AN EXPERIMENTAL COMPUTER-AIDED DESIGN STUDIO

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ABSTRACT

A pilot experiment was conducted in the use of microcomputers and Computer
Aided Design (CAD) software for architectural design education. The CAD
workstations were incorporated into two consecutive semesters of the third
year design studio and consisted of TANDY 3000 HD (tm) microcomputers with 20
megabyte hard disks, digitizer tablets, digitizer mice, enhanced graphics
capabilities, dot-matrix printers and multi-pen plotters. Software packages
included the Personal Architect (tm), VersaCAD (tm), DataCAD (tm), word
processing software etc. Student to machine ratio of 4 to 1 was maintained
and the use of the equipment was made available to students for approximately
20 hours per day.

Design assignments neither emphasized nor required the use of CAD techniques,
as the experiment was designed to measure the students' acceptance of and
adaptation to the use of CAD tools. The objective was to "teach" design in the
traditional sense of a design studio, while making the computer an
integral part of the setting in which the student learned designing and
problem solving.

Measurements were made of (1) time for the "fundamentals" learning curve, (2)
time for a "basic competence" learning curve, (3) hours utilized by categories
of type of use, (4) hours utilized by equipment and software type, and (5)
progress in design ability as evaluated by the traditional jury review methods.

INTRODUCTION

Planning and design of the built environment is an increasingly complex
activity with more constraints - physical (codes, regulations etc.), economic
(capital & life-cycle costs, depreciation, etc.), and social (response to
surroundings, barrier-free, image, etc.) - now than ever before. These con-
straints have lead to the recognition of design specialization and multi-
disciplinary design teams as viable approaches to environmental design in the
future. Yet at the educational level, potential architects must be instructed
and exposed to all facets of this increasingly complex discipline.

The overall goal of architectural design education at the university level is
to refine students' skills so that they may be effective designers and
builders of the environment. In order to achieve this goal, educators must
take full advantage of all existing and developing technology. The rapid increases in the capabilities of microcomputers and their affordability in the last few years must be considered as a major advance in technology when related to architectural design. The question then arises whether computers can be effectively used in architectural design studios to enhance the quality of the studio experience and the quality of the designed project in an academic environment. The hypothesis of this experiment being that “students given the choice of using manual or CAD tools in a traditional design studio will choose the CAD approach over the manual methods with superior educational benefits.”

Design is not a wholly repetitive or iterative activity. The process of design and the methods used can be repeated but the entire activity must always vary in response to the design problem at hand. Similarly, design education varies in response to the level of student maturity, design philosophies of the teacher, and goals of the studio experience. For this experiment four factors were identified as being important to the quality of the studio experience in architectural education. They are:

1) The extent of information presented and treated in the studio.
2) The depth of detail to which the information is treated.
3) The variety of approaches used in architectural problem formulating and problem solving.
4) The extent of analysis performed on preliminary design solutions.

The quality of designed projects in an academic environment is inextricably linked with the quality of the design studio experience. Though project quality is dependent on the same factors as those that enhance the design studio experience, the following factors also significantly effect designed project quality:

1) The number of alternative design solutions generated.
2) The rigor of testing design solutions against design criteria.
3) The validity of selected design criteria for the problem.
4) The appropriateness of design representation and communication.

The factors listed above represent influences on the quality of the design studio experience and the quality of the designed product wherein automated assistance provided by computers could have a significant effect on both.

Traditionally, we have taught architectural studios by using the standard tools of design—the pencil, triangle, and T-square. We have also wanted our students to use modern automated tools (computers) to enhance their learning experience, so we have given them courses in computer programming and computer applications. Very seldom—almost never—are these experiences gained in the same course. For the most part students have been expected to make the connections between design and computers on their
own time, but we have never explicitly made this connection within the actual design environment. On one hand, the student learns design at the drafting table, while on the other, he is thrust into a totally new setting of terminals and "work stations" to learn computer applications. This is not only true at our institution, but at most others as well.

The use of computers in design education is certainly not without precedent. Many schools have developed design courses with CAD assignments; however, we did not assign students to perform their work on computers. The CAD involvement was totally optional. The key element in this experiment was to make the CAD equipment, software, and knowledgeable personnel freely available and easily accessible to all the students in the design studio, the same instructors performed design and computer techniques instruction. In this regard, our approach has a degree of novelty when compared with some other approaches. Most of the previous approaches have not utilized the computer as a true "low-key" design partner as we propose. Our concept was to take the computer out of the laboratory and put it at the designer's side to be used in a partnership role and a real design aid - not just to do CAD, but to also do engineering evaluations and everyday text processing. Students and instructors were able to switch back and forth between drafting table and terminal easily since they were all in one space.

The design studio chosen for the experiment is taught as a "traditional" studio at the third-year level, the course description of which is "Theory and Practice. Analytical approaches to problem identification and problem solving emphasizing architectural programming techniques and design methodologies. Analysis, synthesis and critique of physical and social systems intrinsic to the built environment." The course is normally conducted as a series of seven or eight short projects during which each student formulates a context statement, a set of architectural problems with generic solutions, and demonstrates these solutions in the design portion of the project.

OBJECTIVES OF THE COMPUTER-INTEGRATED DESIGN STUDIO

Besides meeting the objectives of the "regular" studio, the objectives of this experimental studio are three-fold:

1) Evaluate "state-of-the-art" technologies in microcomputer-aided design and their significance to architecture.

2) Develop, test and validate methodologies in architectural design education using the computer as an integral part of the design tools traditionally used.

3) Identify and prioritize directions of future research in methods of improving design quality in education and practice.

Factors that effect the quality of the studio experience and the quality of the designed product have not been treated in great detail in the above sections. To examine every factor that may influence quality is beyond the scope of this inquiry. It is sufficient to say, at this stage, that the factors enumerated above are widely accepted as having an effect on quality.
The importance of any particular technological, methodical, economic, social or aesthetic consideration in architectural design is a matter of personal opinion. To examine the relative strengths and weaknesses of these considerations (or priorities) is beyond the scope of this experiment. Constraints put on design by these considerations are undoubtedly important factors that determine the quality of design. The personal philosophies of design teachers, the talent of design students, the previous design related experiences of the student, and the prevalent emotional state of the design student also have an effect on the quality of design and the quality of the design studio experience. These factors were not considered.

It was assumed that:

1) There does not exist any bias or resistance to change in operating the traditional design studio on the part of the teacher.

2) Only the eight factors mentioned in the previous section will vary, and all other factors that influence the quality of design can be held constant.

3) The availability of computers to the students will not be significantly different than the availability of other design tools currently used.

4) The educational objectives to be met by the design studio will remain constant.

SYSTEM DESCRIPTION

We felt that the student to machine ratio should not exceed 3 or 4, so that access can be maintained freely for about 16 to 20 hours per day, as is now common for all architectural studio environments. Assuming that about 27 of the 36 students opt to use the computer approach this would mean that the necessary number of computers would be 9 if three persons had access to one machine. It was felt that two plotters would be sufficient to serve all the design needs of this group; since most of the design work would be created on the screen and held internally, plots would be made only infrequently. Each computer, however, would have to have a mouse and/or tablet style digitizer as the graphic input device. Computers need to be PC-compatible in order to take advantage of the wide range of available software packages, and each computer will need to have a minimum of 640k RAM, a 20MB hard disk, and high resolution color graphics. The system configuration along with the software which was made available to the students are shown in Fig. 1 on the next page.

METHODS AND APPROACH

The basic method for exposing students to CAD was to simply provide to the students the equipment, software and knowledgeable personnel to make CAD as simple to use as possible. Our plan was to utilize the microcomputer as the "whole" machine. Whereas there are many "special purpose" machines, some of which will do drafting and some of which will do analysis or word proces-
ing, the micro was introduced as an all-purpose computing/writing/designing aid. The software included, but was not limited to, the following:

- Conventional word processing (e.g., WordStar, Volkswriter).
- Building space planning through space allocation (e.g., Corel). 
- 3-D Form Generation (e.g., VersaCAD, Personal Architect).
- 2-D CAD drafting and manipulation (e.g., AutoCAD, VersaCAD).
- Energy Design and Simulation (e.g., SOLAR5, EnerCAD, RENCON).

In order to avoid student bias against the computer or resistance to its utilization, the CAD experience was voluntary. Since there were a significant number of students (about 36) the option was open to perform the design problems in the conventional manner or by use of the computer. This allowed for some sort of comparison of progress by the course instructors, and permitted more natural gravitation toward computer use on the part of the students, as no one was actually "assigned" to do their design work on the computer. The voluntary approach also enabled us to assess which CAD software was most appropriate and the optimum "student-to-computer work station" ratio. Our initial expectation was that the ratio would be 2 or more per machine, but should not exceed 4 because of the enrollment; this ratio was maintained.
In the absence of many precedent studies, documented experiments or established methodologies of inquiry in this area, a combination of various generic methods of systematic inquiry were used in approaching this experiment. In keeping with the objectives of the experiment, computer-aided design technologies must be evaluated in a controlled design-process situation and subsequently methodologies of architectural design education must be developed for testing in a 'real-world' design studio setting. The approach was planned to be generally sequential and consisted of the following steps:

STEP 1:
A "base-level" of student participation and student achievement in the conventional design studio was established by teachers for the purpose of establishing a benchmark for future comparisons with student participation and achievement in the re-structured design studio. Student participation was measured by the amount of time spent on projects and particular aspects of projects, the number and complexity of alternative solutions generated and tested. The level of student achievement is measured by the normal methods a teacher evaluates students. This method varies with the teacher but is constant for one teacher evaluating different groups of design students.

STEP 2:
A re-structured (non-conventional) design studio was set up within an existing setting and computers were integrated into the teaching and working modes of the studio. The use of the computers in this studio was controlled in terms of their capabilities and accessibility. Integration in the teaching mode was achieved by using the computer as a medium of transferring information from teacher to student. In the working mode, the student used the computer as a medium of drawing, analyzing and testing and communicating design solutions.

STEP 3:
The re-structured studio was with one group of students to gain experience in (eliminate logistical inconveniences) operating the studio, and test the implementation of teaching and design methodologies. The design and teaching methodologies were adaptations of those normally used in the conventional studio, i.e. search of solutions based on student identified design principles. This studio was run as a pilot study to refine the implementation and methodologies mentioned above and to identify and refine data collection plans, procedures and content.

STEP 4:
Optimum software configurations and specialized software for course objectives were developed. The software configurations that most closely suited the stated design course content was considered optimum and specialized software was restricted to interfaces between user and machine so that communication between the two was less cryptic and did not require elaborate interpretation and instruction.

STEP 5:
The re-structured studio was run with a group of students unaware of the experiment before registration for the course. This studio was run through the normal semester with no special pre-requisite conditions imposed on the students registered for the course. Surveys established the level of prior computer and CAD knowledge of each student, potential willingness to learn CAD techniques outside of formal instruction.
DATA COLLECTION AND EVALUATION METHODS

Some of the factors that are seen as being significant in assessing the degree of success in applying CAD to the studio environment are listed below. These factors were measured by the course professors by methodical recording and periodic sampling of the student reactions.

1. Time interval between being shown the computer and "warming up" to its use in a routine way.

2. Time interval between being introduced to a CAD software package and feeling competent in its use (by CAD software type).

3. Logging of student hours categorized as to learning time, experimental time, entertainment time, and production time.

4. Logging of student hours as to equipment type, CAD software type, and other software type.

5. Measurement of the student's progress in design ability evaluated in the traditional jury review method of project grading. Design projects will in no way be tailored for machine applications — they will all be "regular" design projects.

For the assessment of the value of CAD a cross-correlation analysis will be performed to determine if there is any degree of correlation between hours logged on the computer and derived design ability. In this regard, the fifth item in the above list will be the dependent variable and items 3 and 4 will be the independent variables. Items 1 and 2 will only be collected as determinants for future planning of this type of approach in design/CAD education. If items 1 and 2 are very large, this could have negative effects on the outcome of design progress as assessed under item 5.

The second type of measurement would be to determine the difference, if any, between design ability of those who used CAD and those who chose to use conventional manual methods. Given the small number expected to choose manual methods, this comparison will probably not be statistically valid, so it will most likely not be done. Also, it is quite possible that all students will do some CAD, applying it to some projects while not to others. If this is the case, there will in fact be no "CAD" group vs. a "non-CAD" group. Given these possibilities, strict records will be kept on the numbers of students selecting to use CAD on each project that is assigned. In this way it will be possible to determine which "types" of design projects seem most amenable for CAD application.

SIGNIFICANCE TO THE ACADEMIC PROGRAM

Some of the significant aspects of this effort could be regarded as:

1. While many schools are offering CAD instruction, their efforts are sometimes divorced from the studio environment — the courses in design and computers are taken from different professors — the students who take the initiative to apply computers to design work have to move themselves to another location. Our concept was
that the computer be accessible at the table-side of the designer, and that problems be solved WHILE THEY ARE STILL WARM IN THE DESIGNER'S MIND and while they are still in the computer's memory. The computer, in effect, simply becomes another working partner as would T-squares, triangles and other drawing instruments, yellow paper, hand-held calculators and reference manuals.

2. This experiment has also been useful in exploring the ways high powered microcomputers can change the way design is introduced in architectural studio education and the way computing is introduced to the design student.

3. This project has been a demonstration of bringing the computer to the designer, rather than vice versa, i.e., bringing the designer to the computer.

4. Using computers in the design studio does not in any way diminish or belittle the traditionally acclaimed "crafts" or "talent" of a design student. It merely serves as an enabler to enhance the student's capabilities (often achieved by mixing manual and automated techniques).

5. Students' use of computers in the design studio is limited to tasks they feel competent at and confident of higher quality results. The computers do not "take-over" the design process nor do they inhibit student creativity in design solutions.

6. Traditional thinking is that high quality design and graphics work can be done only on mainframes and minicomputers. This project demonstrates a reversal of this trend if we can provide high quality graphics at the personal work station. For this application, we would want to be sure that the microcomputers and the software utilized would have the speed and the color capabilities to guarantee a good working relationship between student and computer. The student will always have the tendency to gravitate toward those techniques he finds the most useful, pro-

ductive, and enjoyable.

We are hoping that the "natural" choice of approach to designing will include the computer. This will have far reaching significance to future architectural educational methods as demonstrated by the experiment. The findings of this experience will be utilized for formulating future goals and directions for design studio education in our Architecture Curriculum.

BIBLIOGRAPHY
