Teaching CAAD at Sheffield University

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The University of Sheffield Department of Architecture has been using Computer Aided Architectural Design in its teaching now for over ten years. During that time there has also been a major research unit in CAAD working in the department and most of the software used in our teaching programme has originated in our own research unit. Our students have now got access to a wide range of CAAD programs including 2D draughting, 3D colour visualisation, environmental analysis, structural design and cost estimating. We have generated our own specialised systems of terrain modelling and intelligent building modelling which link to both the visualisation and environmental appraisal software. Students also have access to data base and word processing software. CAAD has been used in all five years of our course and we also have students working with CAAD during their professional experience years. Over this ten year period we have gradually altered and refined our approach to the educational use of CAAD and this paper will describe this approach and present some of the lessons we have learnt. I want to organise the paper into two main sections; firstly what are we trying to achieve by teaching CAAD on our course, and secondly, how do we fit this into the curriculum and what effect does it have.

The first question then which I want to consider is; why do we teach CAAD in architectural education at all? We think there are four major reasons for teaching architectural students about computer aided design and its associated fields. These reasons are not all equally important and are quite different in their educational impact and the demands they make on the curriculum. I shall call these four functions which CAAD can fulfil in the architectural course; the Educational, the Professional, the Research and the Creative.

Firstly, it seems to us that computers are already such an important part of our society and increasingly more important that it is our duty as educators to try and help students to understand the impact of computers on their future lives. This has two major components, which we might call the technology and systems components. The technology component is quite simply a matter of developing a basic understanding of the concepts behind computer hardware, its capabilities and limitations, and a realistic appreciation of the rate and nature of technological innovation in this field. Whilst a large part of this material is not specific to the needs of architects as opposed to other professions, there are of course specialised areas of study in connection with graphics devices and workstation design.

The second component, the systems component, is slightly more philosophical but nevertheless intensely practical. It consists of developing an understanding of the concept of information. Students need to be introduced to the idea that while design itself is undoubtedly an inspirational and creative act, the business of designing and constructing buildings in our modern society involves access to and processing of vast quantities of differing kinds of information. In this context we believe there are considerable advantages of general intellect development which result from including a disciplined study of modern information technology techniques in design courses.

The second major reason for including CAAD in architectural design courses is quite simply that our profession now needs graduates familiar with the CAAD techniques which are available in practice. CAAD, and in particular computer aided draughting, is now commonplace in the United Kingdom and we would be neglecting our duties as educators not to prepare our students for this aspect of their professional careers. Draughting by computer can of course be merely a machine interpretation of a previously exclusively human activity. However this is to miss the potential and power of the computer as an information processor. Computer draughting is in many ways a fundamentally different process to traditional manual techniques. The separation of the creation of the image in a computer file from the process of composing and generating an actual plot seen in computer aided draughting can have no parallel in the manual process in which the drawing is composed as it is created. The use of layered files and files as symbols in other files are certainly the biggest revolution in draughting since the invention of the print machine and the copy negative.

Similarly the leap into three dimensions provides another fundamental change in the approach required to draughting. The idea of first establishing a three-dimensional model in the computer's memory from which plans, elevations and sections may be produced is obviously quite different from the idea of using a 2D draughting system to develop each drawing separately. The effects of such techniques on the reliability and co-ordination of contract drawings in the professional context is clearly an appropriate matter for study in a school of architecture. The effect of common computer based drawing data bases of this kind on the communication of information between members of the design team such as architects, structural and heating and ventilating engineers is likely to be significant, particularly in inter-disciplinary practices.

Computer draughting brings with it benefits not just of increased speed but also of an opportunity to eliminate many of the mismatches of information so commonly found in contract documents in the building industry. The potential for the co-ordination of data base information with the drawing files implies a new approach to the management of building contract documents which clearly is an important area to be explored in a professionally oriented course.

I want to turn now to the third reason why we teach CAAD techniques on our architecture course at Sheffield University, that is the Research reason. During the last ten years we have also had a very active CAAD research unit in the Department of Architecture, and so it is not surprising that we wish to involve our students, albeit to a limited extent in our research effort. If we write CAAD programs which are of any real use then it seems likely that at least some of our students will wish to make use of them to assist with their design project work. This use by students provides the research team with extremely valuable feedback information at several levels. Firstly, and most simply, such use proves whether the programs actually work and flushes out bugs. Secondly, and rather more importantly, voluntary student use helps to establish if the functionality of the programs is good. That is, do they do what our students want then to do. Thirdly, and this is often very challenging, do the programs offer sufficient flexibility in terms of the range of data they accept and the way that data can be altered. In particular in this respect students are, on the whole, more likely to try unusual, and indeed often unworkable, architectural forms then are established practitioners. Finally, and most subjectively, do the programs have an understandable and useable command structure and interface. That is, can we easily and quickly train students to understand and use the programs.

I want to turn now to what is, to my mind, the most important function of CAAD in architectural education. That is to enable our students to develop a better understanding of architecture itself and to provide them with more creative design opportunities. One of the most demanding tasks facing a student of architecture is that of acquiring an understanding of the inter-relatedness of the dimensions of the built environment. In my opinion this is one of the areas in which schools of architecture are weakest in the quality of service they provide for their students. We all teach the basic technical subjects and we provide extensive opportunities to develop design skills, but whether we really effectively link these two is still very much open to question. How often do architectural students submitting a building design for criticism really understand the environmental consequences of their chosen forms and construction? Will the designs of our students really avoid the problems which beset so many buildings of the recent past?

Overheating in summer, poorly organised use of available solar energy in winter, generally inadequate attention to insulation, and poorly understood characteristics of ventilation and the resultant formation of damaging and unsightly condensation. Do our students really understand the way building costs are made up and the design implications of the capital cost to cost in use relationship?

The use of computer models of buildings or parts or aspects of buildings can provide invaluable assistance to the teacher in demonstrating these relationships and if these models can be interactively manipulated then they can genuinely allow students to explore for themselves. There is therefore no doubt in my mind that CAAD techniques used as CAL or Computer Assisted Learning have an important role to play in an architectural course.

I want now briefly to deal with the use of the computer as a three-dimensional visualisation tool in architectural education. Some students have a natural ability in three-dimensional imagery others markedly less so. Often as a tutor in the studios I hear myself exhorting my students to draw more perspectives and axonometries to test whether their buildings will actually work, not just in plan but in three-dimensional reality. For some this is a slow and often unreliable process. They tend to draw a perspective, not of what would actually be there, but what they have already imagined from their plan would be there. Of course we can insist on the use of measured perspectives, but these often take so long to set up that they are more use as presentation tools than as design aids. Clearly the computer can, once it is provided with a three-dimensional model, produce an unlimited number of types and angles of three-dimensional projections. it would therefore at least provisionally seem reasonable that such a tool would have value to design students. However this is a more contentious issue and I shall return to this later.

I want now to cove from considering why we have taught CAAD at Sheffield University to how we taught it. We believe the main reason for teaching CAAD is what I have called the Creative reason, that is, to help develop a better understanding of architecture and to provide better opportunities to design good architecture. Since this is true then it follows that we do not view CAAD an end in itself in the course. Rather it is very much seen as a means to an end, and this implies that it should have a very low profile in the curriculum. This is in contrast to the profile of CAAD within the general life of the department. The CAAD research unit occupies quite a large area of space in a central position in the department and is glazed so that passers by can see in. This unit has become fairly well known and visitors are often being shown around. Indeed we now get a significant number of students both at the undergraduate and post-graduate level applying to join the department because of their interest in CAAD. However the compulsory and formal part of our course which is devoted to CAAD is really quite small.

CAAD is taught formally through a course of lectures and demonstrations at the start of the second year of the undergraduate course. The timing of this is a carefully calculated compromise. Our first year is already approximately fifty per cent taken up with the formal teaching of subjects through lectures and lab classes, with the other half of the time devoted to studio design projects. This seems a good balance and we are reluctant to decrease the amount of time available for studio work. Whilst some first year students may be itching to get their hands on our computers, most find that trying to begin to understand what architecture is all about is pretty demanding. Quite a number of our incoming first year students have had no previous instruction in technical drawing, and many have to learn the basics of handling traditional draughting tools and techniques. It seems to us best to learn these skills from the bottom up as it were, and we do not even provide drawing machines for our first year but rather insist that they should first Master the tee square and set square. (Studio workspaces are provided for all students and in the later years these are equipped with drawing machines).

By the start of second year these initial difficulties have been surmounted by most students and they are already in a position to see some of the advantages of CAAD. It might actually be better to leave some of the conceptual material about CAAD until later in the course when students have a better understanding of design practice not in the rarified and artificial environment of the academic studio but in the professional drawing office. Such a change in our course is currently being contemplated. However by second year our students seem ready for CAAD and I feel they should not just have access to computers and software without some formal explanation of the general issues in CAAD. This course then introduces the students to CAAD itself and to the range of computers and software which, from this course on, are freely available to them to use in any way they see fit for their studio project work. We have, after much experimentation, abandoned the idea of setting compulsory projects which demand computer usage, although optional projects of this kind are sometimes offered at the end of second year.

A fairly typical example of this project was a nursery school design programme of a few years ago. This was a relatively short project to tackle a fairly simple set of problems with the emphasis on integration of form, space, environmental comfort and cost in use and capital cost. The accommodation required did not pose any extraordinary structural problems and the siting was not tight but set in a residential area.

Students then were asked to look at providing an easily maintained and supervised set of both indoor and outdoor play spaces, and were asked to take particular care to create spaces which were interesting in themselves giving a wide range of opportunities for imaginative play. Most schemes attempted thorough use of the daylighting analysis provided by the computer to achieve contrasting areas of light and shade. Considerable study of sunlighting was conducted with the scheme being examined throughout the day at several times of the year. This resulted in solutions which would give bright sunny patches of light well into the main play space on winter days while carefully restricting solar gain on hot slimmer days.

There was generally a conscious attempt to provide a heavily modelled building which, while able to enclose external space and provide interesting nooks and crannies internally, was nevertheless inexpensive to build and maintain. At this stage in our research program we were unable to provide rapid fully hidden line perspectives or colour on the computer. In spite of this the students generated their own drawings as overlays to the computer plots both for external and internal studies. Although only a short project, students were able- to present far more three-dimensional views of their schemes than usual while still considering environmental control and cost as major design factors.

It might seem that using computers to draw perspectives or axonometries would be a bad thing in a school of architecture, since we have taken away from the student the very task which will encourage three-dimensional co-ordination. Nothing of course could be further from the truth, since before our computer will draw the perspective it must be fed with three-dimensional information. My experience of watching and helping students with this task leads me to believe that such an exercise is likely to reveal many more three-dimensional weaknesses to the student than the same amount of time spent drawing perspectives by hand.

Whether the final drawings as they appear on our exhibition screens actually reveal their computer originals is unimportant. One of our fifth year group projects a few years ago won a prize in a major housing design competition for this department. Two of the students had spent some considerable time on the computer in examining both the design of the individual dwellings and the way they could be arranged to create spaces between. Although many of the final three-dimensional views were originally drafted by the computer, the students choose a more freehand style for their final presentation.

Two years ago our third year were asked to design a building on a pier in the London Docklands area. One student chose to do the project entirely on the computer. For his final presentation he chose to work by hand on top of the actual computer generated plots themselves. This particular piece of work clearly shows evidence of the building being thought about as a three-dimensional whole. Some of the drawings are axonometries while others are perspectives. Sometimes the computer model has been used to display the exterior, and sometimes the interior. Some of the drawings are intended to reveal the overall organisation, while others show a close up detail either internally or externally. Others still represent vistas which would actually appear as one moves in and around the building. Prior to this project this particular student was on the borderline of the pass/fail -mark for his studio project work. His work was generally considered dull, flat and rather two-dimensional. After this project his work was seriously considered for a prize. I am sure that a major reason for the improvement was his experience of working with a three-dimensional compute r modelling tool.

I would like now to make some observations on the effects of our CAD work on the students and their work at Sheffield University. Unfortunately we have not made any serious attempt at an empirical study of this, nor am I sure how we could, so I can only offer anecdotal and circumstantial evidence. I can say however that my evidence is based on some ten years of observation, and whilst I cannot be described as a detached observer my experience does lead me, however subjectively, to feel confident in my conclusions.

I detect three levels of impact of CAAD on our students and their work. The first, and least significant level, is when the use of CAAD impacts on a particular project. Not all of our students choose to use CAAD techniques and of those that do some only do so occasionally. One example of this was a student who was designing a building which included a small theatre. Now the problems of achieving satisfactory sightlines and good access together with the more technical issues of acoustics and lighting make this an intensely three-dimensional problem. This particular student had made life even more difficult, as students often do, by choosing to use a series of stepped boxes flanking the walls of a single raked stall. It was only when he realised how difficult it was to get the geometry right that he came to model the auditorium on the computer. It proved much easier to tune and adjust the computer model than to continually rebuild a physical model and manually recalculate. In this case CAAD had a direct impact on one particular project.

Another example of this principle may be seen in the work of another final year student who chose to design a brewery for his thesis. Now this involved housing a rather complex arrangement of containers and their connecting pipework, which is effectively a small chemical engineering installation. This student first modelled this equipment in 3D on the computer and, almost literally designed his building around the contents directly onto the computer. So interested did he become in working with CAAD techniques that he went to look after a CAAD installation in a London practice after qualifying.

The second level of effect I detect is when the use of CAAD appears to have an influence on the student's work beyond simply offering a good way of solving their current problem. Although impossible to prove, students have themselves confirmed the effect. Over recent years there is no doubt in my mind that students who have used environmental science routines which were integrated with graphics facilities have had their interest in environmental considerations substantially stimulated. At Sheffield University our students ray use a wide range of purely numerical environmental science software, but they may also call on routines which work from CAD building models which are 3D and graphical. The use of this latter kind of software supported by enthusiastic architectural studio staff has for example led to some extremely interesting projects exploiting the ideas of my colleagues Cedric Green and Robert and Brenda Vale.

I have already suggested that I believe strongly that the use of 3D visualisation software can dramatically enhance the general architectural work of students. I think this probably applies more to otherwise weaker students, particularly those with less natural graphical ability who can easily be intimidated by the obviously superior drawing of some of their peers. I feel that the use of CAAD as a deliberate educational tool in this regard needs researching, meanwhile we see it happening on individual cases in a rather unstructured way.

In the last year we have also introduced colour graphics into ou,3D modelling software and made this available to a limited number of students, although it will be generally available next year. The results so far are indeed encouraging. Again I see a possible lasting effect. Students who previously were not our strongest colourists, but who had already become CAAD enthusiasts seem naturally to want to consider colour at a much earlier stage in the design than before. A couple of final year students both began their year by establishing colour models of the architectural context of their thesis site. In one case a rather, attractive mill in a meadow, and in the other a very unpromising urban site in a none too exciting Midlands town.

What matters to me here as an architectural educationalist is not how good these schemes are, but what is happening to the students' three-dimensional thinking and to their attitudes to the importance of colour or environmental science in building design. I have to say that on the whole I am tremendously encouraged by what often seems to be a major transformation in some students.

Let me speculate for a moment on what I think is happening here. Since we have deliberately taken a low profile optional approach to CAAD it seems to me likely that the students who select themselves to spend time learning to exploit the computer will be, on the whole those whose personality tends towards those matters. They will not necessarily be drawn from the ranks of our most original and creative thinkers or our most naturally gifted graphically, and indeed I think this has largely been true. However, once familiar with the use of our CAAD system they find themselves able to experiment in such matters as colour and three-dimensional form without having to express these ideas through a possibly less than average set of manual graphical tools. This experience is for them not only liberating, but also enormously confidence boosting, as they begin to win accolades previously reserved for others.

If this is true, you might ask, what happens to them when they have no computer? Well, I used to worry about this problem more than I do now. I am convinced that CAAD is here to stay, not just in education but also in practice, and there seems to be no shortage of employment for such students. Even if I an wrong about that I cannot believe that on the whole their use of computers while at university will have done them any harm, and has probably done tham a lot of good.

For a few students this experience leads to the third level of effect, and for them the computer becomes the focus of attention not the architecture. At Sheffield University there are two points at which this can happen. Our course structure allows a third year student to drop out of the mainstream professional course and to continue to study for the degree without gaining RIBA Part 1 exemption. Instead they may replace their third year project work with specialised study in an area the department can support. In the last five years we have had a number of students choosing this route using CAAD as their option. All but one have gone on to make successful careers in the CAD field. Secondly, cur final year students may in the nom4al way stay on to do research with us, and I an glad to say that is now happening more.

Whether students are antagonistic, or enthusiastic about CAAD, I find few are indifferent, they all contribute enormously to our, research effort, sometimes through special projects, but more often by simply struggling with our software. I cannot imagine how our research unit could have achieved what it has without the daily involvement of students, and we owe them a considerable debt of gratitude. I hope that this involvement also gives even our undergraduate students some feeling of what postgraduate research is all about.