THE IMPACT OF CAD ON ARCHITECTURAL DESIGN EDUCATION IN THE UNITED STATES

Yehuda E. Kalay, President, ACADIA

School of Architecture and Environmental Design
State University of New York at Buffalo
Buffalo, New York 14214 USA

INTRODUCTION

Computer-Aided Design (CAD) began to appear in schools of architecture in the United States over 15 years ago. By 1982, over 50% of all accredited schools of architecture in North America included some form of CAD in their curricula. This number has continued to steadily increase. For the most part, the use of CAD has. been restricted to the few individuals working on special "CAD projects" and to the researchers developing CAD products. The reasons for this limitation have included the low availability, difficulty of use, restricted access and high cost of the CAD systems, as well as limited faculty and administrative support. Recently, however, partly due to the introduction of micro-computer CAD software, and partly due to the growing awareness of the importance of CAD in architectural education and practice, some schools have begun to introduce CAD as part of the general design curriculum.

With every reason to believe that the role of computers in design will continue to strengthen in the coming years, it appears an appropriate time to study fundamental issues concerning CAD in design education. An important issue which arises concerns the impact that CAD has had on architectural design education: specifically, whether CAD has, or could have, a beneficial effect on the learning and teaching of design skills that are at the core of architectural education. Two questions can be formulated that are critical in examining this fundamental issue:

1. What are the potential benefits of CAD to design education that make the effort of introducing it into design courses worthwhile?

2. How will we be able to measure the impact of CAD on design education?

To answer these questions, ACADIA (The Association for Computer-Aided Design in Architecture) solicited contributions from its member schools to find out how they use computers in design education (or how they intend to use them), and what their efforts have realized so far. This report is based on an unofficial interpretation of the results obtained so far (only about 15 out of the more than 60 schools that use CAD are included). In addition, it addresses only those uses of CAD directly related to design education neither general computer literacy nor CAD research. We believe, nevertheless, these early results, are indicative of the trends of using CAD in schools of architecture in the US.

From these preliminary results it appears that schools follow one or more of four categories of applying CAD in design education:

1. They use computers to learn about CAD itself, and to execute special CAD projects.
2. They use computers to enhance the teaching of basic design concepts, such as color theory and spatial composition.
3. They use computers to support design through non-graphic applications, such as energy analysis and cost estimation.
4. They use computers as a tool in regular architectural design studios to draft and/or model conventional design projects.

Although it is apparent that schools do not always fit neatly into these categories, we have nevertheless attempted to place individual schools in the categories they seem to emphasize, in order to form some systematic basis of comparison.

USE OF COMPUTERS TO LEARN CAD

In light of the changes now affecting architecture as a profession, most schools of architecture find it necessary to expose their students to the emerging technology of computer-aided design. This trend has been reinforced by the computer literacy requirements set by the National Architectural Accreditation Board, which certifies the curricula of schools of architecture in the US.

After overcoming the initial hardships of recruiting faculty knowledgeable in CAD, and acquiring appropriate hardware and software, schools that have made the decision to introduce CAD are now faced with the problem of making the best use of these expensive and relatively scarce resources. An obvious, and practical, solution to this problem is to let interested students execute certain "special" design projects on the CAD systems, either on an individual basis or as part of an organized effort to expose all students to this new technology. Carnegie-Mellon University, the University of Houston, Iowa State University, Ohio State University, and Texas A&M University, are among schools that have taken this approach. The particular projects that individual schools have chosen to develop span a wide range of complexity, and are highly dependent on the sophistication of their CAD facilities.

The University of Houston, using a Prime/Medusa CAD system, offers interested students the tools to explore special projects such as the design of space habitats for NASA.

Carnegie-Mellon University requires all students to experience drafting, painting, and modeling with the aid of CAD, as a special course that has its own series of design projects. In some cases, these projects form the basis for regular studio projects that are executed manually.

Iowa State University uses a blend of commercial and in-house developed software (MOVIE.BYU and GRAPHICUS) for individualized projects, after all students have been exposed to these tools at the undergraduate level. At the graduate level, students are involved with software development that evolves into thesis projects. These two uses can create, for the interested student, a transition from tool-using to tool-building.

The sophisticated ARCHIMODOS system that was developed at the Ohio State University is used by graduate students who specialize in CAD to explore both the advantages and disadvantages of CAD for design, and as a basis for enhancing the software itself as part of their Master's Theses. The approach treats tool-using and tool-building as inseparable components, enabling the use and development of CAD systems to occur in close conjunction with input from designers at all phases.

USE OF COMPUTERS TO ENHANCE BASIC DESIGN SKILLS

Several schools make use of the color and 3-D capabilities of computers. in teaching students fundamental design issues, such as color theory, composition, and spatial relations.

The University of Clemson (South Carolina) has been using Tektronix hardware with software developed in-house to "computerize" Alber's color exercises, and to explore the effects of color on the design of building facades.

The New York Institute of Technology expects to utilize its considerable computer graphics resources to teach students two- and three-dimensional spatial composition, massing and shadow casting, using "kits" of primitive elements.

The University of California at Los Angeles teaches students how to use a graphical programming language it has developed for the purpose of studying two-dimensional, three-dimensional, and color composition of buildings. Students are given a series of exercises that span many basic design issues and teach basic computing skills. The exercises follow a progression that includes simple 2-D composition of lines (floor plans), 3-D composition of lines, and 3-D composition of colored polygons. Although basic and interactive graphics programming skills are taught, emphasis is placed on formulating basic design issues in computational terms.

USE OF COMPUTERS TO SUPPORT DESIGN

Adhering to a broader definition of CAD, several schools have made use of the numeric powers of computers to aid a number of analytic problems, either with or without conjunction to the graphic capabilities of computers. Numeric analysis forms a large set of the design criteria that are involved in any design process, and that can be efficiently manipulated by computers.

The University of Arizona at Tucson applied these capabilities to develop a project in which students re-design well known residences after they have been relocated to the Tucson desert region. The project goal requires that a balance of heat gains and losses be achieved throughout the year. The physical changes that are derived from a computational energy analysis are incorporated into traditional design studio methods.

At the Miami University, the Solar Graphics program aids in the design of passive solar buildings by performing thermal and passive solar simulations that calculate the effectiveness of solar collection areas and solar gains. Buildings are represented in a simplified graphical model in which various solar orientations can be examined.

The Rensselaer Polytechnic Institute uses a computer program that animates the effects of different structural loads on various architectural components (beams, columns, arches) to teach students how they behave under various loading conditions.

Students at Texas A&M University can make use of several computer aids that act as a "design support system" in developing a design solution. "Numeric support" is available for energy, structural and daylighting calculations, and "visual support" is available for building massing and perspective generation.

The University of Michigan at Ann Arbor uses customized spread-sheet software to derive cost estimation of buildings, and to calculate bills of materials and schedules.

USE OF COMPUTERS FOR DESIGN

The most far-reaching use of computers in design education is represented by schools that allow or require students to execute their regular studio projects on a CAD system, either exclusively or as part of a combined manual/computerized design process.

At MIT, students use AutoCAD in a "design workshop," a course that blends traditional studio with CAD Lab facilities. The computer is used non,-exclusively, as part of a larger design "tool kit."

At the Ohio State University an emphasis is placed on the use of CAD for the exploration of design alternatives. Students in the "CAD studio" are given a design problem that is not different from the problems given in the conventional studios. Reviews and critiques occur as in any studio course with the added dimension of the "tool-building" system critician discussed above.

The University of Michigan at Ann Arbor offers a "computer-aided design studio" in which the students are encouraged, but are not required, to make use of sophisticated solid modeling software (ARCH:MODEL and CAEADS) for uses ranging from complete computer solution, to computer presentation, to no computer use at all. The approach is designed to treat the computer as an acceptable design/presentation tool for studio that is available to all students who choose to use it.

At Harvard's Graduate School of Design, students use Apple Macintosh computers that run SCHEMA, an in-house developed 3-D modeling program, to build sketch models of architectural projects of moderate complexity in site context. The CAD systems are accessible to the students as a resource, much like the library, rather than as a special organized course. In addition, the school offers a broad range of programming and application courses related to design.

The Mississippi State University uses an Intergraph System to support a few students who elect to execute their projects with the aid of the system, while the others do so manually. All projects, whether computer-aided or not, are evaluated and graded together. This use follows a required course that introduces all students to CAD, and a five week training session on the Intergraph system.

One of the most comprehensive uses of computers in design education has been undertaken by the State University of New York at Buffalo, where all graduating students have executed at least one of their regular studio projects using CAD. This is accomplished through the use of the WORLDVIEW system, an integrated modeling/drafting system developed in-house, and through the collaboration and commitment of the first and second year studio faculty and the school's administration. Sections of both the first and second year studios are required to execute projects using the CAD-LAB resources. The sections rotate on a per-project basis so that all students will use the CAD system for at least one project. Manual and computer-aided projects are graded together. Training on the system is done through an independent, one-credit two-week course, prior to using the system. A new method to critique students projects, called a "Terminal Crit" (or "Term Crit"), which is analogous to the ubiquitous "Desk Crit," has emerged through this experience.

Students may discuss and present their work on the terminal itself, in addition to, or in lieu of, slides, drawings, and models.

FUTURE PLANS

In addition to the above uses, many schools are currently planning more wide-spread educational uses of CAD. Carnegie-Mellon is developing an extensive multi-year plan to incorporate computers, including their psychological and technological aspects, into a series of related software development and design courses. The New York Institute of Technology proposes to integrate the elements of its design fundamentals program (color, materials, scale, composition) and a series of support functions (life-cycle cost, energy analysis, structural analysis) into existing studios. Mississippi State University plans to offer a wider spectrum of computer education that involves the conjunction of studio projects with other computer courses. As is too often the case, the development of many of these plans is dependent on acquiring resources and faculty support.

There is also a substantial number of schools that have just begun to introduce CAD into the design curriculum. Most of these schools, including the University of Arkansas (Fayetteville), Auburn University (Alabama), Louisiana State University (Baton Rouge), and Tulane University (New Orleans), have taken the route of microcomputers and commercially available software as a relatively inexpensive and practical, although limited, approach.

CONCLUSION

With these experiences at hand, what can we say about the impact of CAD on design education? To answer this question, it is necessary to establish some criteria by which this impact can be measured. We have formulated these criteria in terms of basic goals and their associated evaluative measures. These goals reflect the reasons for introducing CAD in design education, and thus establish what we expect the benefits of their introduction to be. Evaluative measures will let us know if the goals have been achieved, and to what extent. Together, they may be able to provide an answer to our initial question "Has CAD had any impact on architectural design education?"

The reasons for introducing CAD in design education are numerous:

1. CAD may alleviate certain technical difficulties students may have in expressing their ideas and exploring complex architectural forms that they may not be able to express through manual methods.
2. CAD may allow students to explore more alternatives in a shorter time period, and thereby perhaps arrive at a better

solution to the design problem and a better understanding of the problem itself.

3. CAD may help students to visually and numerically understand the implications of the design decisions they make, and to better integrate technical aspects that are typically taught in other courses (e.g. energy, cost estimation) into their studio design projects.
4. CAD may let students "discover" new ideas, by removing the risk in having to reproduce the design if an approach does not pay off (i.e. CAD reduces the "scholastic risk" of exploring bold ideas).
5. CAD may provide "instant feedback" at any time of the day or night.

How will we know if any of these potentials have affected the design skills of the student? Ultimately, the answer lies in comparing the results obtained with the aid of computers to those obtained through manual means. This comparison is difficult to make at present. Hardware and software are not abundant, and suffer from many flaws that may hamper, rather than aid, design. The use of the new technology may require a restructuring of studios and teaching methods in order to fully realize the potentials. In addition, faculty and administrative support must be greatly increased from its present state.

Based on the accounts reported by schools who contributed to this report, it is safe to state that computers have not yet had a measurable impact on design education. They have, nevertheless, made some difference for certain students in certain circumstances (sometimes beneficial, for projects that were particularly amenable to CAD, and sometimes detrimental, when the project and software/hardware were not compatible). By and large, we feel that it is too early to make a conclusive statement about the impact of CAD in architectural design education. Although CAD is becoming increasingly prevalent in schools of architecture, and particularly in design studios, a large portion of these schools are still in the "gearing up" phases. There are still many technical, administrative, and pedagogical obstacles that must be overcome before CAD can even attempt to gain a favorable status next to the traditional design methods. Many critical issues have been identified as needing further clarification. Some of these involve the distinction (or lack of distinction) between special CAD studios and regular studios and the relationship between tool-using and tool-building in design education.

Only time and considerable more effort will tell what benefits CAD will eventually bring. However, the largely non-negative results we have found so far, combined with the few positive results and, perhaps most importantly, the acknowledged potentials, are an encouraging incentive to keep pursuing vigorously the incorporation of CAD into the mainstream of design education.

ACKNOWLEDGEMENTS

This report is based on contributions from ACADIA members solicited by Professor Chris I. Yessios of the Ohio State University, for the preparation of ACADIA's presentation at the 1986 ACSA Annual Meeting held at New Orleans in March. His considerable effort in soliciting and editing the submissions, as well as the efforts of contributing members, are greatly appreciated. The content of this report, however, is the sole responsibility of the author. A full report, with relevant graphic materials, is available from ACADIA's Newsletter editor, Professor Patricia G. McIntosh, at the School of Architecture, Arizona State University, Tempe, AZ, 85287, USA.