ALTERNATIVE APPROACHES TOWARDS THE TEACHING OF COMPUTER AIDED ARCHITECTURAL DESIGN

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ABSTRACT

The problems of architectural education in general and CAD education in particular are discussed. The paper suggests that the computing requirements of architectural practice are different to those of architectural education and that much of the software used in schools of architecture is not used in an educationally structured way. A number of proposals for the educational use of computers are made, together with recommendations for a common computing environment.

Introduction

it may be considered that there is sufficient debate as to what constitutes the basic body of architectural knowledge to be imparted to students at schools of architecture without adding another subject to the already overloaded curriculum. Nevertheless the importance of computing in architectural practice is growing and the nature of practice is changing accordingly. It follows that all students should, therefore, be given the opportunity of developing some degree of familiarity with the computer during their education. However, this paper argues that the requirements of education are different to those of practice and, more cynically, suggests that, with record numbers of architectural students at college (far more than the profession can absorb), with architects' salaries amongst the lowest of all professions, and the practice of architecture taking on an increasingly less central role in the design team, design-oriented computing offers an attractive career alternative to traditional practice.

Some Problems

The additional load placed on the undergraduate curriculum is one of the most crucial factors affecting the teaching of CAAD. The volume of information related to architectural education has increased to such an extent that it is no longer realistic to expect that it can all, be covered to the same depth in the course of the normal undergraduate training. Different schools lay emphasis on different parts of the curriculum, but, unfortunately, these differences are not readily perceived by the prospective students. All schools, therefore, to a greater or lesser degree, attempt to cover everything they can, and concentrate on specific areas according to their different educational aims or, more pragmatically, the strengths and interests of their staff members. Given (in Britain at any rate) the recent cutbacks in educational spending the specialist skills of the reduced staffs of many schools tends to distort the educational balance even further.

To find the time and the personnel to teach the emerging subject of CAD is a serious enough problem in many schools, even without considering the more fundamental educational issues involved. These issues may be broadly summarised in the philosophical question 'Are we promoting CAD education or architectural education using CAD'? Put the other way around, are students in schools of architecture learning how to use the computer in design, rather than how to design making use of the computer.

A number of factors contribute to this state of affairs but the real difficulties concern the availability of suitable software and staff expertise. The effects on education are very noticeable. Few schools have staff with the expertise to modify or adapt software written elsewhere to either suit their own requirements or run on their own hardware if it is materially different from the original machine the software was implemented on. The result is that courses tend to be based around the local availability of computing facilities and the interests of teaching staff (often in a part time role) with little overall coverage of the subject or academic structuring. The software available for use in teaching in schools of architecture is often limited to software developed within the school itself. Therefore its use is often for pragmatic rather than educational reasons.

Very rarely is software available which was specifically developed to meet educational requirements: and the needs of education (as distinct from practice) are such that the use of 'professional software' developed commercially for sale to architectural practices would be no better educationally.

This gap between education and practice is particularly sharply defined in CAD. The practice view of CAD is predominantly Computer-Aided Draughting rather than Design. Such software as is used in education tends to be for design analysis and ad hoc problem solving, whereas the software used in practice is mainly for production information and management. Production information plays a minimal part in most school courses, but can account for some 80% of a practices costs. Again, management is a relatively minor element of most courses, but, with the software industry able to sell accounting packages to a wider market than just architects, the software is relatively cheap to acquire and, therefore, often cost-effective for the user.

It is not even really possible to 'train' students in the operation of the professional systems, as distinct from 'educating' them in the underlying principles. There are a wide variety of draughting systems available but all so different in their operation that a 'training' on one is of little use should one need to use a different system. Even the terminology varies. Different systems use different terms to describe similar (or, in some cases, identical) features. As a trivial example, what an architect would call a standard detail some systems call 'components', whilst another divides them into 'objects and blocks'. What is important in all cases is not the mechanics of operation but the implications on the structuring of drawings and the requirements for the architect to become a 'database manager'; in fact, to consider Architecture as Information Processing. Education should concentrate on the generic issues rather than the time dependent skills of 'driving' particular systems.

Further considerations reinforce this gap between education and practice. Most programs currently available suffer from user interfaces which are not easy for the casual or intermittent user to master; from onerous data preparation requirements; and concentration on specific (limited) aspects of design. These limitations can all be tolerated in practice be-cause of the economic returns, but in education there is neither the time nor the facilities to overcome the problems. The result is that rather than computer programs being adapted to suit educational requirements courses are adapted to suit the available programs.

What should be taught?

Whilst many schools of architecture have tackled the problems of teaching CAAD a number of external authorities have also attempted to define basic elements of the subject that should be taught.

The National Architectural Accrediting Board (NAAB) reviews architectural courses throughout the USA. In December 1983 NAAB established ninetyfour performance requirements which should be met by students graduating from accredited courses. Four of these performance requirements explicitly mention computer awareness; they require students to:

- Understand techniques of analysis including such visual tools as diagrams, charts, models and drawings; also quantitative and computer based tools applicable to architecture.

- Understand the types of communications media generally used in architecture, including computer-based techniques of graphic presentation.

- Be able to convey the essentials of the building or project design by such means as orthogonal drawings (plan, section and elevations), oblique and perspective drawing, freehand drawing, computer-aided drawing and photographs.

- Understand the basics of computer usage in the process and some illustrative areas of application including design, documentation, Financial management, word processing and information storage and retrieval.

In Britain the only formal recommendations are those contained in the Lickley Report, presented to the Engineering Board of the Science and Engineering Research Council in June 1983. The Report is the result of an Engineering Design Working Party which was established in 1982 specifically to make proposals on:

a. the teaching of design at postgraduate level in the engineering disciplines within the Board's remit;

b. design as a subject for postgraduate research;

c. studies of the design process; and

d. the impact of CAD/CAM on design and the design profession.

Paragraphs 52-54 of the report summarise the impact of CAD/CAM on design and the (engineering) design profession.

52 CAD will contribute to improving the status of the design profession in five ways:

- by its association with the high technology of computing;
- by reducing much of the drudgery of detailed repetitive drawing;
- by allowing much quicker changes in design it will facilitate better design optimisation;
- by reducing the ratio of draughtsmen to designers; and
- with CAD/CAM the involvement and knowledge of the designer will become of increased importance in the manufacturing process.

53 The ready availability of data banks and programs to calculate the effect of design changes will reduce the dependence of the designer on the specialist. CAM, together with its associated discipline of design for economic manufacture, will make new demands on the designer and change the criteria used in evaluation and formulating a new design. CAD/CAM itself will strengthen the links between design and manufacture: the design department will simply no longer be able to be treated or to act as a separate part of the manufacturing process. The implications of this will need to be reflected in the training of designers.

54 We have said that we would expect all graduates to have received instruction in CAD/CAM. However, given the multiplicity of software packages, there is a danger in producing graduates too specialised in particular systems or lacking the basic skills to operate in firms without such systems. The rapid expansion of systems in this field and the high capital cost of incorporating CAD/CAM in the education of engineers could result in substantial demands on UGC support for engineering departments if this development is not properly controlled along the lines of the present SERC interactive computing policy.

Individuals involved in teaching Computer Aided Architectural Design have also attempted to define the ways in which computers may be used in design. John Lansdown (1984) suggests four ways in which computers can be used to assist the design process:

- for visualising problems and solutions
- as a means of direct experimentation
- to store information and knowledge
- to improve management and control

and Lawson (1982) gives four very similar suggestions:

- information presentation (including drawings)
- solution evaluation
- form generation
- organisation and management

More formally, groups of teachers involved in teaching computer applications in schools of architecture have attempted to define criteria for computing in architectural education. Maver and Schijf (1983) specify what has become established as the eCAADe (education in Computer Aided Architectural Design in europe) basic course elements:

1. Exposition The concepts underlying CAAD, survey of the state of the art, demonstrations.

2. Preparation Hands-on experience of a range or programs and discussion of their form, content and interfaces.

3. Application Using one or more programs in a studio design project.

4. Instruction Acquiring programming skills and knowledge of hardware and software systems.

5. Development Specifying, implementing and maintaining hardware and software systems.

Units 1,2 and 3 prepare students for CAAD use whereas units 4 and 5 are needed if the students wish to go on to develop CAAD expertise.

More recently, the Committee for the Built Environment of the Council for National Academic Awards has been considering the curriculum content of architectural courses. A draught paper was issued in March 1986 and, in response to the proposals concerning Computer Aided Design and Learning the Schools of Architecture Computer Conference (an annual meeting of subject specialists in Computing in Schools of Architecture) defined the following broad criteria:

1 Computing in Schools of Architecture can be divided into three main areas with five activities:

.1 As a general facility (wordprocessing, spreadsheets, office and job administration, games, etc)

.2 Computer Aided Architectural Design:

a. Education in computing and CAAD techniques
b. Using CAAD tools in the studio

.3 Research:

a. Use of computers for research
b. Research into computer use and applications

2 Desirable standards for Computer Literacy:

.1 A basic understanding of:

- computers and computing
- hardware and software
- programming

.2 Practical experience of:

- wordprocessing, office and job administration
- information storage and retrieval
- draughting and 3-D modelling

.3 An awareness of:

- the opportunities that computing offers
- the likelihood of change and development

.4 An understanding of the implications of computing on:

- the design of buildings
- the organisation of architectural practice
- the architectural profession

3 The methods, techniques and subject range will vary between institutions depending on resources available and staff expertise.

All of these attempts to define the subject area founder because they do not satisfactorily separate the three basic elements involved in computing in schools of architecture. These elements may be defined as:

1 - the technology of computing
2 - the application of computing in architecture
3 - the use of computing as a teaching resource

All of the definitions cover, to a greater or lesser extent, the first two elements. However, the third may well be the most important and, if it is carried out well, may subsume the first two. Indeed it may well be the case that computing is not a subject to be taught in its own right but a component part of almost every other subject in the curriculum. As the educational uses of computing have been so neglected the next section of this paper discusses the possibilities offered.

The Promise

Computer applications in architecture encompass a wide range of technical computing factors, yet also embrace a number of important ethical, social and aesthetic issues. The applications cover every phase of the design process from feasibility studies and sketch design through to production drawings and bills of quantities. With this range of applications the constructs and vocabulary of computer aided building design provide a useful, rigorous framework within which to research, discuss and implement fundamental principles of design theory and method. This is of utmost importance as university based education should not so much provide a direct training for practice as develop an understanding in students of basic concepts which will provide a firm foundation for continued learning throughout a long professional career. Within the framework of computer aided design many concepts traditionally taught by example and apprenticeship may be concisely and rigorously expressed theoretically.

Computer aided design may also be considered as a learning resource in itself, serving specific educational objectives, rather than simply anticipating the needs of design practice. The range of possible uses is extensive, but the main educational use of CAD is as a simulator of complex systems from which students may gain awareness of the essential complexity and multivariate nature of design. Typically such a program presents the students with interactive access to manipulate the principal parameters of a computer based model and the opportunity to calculate and display the effects of their variation. The complex interaction of design and performance variables (e.g. the inter-relationship of window size, lighting, heating and cost) may thus be studied on problems of a meaningful size rather than on trivial set examples. This type of software should be designed to answer the. students question, 'What if ... ?'

A more focussed application of a similar type of program (indeed the same software may be utilised at the care) is in particular subject areas. For example, in theory of structures, the mathematics and theory of structural design are taught at many schools but few students are able to translate that abstract formulation into a real, intuitive understanding of structural design that can be used in their studio work. A computer model enables students to actually 'build' their structural experiments and to see the resultant stresses in the members. By interacting with the system the key parameters may be identified and their range and sensitivity established.

The more traditional uses of 'Computer Assisted Learning' have, rightly, been criticised, but a new generation of 'expert tutors' offer realistic possibilities of student-controlled tutoring systems. These systems may be used for 'remedial' teaching (or revision) or to convey basic information and thus release the human tutor to spend more time discussing design applications with students (rather than reading lecture notes). A further possibility in this direction is to consider the computer as a 'textbook'. Many students have difficulty in interpreting two-dimensional diagrams and the static, formalised representations used in many textbooks (e.g. 'how does the damp proof course fit in at a window opening - both horizontally and vertically'). Students may manipulate a computer-based three-dimensional model to view the object from any direction rather than struggling to understand a set of predefined pictures. Animation may be used to explain time-dependent systems and, if the software is carefully written, the order of drawing on the screen may represent the actual process of construction or, possibly, in another application, highlight particular features such as symmetry in a plan. Of course access to such high quality graphics may equally be well utilised in lectures. By linking the terminal to a video-projector the computer may be used as a 'blackboard'.

Further exciting possibilities are offered in the use of the computer as a communications medium. Obvious examples are in straightforward graphics and text processing, but the use may be considerably extended by access to library databases, electronic mail and newspapers, and links to computer controlled, videodisk databases. The most dramatic use for architectural students may, however, be in the use of high quality colour graphics to simulate the appearance of their designs: 'synthetic photographs' which show how their design would lock if it were built. This is particularly useful in showing the effects of different internal lighting arrangements or, when mixed with Framegrabbed images, indicating how the building would appear in its urban context. Both of these tasks are very difficult and timeconsuming to do by hand and this leads to another advantage of computer simulations - it is not just the added reality but the speed of response and consequent opportunity to explore design alternatives that is important. Design motifs may be stretched and scaled or otherwise transformed, colours modified, elements may be rearranged, all in a way that is impossible to do manually. The computer could become the actual design medium: it can diminish the reliance on formula and emphasise the visual aspects of problem and solution. All the student has to do now is think!

Some More Problems

Many schools are still struggling to address at least two different aspects of CAD - one dealing with the technology of computing and the other with the application of computing in architecture - without the introduction of this third area of the computer as an educational resource and special design medium. Any one of these topics inevitably places special demands an the availability of both staff and equipment resources.

One response has been the formation of associations - in America ACADIA has emerged as a specialist architectural group, following the lead of the engineers' College CAD/CAM Consortium, and in Europe the eCAADe has been formed to collaborate on specific projects. However membership of both of these organisations is relatively small, eCAADe has some 45 members and ACADIA 15 (out of 90 schools of architecture in the USA). Effective collaboration is only really possible if sensible strategic aims can be agreed.

The computational environment is one such aim that might be defined. The time, cost and resources involved in developing teaching packages is such that a shared development effort is very desirable, yet is only possible if collaborating institutions have compatible computing environments. Most schools of architecture have computing facilities based on time shared mainframes or, alternatively, PC's. Time-sharing systems fail to provide a predictable response for computationally intensive applications or interactive graphics. The PC's lack of information sharing and communications facilities mean that they are also inadequate unless set up as part of a network. The operating system is also of vital importance - it should be capable of insulating the user (and the applications software) from changes in technology and differences in hardware supplied by different vendors.

Suitable machines would be the emerging single-user workstations. These have a large memory, high performance processor, high bandwidth bit-mapped display and open design to enable networking and optional add-ons. UNIX provides a satisfactory foundation to port all applications to all workstations and, in addition, enables the same suite of general purpose software (e.g. editor, wordprocessing, graphics library, etc) to be made available at every workstation. UNIX hides the underlying computer technology from the user, limits training costs and provides the framework for the writing of portable applications software. The new workstation technology also provides the opportunity to redefine user interfaces to take advantage of the bit mapped displays. However, if three specific interfaces could be agreed then a strategic foundation for true collaboration could be established. The form of the user interface, being the interaction between the user, the application software and the operating system should be agreed. The two other interfaces are the Applications Interface (that is the interface between various application programs) and the Systems Interface (between the operating system and individual application programs). Given these three cleanly defined interfaces software modules from any source should be able to operate together.

Conclusions

The volume of information related to architectural education has increased to such an extent that it is no longer realistic to expect that it can all be covered to the same depth in the course of the normal undergraduate training. Similarly, the rate of change in theory, techniques and technology is such that the knowledge base acquired cannot be expected to serve graduate architects throughout their professional lives. The field of computer aided design is an extreme example of both the extension of the field of study and the fallibility of outdated information. Furthermore, many architects already practicing have had little or no contact with computers in their professional education.

The adoption of a computer based teaching system as discussed above could lead to fundamental changes in educational philosophy by allowing staff more time for tutorial instruction and leaving students much more freedom to select their own route and timing through a predetermined course of instruction. The flexibility of such packages make them equally as useful for continuing professional education as for undergraduate teaching. The students and tutors should then be able to concentrate on the broader design issues which are currently often overlooked in the need to convey the specific details of individual subject areas. Also, as CAL packages are more easily updated than books, the knowledge and information contained in them should be more relevant than that in traditional teaching resources. Of course, this type of education will not replace the traditional studio (atelier) principle of learning but complement it in the same way the current seminars, tutorials and lectures already do.

However a number of important questions arise for architects. There is very little architectural input to the design of the workstations that are seen as being central to educational and architectural computing in the future. Very little applications research is sponsored by the architectural profession and such research as is done is not widely disseminated. The whole profession needs re-educating - architects are increasingly asking 'What system should I buy for my office?' when really they should be asking 'What do I need to learn to make effective use of computers and where can I learn it?' Perhaps this is the question that ACADIA and eCAADe should be answering.

References

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