. Oral and written presentation skills must be practiced to give added depth to the visual presentation. Computer literacy promotes continued growth and development in communication variables (FIDER, 1995, p.8).

Figure 3. FIDER Standards

Computer-aided design and drafting, word processing and computer graphics must all be introduced and students led to understand the potentials each application offered.

Unfortunately, the minimum level of understanding does not prepare students for real world applications. A minimum understanding of computer applications involves neither critical nor creative thinking. Rather, it focuses on rote skills while reinforcing a linear problem-solving process. Most educators will agree that students must go beyond understanding to a level of competency if they are to remain competitive in today's technological market. We, as educators, are just beginning, however, to understand the impacts of computer applications on traditional pedagogy and methodology. This paper presents possible alternatives to the traditional learning processes currently implemented with computer applications.

Strengths of Computer Applications

Computer-Aided Design

In its infancy, computer-aided design programs catered to structural and electrical engineering "sav(ing) students from doing the tedious number crunching and the iterations of structural design" (Gal, 1994, p.338). During its introduction to architecture and design fields, it was originally termed computer-aided drafting. Users focused on the computer's capability to accurately and quickly output presentation and construction documents. Sophisticated users quickly realized, however, the computer's potential for design development and process work.

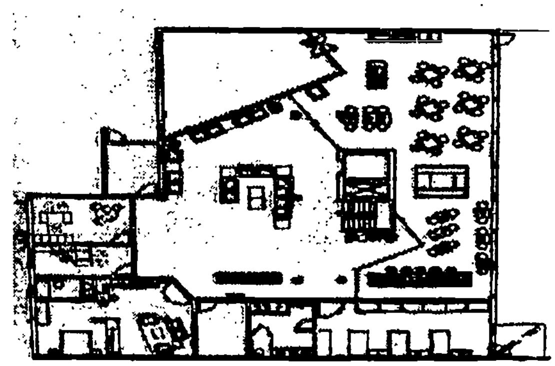


Figure 4. Ski Lodge Floor Plan (student work)

The term computer-aided design currently describes everything from programming and project management through design development and documentation. Design is not specific to the fine or applied arts. Rather "designing demands of students the effort to conceive and refine aesthetically pleasing and useful artifacts, whether they write essays, draft plans ..., compose music, develop organizational schemes, devise historical narratives, create algorithms ..., or plan decisive sequences of scientific experiments" (Ehrmann, 1987, p.10). Virtually all aspects of problem seeking and problem-solving can be addressed through the computer.

<u>Modeling</u>

Three-dimensional study models play a significant role in the design development process. For each given problem, students are encouraged to explore a variety of solutions both in two-dimensional drawings and three-dimensional models. Historically, this meant laborious and often tedious modifications to understand the subtleties of a design detail. Unfortunately, students often ran short of time and motivation during this lengthy cyclical process.

Computer generated wire frame surfacing and solid modeling offer students the ability to manipulate a three-dimensional image or design in a fraction of the time. Students can alter forms and generate new ideas that help them to better understand their applications of the principles and elements of design. As with structural and electrical engineering programs, students were able to perform multiple iterations in less time, and with greater accuracy.

<u>Internet</u>

Internet access breaks down both real and implied boundaries of traditional classroom learning. The global connectivity available through the internet allows educators and students the opportunity to interact electronically with people and resources that were previously unavailable. The idea of remote learning is becoming more viable as students interact with outside educators and practitioners through personal computers and internet links.

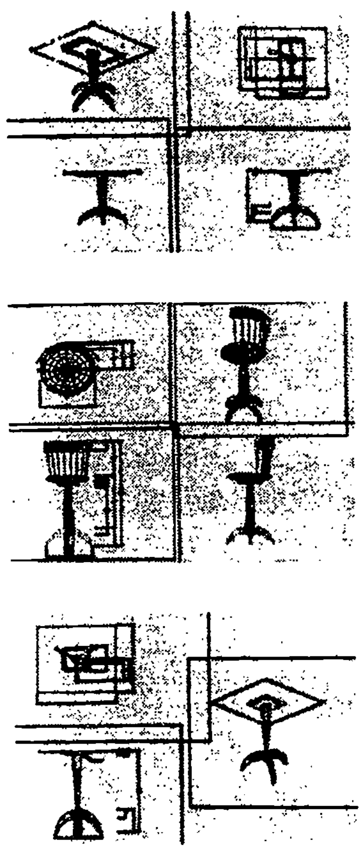


Figure 5. Furniture Design
(student work)

In addition to serving as a global warehouse of information, with students accessing libraries and databases (what might be considered a linear process), the internet also supports a more cyclical exchange of information. Newsgroups and bulletin boards offer opportunities for uncovering new resources as well as providing a forum for reporting on one's own discoveries. This multi-tiered, cross discipline exchange of information is a collaborative learning process that emphasizes interactivity.

Challenges of Computer Applications

Challenges to computer applications can be seen in attempts to execute complex design ideas and the memory and speed limitations of hardware. Quite often students are able to generate complex ideas and designs but fall short in their ability to express those ideas graphically. Actual model building helps in providing visual, three-dimensional trials on a given design solution. The traditional materials (bristol board, foamcore, knives and scissors)are familiar to students and easy to manipulate. On the other hand, computer-generated models often compound the complexity of problem-solving by requiring an understanding of computer software programs prior to application and testing of design ideas. Not only must students understand the computer commands necessary to perform the exercise, they must also comprehend the value of each command in achieving specific goals and solving complex problems.

Perhaps the greatest challenges in integrating computer applications into the traditional classroom resides in the limitations of the computer hardware. Most institutions of higher learning work on and with computers that are less than "forefront" technology. In order to utilize many of today's graphic and design software packages, computers must be faster and provide greater memory storage. Unfortunately, upgrading hardware is both time-consuming and costly. Quite often faculty are left the challenge of merging new software with old hardware or vice versa. As educators, we are forced to develop better and faster ways to reach our objectives, while working within the constraints set by the computer hardware.

In addition to software and hardware challenges, lies the burden of accountability on the Internet. Unfortunately, as the collaborative exchange of information grows, so does the difficulty in accessing reliable and authentic information. There are currently no restrictions on who can put what on the Internet. Students must be prepared to dig for and verify all information they uncover. The user must creatively search out and critically assess all information for authenticity.

Theory: Linear vs. Cyclical Design Processes

If students are taught that the computer is just another tool among many more traditional design tools, its unique strengths are not well utilized. "The computer is not just another tool for making education more efficient, but a catalyst for reconstructing the whole learning curriculum" (Balzano, 1987, p.83). Computer -aided design, with its worldwide interconnectivity, lightening speed, and immense potential for the storage and retrieval of information, highlights the inadequacies of the traditional linear models of creative problem-solving. If the medium is the message, then a linear, standardized process will not work equally well in all environments, non-electronic and computer mediums alike.

Learning even one computer program well, is a complex proposition. In computer-aided design (CAD) several program applications are typically needed. This exponentially compounds the time required within the design education curriculum to gain proficiency. A long learning curve threatens to overcrowd the design curriculum to the detriment of all visual media. Learning to use a rich mixture of traditional art materials already takes considerable time to reach a level of proficiency. Only when proficiency is gained can the appropriate tool be freely chosen in response to problem-solving needs.

One solution to the time pressures. caused by the introduction of computer aided design media, might be to move visual design education totally into the computer environment. Because computers represent such a drastically different medium, this would then require a change in creative problem solving paradigms to accommodate the unique nature of the medium.

The computer design environment is characterized by intense interactivity, a visually mediated form of thinking, a discovery oriented dynamic, and the empowerment of the individual as decision maker. These unique characteristics of the computer-aided design medium must be understood and incorporated into the creative problem solving process. Each of these characteristics suggest a radically different structure and pattern to problem solving: a cyclical process.

Interactivity

Every system (medium) impresses its assumptions on participants. A linear system suggests orderly sequential progression from stage to stage. Linear models do not utilize the interactive strengths of the computer medium, but rather move the product down an assembly line of inevitable steps to completion.

Computers as a system are more immediately responsive and continually interactive with the operator. There are inevitable moment-by-moment opportunities for synthesis of material and divergent explorations. Computers are open systems, highly receptive to the environment. Networking increases this interactivity and extends it to the whole world. Networking provides access to vast amounts of data that can enrich the problem solving process. New ways of thinking need to be developed to maximally utilize these new interactive patterns that are made possible with computer media.

"To understand the full dynamics of shapes and forms created by artists and designers on the computer, one needs to understand how these new tools can be used in the creative process. The capacity to change and alter images is far different when using a computer than when using a paintbrush or drafting tools. The biggest difference is the ability to rotate, move and animate objects on the computer screen" (Van De Bogart, 1990, p. 307).

As visual possibilities multiply, through playful experimentation and manipulation of images on the screen, the older linear problem-solving processes quickly become too static. Linear problem-solving does not provide for the continual shifts in context of information when something new is discovered "out on the net." To be successful in the computer environment the designer must be continually generating new strategies for further exploration. Computers are more organic in their operations and rigorous controls over the process stages unduly restricts further visual exploration of possibilities.

Visual Thinking

Visual information is processed holistically within the human brain, rather than linearly. To work effectively, then, on a problem calling for visual-spatial manipulation and solutions requires a high order of what psychologist Rudolf Arnheim has called, visual thinking. At each stage of the problem-solving process there is a need for wholeness and synthesis.

In visual thinking, pattern seeking becomes vital if the designer is to be able to "see" and comprehend what is actually taking place. This shift from moving through linear steps to continual pattern seeking as a mode of discovery and educational inquiry, is exactly one of the effects of electronic technology predicted by Marshall McLuhan in 1965.

The multitude of manipulations and variations made possible by the computer are expressed instantly on the screen in concrete representational symbolism. These multiple variations, in turn, create an accumulation of decision tensions among possibilities. All these possibilities are the raw material for reflection, combination, and synthesis into a finished product of novelty and aptness for the problem at hand. In order to bring about a productive hybridization of ideas, the designer needs a disciplined, structured, yet playful exploration of visual possibilities. Out of this disciplined play with visual configurations the underlying structural patterns of the problem surface and become visible and accessible.

Discovery Orientation

Playful, creative discovery is an open-ended discovery-oriented process, seemingly without strict rules of causation. In creative play the human can discover patterns, see contextual relationships to the problem, and eventually hope to make decisions among the many variables discovered.

Working within the computer environment (medium) naturally contributes to this important discovery orientation. With its enormous capacity to support and promote variations, the computer encourages exploration. In addition, the interconnectivity of individual computers through local and international networks breaks down traditional disciplinary boundaries and opens up new possibilities of discovery. Information and perspectives from disparate fields of knowledge are now immediately accessible to the designer working at their individual work station.

The process of visual design is not an objective process, with set rules and standards. The process is interactive within the designer, with the world, and finally with the viewer. Such a disciplinary process needs to provide a number of important characteristics for the designer: discovery at every stage, acceptance of an ingrained ambiguity to the outcome, and unpredictability of goal attainment. The designer must remain open to new discoveries.

Personal Affordance

Both the designer's needs for an original perspective and the larger human needs factors of the design audience must be made an integral part of any visual design process. The designer is not a neutral, detached observer of the design process. The designer is interactive with the developing design idea just as the design client or consumer will be interactive with the finished design product. While creative people need to take chances at each step in the process, they also need security and assurance that the effort being expended will eventually result in a fruitful and productive direction.

One reason that the computer environment is so inherently interactive and engrossing is that the patterns on the screen are essentially patterns projected directly from the mind of the computer operator. This means that the designer/operator must have, at each stage in the problem solving process, a whole and complete sense of personal attachment and meaning. This personal affordance or connection must be continually made with the data flowing into the process. A sense of personal connection or affordance must be a vital human component within the design process.

ETC: Express - Test - Cycle

Robert McKim in his 1972 book, Experiences in Visual Thinking, suggested that the process of generating creative visual forms required a cyclical process of projection, evaluation, and ongoing discovery. He named this graphic ideation process ETC (Express, Test, Cycle).

"Graphic ideation utilizes seeing, imagining, and drawing in a cyclic feedback process that is fundamentally iterative. I have given this 'feedback loop' the acronym ETC (etcetera) to dramatize the importance of repetitive cycling to the graphic development of visual ideas" (McKim, p. 117).

Making a graphic image on the computer screen lets the designer literally Ex-press or externalize visual imagery from the brain and press it in concrete tangible form. Once projected into visible form, ideas must be carefully and critically evaluated (tested) for potential usefulness. If this critical examination is not to short-circuit the on-going design process however, McKim suggests that an integral part of any graphic ideation process must be another round of idea expression. The initiation of this new round of expression is based on knowledge gained from the first round. The process "grows and learns" as it develops. This circling, growing pattern of expression and testing, within the computer environment, leads to a layering of cycles that we call the "layered cycles" approach.

The Layered Cycles Approach

The layered cycles approach to problem solving involves the use of both macro and micro cycles of expression, testing, and cycling. The way to stay productive and creative, within a computer environment, is to pursue an overall process (ETC macro cycle) moving dynamically toward effective creative solutions. But within this macro cycle, the interactive computer environment presents, minute by minute, new sources of information, new contexts to be incorporated, and new possibilities and variations that suggest a reopening of the problem solving process.

Each of these minute-by-minute opportunities is itself a cycle, an ETC micro cycle within the larger, moving toward successful completion. It is suggested that each micro cycle must move through the Express-Test-Cycle feedback loop to keep the macro cycle open to creative exploration and discovery.

"The output of the design process is "determined by a process of continuous exploration. At all decision nodes, orientation is guided by a new (and possibly just discovered) goal" (Beyls, 1991, p. 313).

Each micro cycle should reinforce critical/contextual thinking and personal affordance connections to meaning and heuristic motivation. While the macro cycle moves dynamically toward creative solution, each micro cycle keeps the process open to further creative exploration and discovery, thereby maximally

Layered Cycles

Creative problem-solving in a computer environment

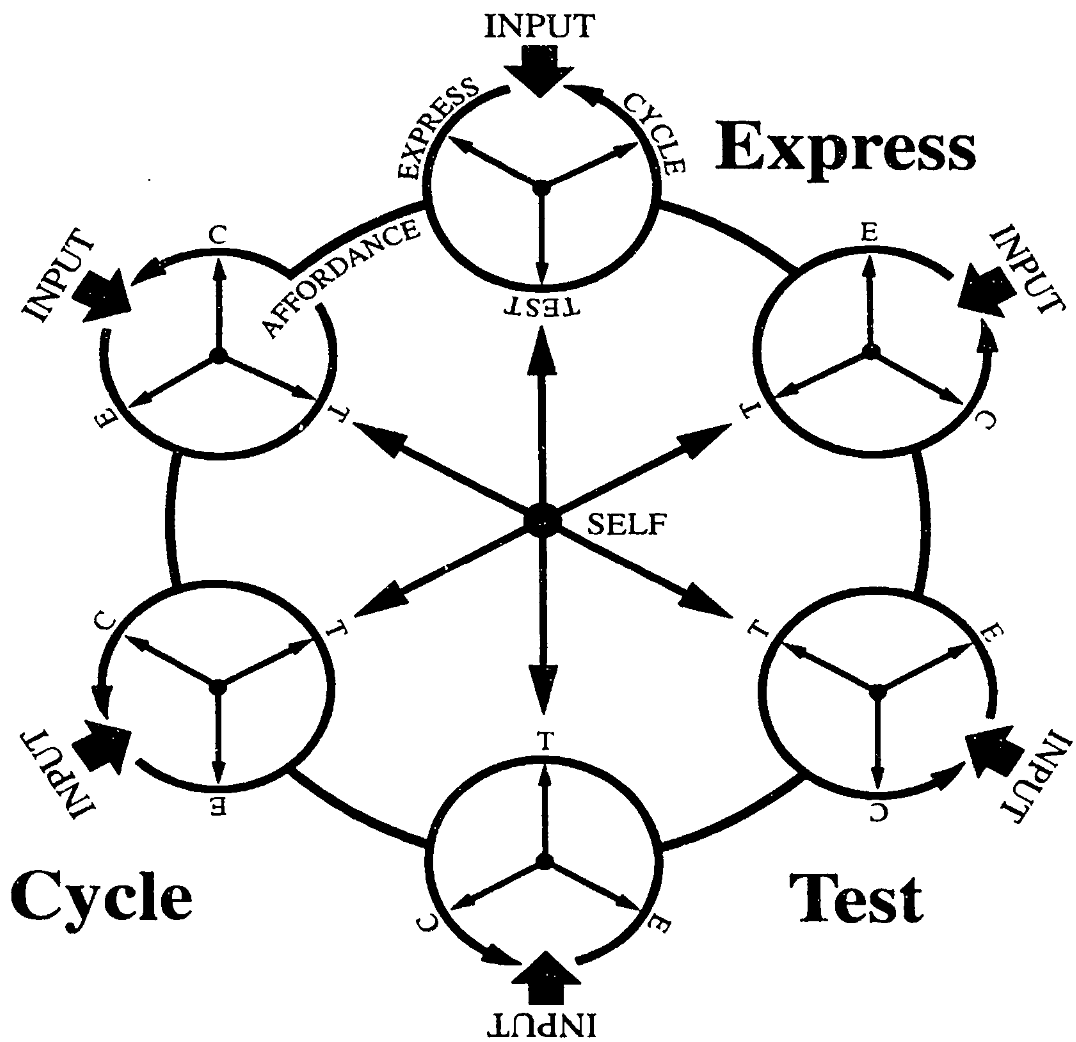


Figure 6. Layered Cycles Approach
Mikovec & Dake 1995

utilizing the unique strengths of the computer medium.

As micro cycles pile up upon one another, the macro cycle is both supported and enriched. The individual designer is continually and individually empowered to explore and integrate new information and possibilities until a maximally effective solution is generated. This layering of micro cycles upon a macro cycle is a new information -processing system. The "layered cycles" approach is a new pattern of problem solving medium needed to fit with the new relationship to computer media.

Putting Layered Cycles Theory Into Practice: Results From Classroom Pilot Tests

Background in Interior Design Education

Prior to 1980, design education relied on manual skills. Along with theory and methodology, students were instructed in graphic communication skills. Students learned how and when to use mechanical pencils, pens, color media, paraline bars, t-squares and triangles. These were roughly all the tangible tools a designer needed to complete the problem-solving process. It was all the designer had. However, during the early 1980s at colleges and universities across the country, computers were introduced as yet another tool for the designer's use. Computer-aided design and drafting software enabled students and practitioners to design and modify drawings, virtually in seconds and was seen as a miracle tool by many.

Within interior design curricula, students began using computers for simple two- and three-dimensional drafting. Orthographic drawings, plans, elevations, and sections, were easily input into computers, and provided the possibility for a greater level of accuracy. Errors could be easily corrected and time saved. Perspective and paraline drawings provided students with three-dimensional views of design solutions, while helping them to better understand form and space. Printers and plotters allowed for quick and reliable reproductions.

As use of computer applications grew, so did research on its potential. In its introduction, computers were used mainly for production drawings, as mentioned above. Little process or preliminary design work was done on the computer. Rather than isolate the computer as solely a production tool, academia began researching ways to integrate computer applications throughout the design process and the phrase computer-aided drafting was replaced with computer-aided design.

Many designers have explored the potential for computers in areas of visual ideation and creativity. Unfortunately, applications and use in preliminary and process drawings have been slow to catch on. Only the most open-minded users, comfortable with the computer interface, the use of a mouse or digitizer pen, have been able to achieve a level of sophistication and subtlety previously exclusive to manual applications. The computer does however hold tremendous potential for modification and iteration. Space plans can be modified, subtracted from, or added to with a few simple key strokes.

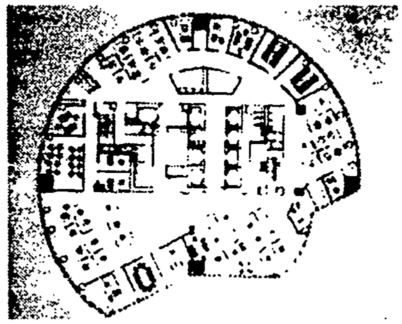
While the uses of computer applications have expanded to include three-dimensional modeling, color imaging, simulations, and virtual reality, little time has been devoted to methodology, the process design students follow in solving a visual or spatial problem. Traditionally our process models have been linear in sequence. The following pilot studies will show the modification of design process from a linear to cyclical sequence and lists the benefits and weaknesses of each as determined by the instuctor.

Fall 1993: Independent CAD Studio
(Linear Process)

As it was designed, the computer-aided studio focused on skill development. Emphasis was on "how" rather than on "why." The students participated in an office design competition that served as the studio project for the semester. While the computer is well-suited for office design, as there is much repetition of form and shape, there is a tendency for students to focus on the space planning (2D design) and not on the overall volume development (3D design). This course was restricted to interior design majors but was not required for their graduation.

Benefits:
* Highly focused concentration of specific skills and technical information.
* 100% of studio time was devoted to learning the computer tools. (Use of output devices was also covered in the studio.)
* High interactivity between students in developing technical skills.

Weaknesses:
* No personal affordance or relevance which was specific to the individual student.
* Current pedagogy encouraged "child learning instead of adult learning" (rote skills vs. comprehension) (Braswell, 1994).
* Focus on two-dimensional space planning rather than three-dimensional design limited students' visual thinking and discovery orientation.



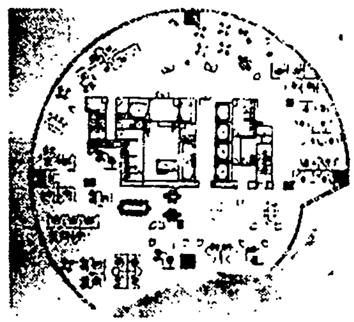


Figure 7. Office Design Competition. Floor Plans (student work)

Student perceptions summarized from evaluation forms:
* The product was more important than the process.
* Students often had the misconception that computer applications resulted in better design.
* There was little three-dimensional design done on or off the computer.

Spring 1994: Independent CAD studio
(feedback approach) (Koberg, 1991)

In an effort to encourage creativity, students were required to integrate manual applications into their design process, reinforcing their acceptance of the

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computer as a tool. The feedback approach combines a linear process with a more cyclical process; a two steps forward, one step back approach. In this case the two steps forward were completed on the computer and the one step back were the integrated manual techniques. Students selected old NCIDQ (National Council for Interior Design Qualification) exams based on interest of subject material. Objectives for the course included full design development, as specified on the NCIDQ exam, from problem definitions through documentation. A furniture design component was added to the NCIDQ requirements to encourage more three-dimensional computer-aided design.

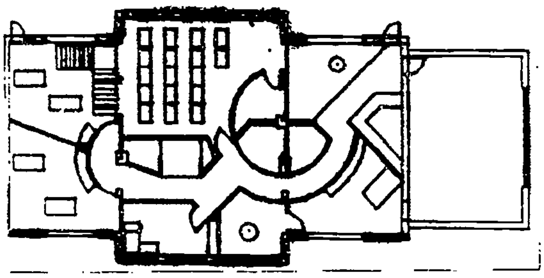

Figure 8. NCIDQ Exam: Artists Workshop Floor Plan (student work)

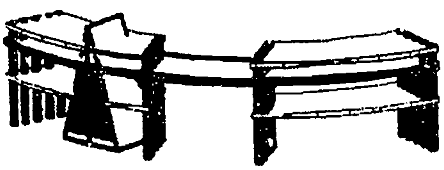

Figure 9. NCIDQ Exam: Artists Workshop Millwork Design (student work)

Benefits:

* The feedback approach more closely addressed comprehension rather than awareness in computer-aided design development.
* Design process was emphasized and less value was placed on product.
* Much greater level of interactivity between students and faculty on both computer skills and design issues.
* Allowing students to select their design problem made the process more personally rewarding for the students.
* Smaller scale furniture projects made visual thinking on the computer more viable.
* Encouraging students to integrate manual applications allowed them to fall back to more comfortable and familiar tools which increased their design discoveries.

Weaknesses:

* Small scale design problems were not taken seriously.
* Students did not maximize their time or design talents.

Student perception summarized from evaluation forms:

* Initial response to the integration of manual applications was positive, however as the end of the semester neared the response to integration became more negative.
* Projects for inclusion in one's portfolio became the driving force for the studio.

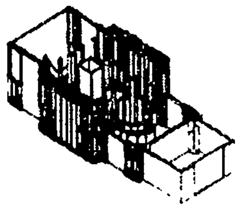

Figure 10. NCIDQ Exam: Artists Workshop Axonometric (student work)

Summer 1995: 3D CAD Workshop
(layered cycles)

The workshop combined the objectives of the traditional computer studio with less traditional computer and manual applications. High levels of interactivity, visual thinking, discovery orientation and personal affordance were key to the success of the pilot study. The "Macro Circles" for the workshop were 1) student selection of simple, small house plan from ten choices provided by faculty; 2) three-dimensional input of architectural information; 3) abstract manipulation of orthographic drawings; 4) vernacular addition to house; and 5) rendering and animation of addition. The "Micro Circles" were the expressing, testing, and circling of multiple ideas. Personal affordance were built into each macro circle as students self-directed their course of action. The workshop required no prerequisites, and was open to all university students of undergraduate and graduate level. Enrollment included students from the departments of mechanical engineering, construction engineering, architecture, and art and design.

<u>Benefits:</u>

* Elective summer course guaranteed some personal affordance and was strengthened by a student -driven syllabus. Problems were selected and modified based on students' own experience, background, and interest.
* The short four-week session allowed for a continual discovery process selecting, inputting, manipulating, exchanging, and outputting ideas.
* Diversity in academic backgrounds made each student the resident expert in their field and would eventually lead to high levels of interactivity.

<u>Weaknesses:</u>

* Interactivity between students from different departments was slow to develop.
* Difficult to manage such diversity in disciplines, skill levels, interests.
* Still product-driven. Students desired hard copies of work.
* Manual study models were unfamiliar and difficult for some students to build.

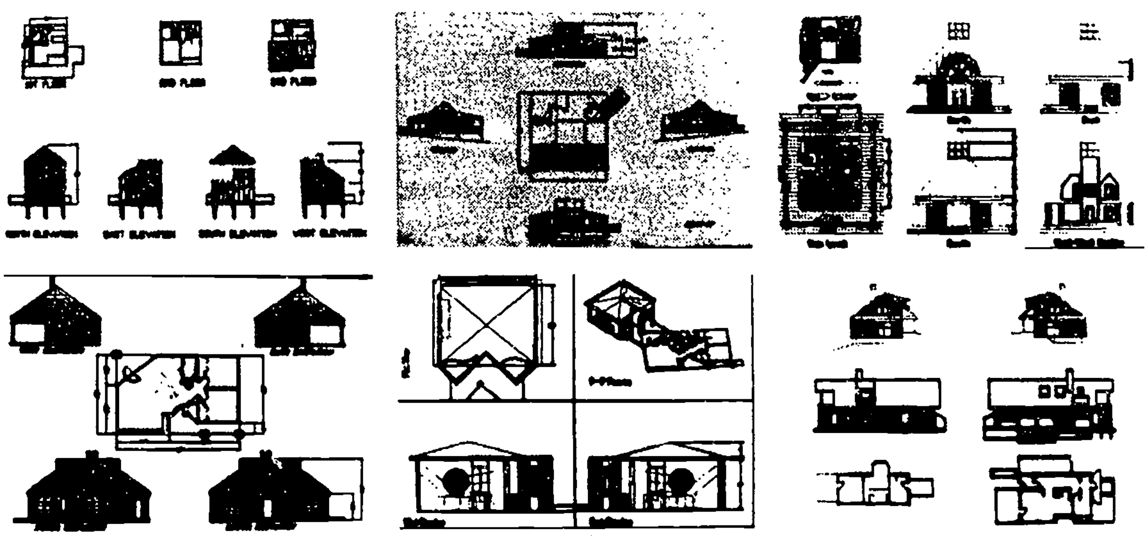

Figure 11. Orthographic Drawings
(student work)

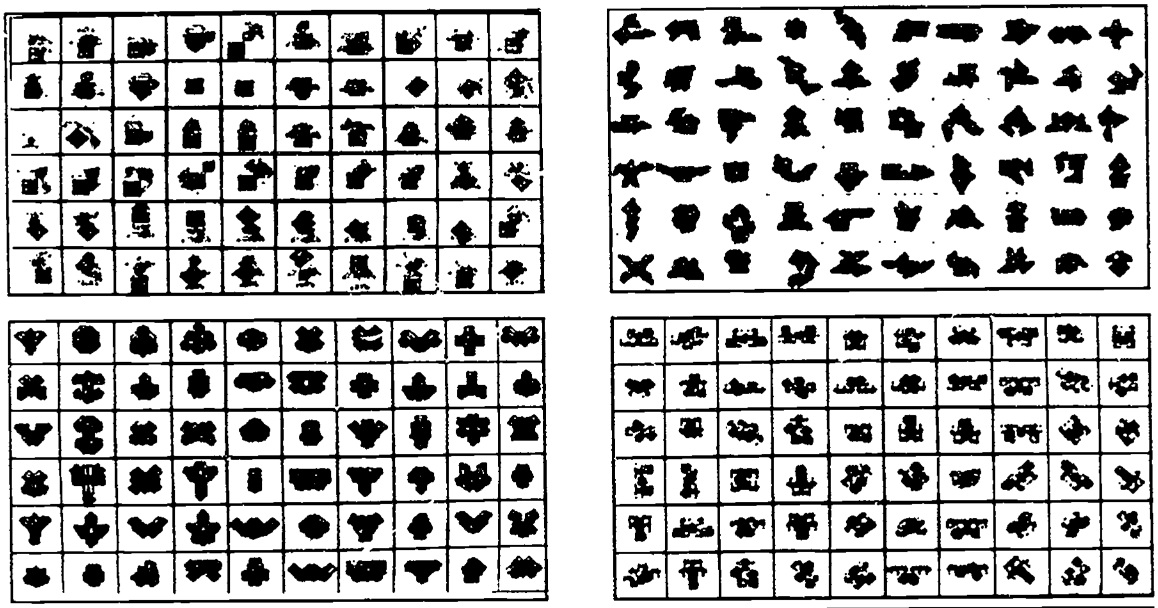

Figure 12. Abstract Analysis
(student work)

Student perception summarized from evaluation forms:

* Students enjoyed process work as long as they were able to generate a hard copy of it.

Students were not responsive to abstract analysis exercise. Did not see the relevance of such studies as sources for design inspiration.

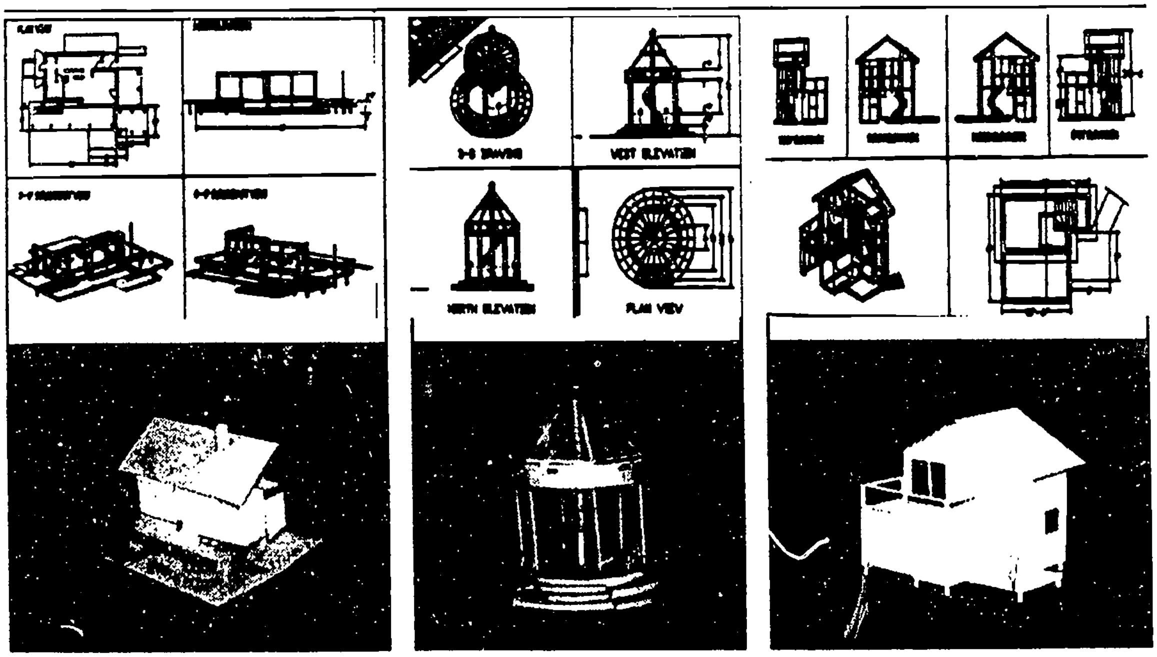

Figure 13. Vernacular Addition:Orthographic Drawings & Study Models
(student work)

Future Directions: Integrated Studio (layered cycles)

While we have shifted from an independent CAD studio to a more integrated design studio, the interior design department at Iowa State University continues to struggle with the refinement of pedagogy. Currently, lower level studios remain more linear in their computer-aided design process. Students spend one studio day each week working on computer projects that may or may not relate to the concurrent manual studio projects. On the other hand, upper level courses are beginning to show signs of a more cyclical process. They address, with varying degrees of intensity, the issues of interactivity, visual thinking, discovery orientation and personal affordance, vacillating between computer and manual applications.

Some Tentative Conclusions

Work on the layered cycles process for problem-solving in a computer environment is still in the formative stage of development but based on several classroom, action research trials it appears that there are distinctive benefits in layered cycles for design students. Four conclusions particularly stand out as areas for further research and testing.

1. Effective use of the computer as a tool in the design process requires controlled exploration. While the computer offers an array of design possibilities and discoveries, the controlled explorations keep students from straying too far from intended objectives.

2. Controlled exploration in a computer environment must be compatible and integral with the nature of the electronic medium. Awareness of the limitations and advantages of any media results in a more creative use and critical understanding of the tool.

3. Computer-aided design is a particularly effective tool for managing, controlling, and maximizing a complex design process.

4. The layered cycles approach to creative problem solving is particularly productive in both encouraging students to explore a variety of inputs and take effective advantage of them as required by the specific, individual problem.

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