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Teaching and Learning Computer-Aided Engineering Drawing*

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During 1994, Cranfield University at the Royal Military College of Science decided to start teaching all engineering drawing on computers using Computer Aided Drawing programs. This involved substantial expense and much hard work but has been successfully implemented. A new course of instruction in 2-D engineering drawing was designed after consideration of 3-D as an introduction to engineering drawing. The course is now delivered using an in-house developed self-learning text (by the author) supported by teachers in contact hours. The students express their enjoyment of this mode of learning and are achieving good standards of work. The software used is MicroStation 95 from Bentley Systems.

INTRODUCTION

IN 1993, the senior management of the, then, School of Mechanical, Materials and Civil Engineering at the RMCS decided that there should be a greater emphasis on computer-aided design. A new post was created for a lecturer in computer-aided engineering, the author was appointed to that post.

In early 1994, the Design Centre of the college was equipped with 18 PCs, some of which were running AutoCAD. The main drawing office was equipped with 60 A1-sized drawing boards for student use. The students using these facilities were mainly undergraduates on B.Eng courses. However, there were some post-graduate users on a variety of courses. The CAD facilities were used to introduce students to the technology; most of the design drawing work on all courses was done manually by traditional methods.

Figure 1 shows the layout of the 2 main rooms of the Design Centre at that time. This main room is 23 metres in length and approx. 15 metres wide.

It was decided that our students would be introduced to CAD at the start of their courses and would use computers throughout. This would clearly involve a very substantial capital outlay and would require careful planning of facilities and teaching plans. It fell to the author to carry out this planning in consultation with staff, students and managers.

WHAT TO TEACH

There was much lively debate on whether to teach 2-D drawing using CAD software or whether to start out in 3-D. Careful review of the software available suggested that, at that time, effective solid modelling was available only with very expensive software packages. Furthermore, the workstation hardware required at the time was very expensive. There was also a perceived need for the computers to be used for other purposes in the support of design teaching. For example, reports should be produced on word-processors, design calculations could be aided with spreadsheets and so on. These considerations suggested that a PC-based system was appropriate.

It was noted that some universities around the world were introducing their students to 3-D modelling from the outset. The arguments for doing so are well understood but we decided to play safe and duplicate the 2-D drawing process in CAD. Thus, the CAD software is perceived by the student as a tool for producing engineering drawings, rather than as a modelling tool. The principle concern with 3-D solid modelling was that the range of software that was financially viable was limited in its functionality. In particular, blending of surfaces was particularly poor—this would lead to limitations in design. It was strongly felt that students should be designing shapes that suited the purpose and manufacturing methods rather than being driven by the software capabilities.

From the outset, then, the aim was to teach engineering drawing using CAD. This emphasis is important and presents difficulties. In particular, the great majority of our students have never done technical drawing of any kind before they arrive at university for an engineering degree. 15 or 20 years ago, almost all students would have had an O-level qualification in Engineering or Technical Drawing. (The General Certificate of Education Ordinary Level examinations were taken by fifth-year students in secondary education. These were a pre-requisite for study of

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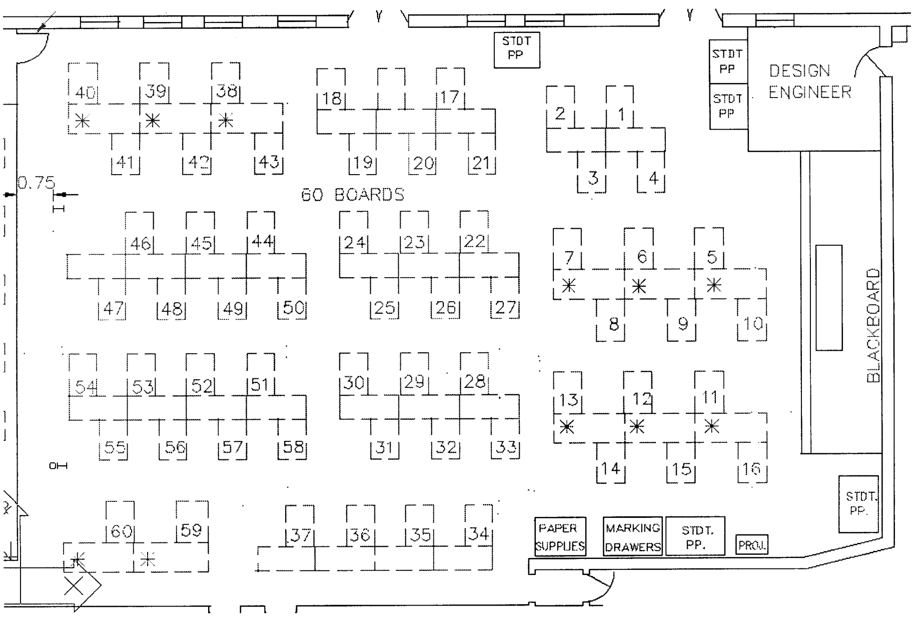

Fig. 1. The old drawing classroom with drawing boards.

Advanced A-Level qualifications for University entry. The O-level has now been replaced by the General Certificate of Secondary Education with a National Curriculum. The A levels remain, with a variety of examination boards and curricula.)

The fundamental changes in emphasis in secondary curricula, internationally and in recent years, have had a great impact on higher engineering education that few teachers will have not recognised. (The emphasis in Secondary Education in the United Kingdom is thought by the author to have shifted from preparation of a work force for an industrial production economy to one of preparation for service industry. Students consequently enter engineering degrees with a much lower level of technical and scientific knowledge and awareness than they would have had in the past. This puts engineering Higher Education under great pressure to adapt teaching strategies.)

The student body at Shrivenham is truly multinational. It has been observed that students from some non-Western cultures have more difficulty with 3-D work with others. This has been particularly so with students from the Middle East where there is a strong 2-D theme in visual artwork. Some students from that culture find great difficulty in interpreting and creating orthographic projections. When the decision is taken to start out in 3-D, it is anticipated that teaching strategies will need to make allowance for group or individual perception problems.

TEACHING AND LEARNING CAD

For the first year of full CAD teaching, the students were required to watch demonstrations of the drawing construction on a screen projected from the teacher's PC. Each student would then duplicate the procedure on his or her own computer. This method of learning was effective but inefficient; the class had to progress at the pace of the slowest participant and several teachers were required to dash to assist students who were in difficulty. The level of concentration of individuals would, on occasion, vary and consequently much time was lost in picking up on student's mistakes. However, by the end of the second term of CAD learning, the students were competent in 2-D drawing, which had been the aim of the course.

At the end of the first year, however, the CAD teaching team decided that a more flexible learning mode was needed. An extensive investigation was carried out of existing CAD instruction books and books on how to prepare self-learning texts.

There are a good many existing books on CAD programs, particularly for AutoCAD. Some have had very wide recognition and solid sales. Probably one of the most successful series of books is exemplified by Boersma *et al.* [1]. This book is one of a series of books developed by the publishers as the AutoCAD market grew. In the UK market, Yarwood has published several excellent works on CAD programs, starting with AutoCAD and, more recently on the MicroStation 95 program from Bentley Systems [2, 3].

The team of teachers involved in CAD learning at RMCS jointly decided that we would use MicroStation from early 1995. The decision was based on a number of criteria; cost was not the least significant. Yarwood's books on MicroStation are a valuable reference asset and a dozen copies of each are kept in our Design Centre.

These types of books are very good for experienced engineering drawing operators but

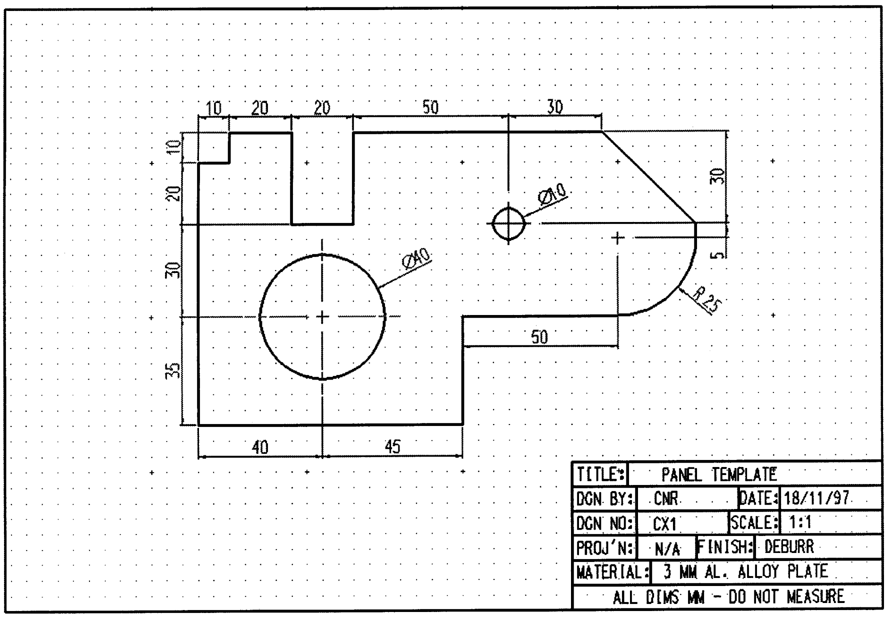

Fig. 2. The first CAD exercise.

their emphasis is on mastering the program rather than the construction of drawings. The author felt that what was needed was a self-learning program on engineering drawing using the selected software. This would be based on past teaching exercises that had been done 'manually'. Furthermore, it was felt that actually producing engineering drawings was important to the student. The learning of the software should be of secondary importance and comes with time. These ideas have proved to be successful with students at the RMCS.

Petit [4] and Davis [5] were particularly useful guides on the development of training material. With their help, a book was produced which takes the student through a series of increasingly demanding drawing exercises. The book is given to the student at the start of the course and they are told that they will be teaching themselves and each other. The first exercise in the book is shown at Fig. 2. It is a simple 2-D exercise (on an A4 page size), and is completed during the first three hours contact session of the academic year. Note that this is before the student has even mastered the concept of projection.

The students work in pairs, selected by the class manager at the start of the year, to mix experience. They take turns in reading instructions and monitoring the actions of the operator. This has proved a valuable learning model since they prevent each other's mistakes and discuss their actions to deepen understanding. (An additional benefit for the author is that the students will ask if they are unsure of a particular piece of text. This enables the author to review the text and improve or clarify the material. Sometimes, the substitution of shorter, simpler words has been of benefit to a number of students.)

At the end of each completed engineering drawing exercise, the students are given similar tasks, without detailed instruction. For example, Fig. 3 shows one of the exercises given on completion of the drawing in Fig. 2.

These tasks are for completion, individually, in unsupervised time and they enable rehearsal of the key concepts of skills to reinforce memory. The individual efforts are used as a basis for continual assessment course work.

The exercises become progressively more involved and realistic as the student learns more about the program and more about engineering drawing.

A particular problem in the real world of the 'surviving' student (as opposed to those seeking 'metacognition') is copying. The copying of each other's work enables students to submit solutions with a minimum of effort. For example, many will copy a file, change the filename and substitute their own name initials into a title frame. This is easily detected since CAD files which are identical are either perfect or are copied complete with identical errors. The latter is very much more frequently encountered than the former! A strategy has to be found to counsel and persuade the student away from such practice. It is not often possible to cajole students into admitting who copied the work of whom.

At the RMCS we mark duplicated work at face value but warn that we are aware of copying and that it is not in the student's interest to do so. We also warn of and give a tough CAD progress test in week 10 that counts for many more marks than the coursework.

Figure 4 shows an example of the sort of test the students take after 9 weeks of instruction. This means that they will have done about 15 hours in

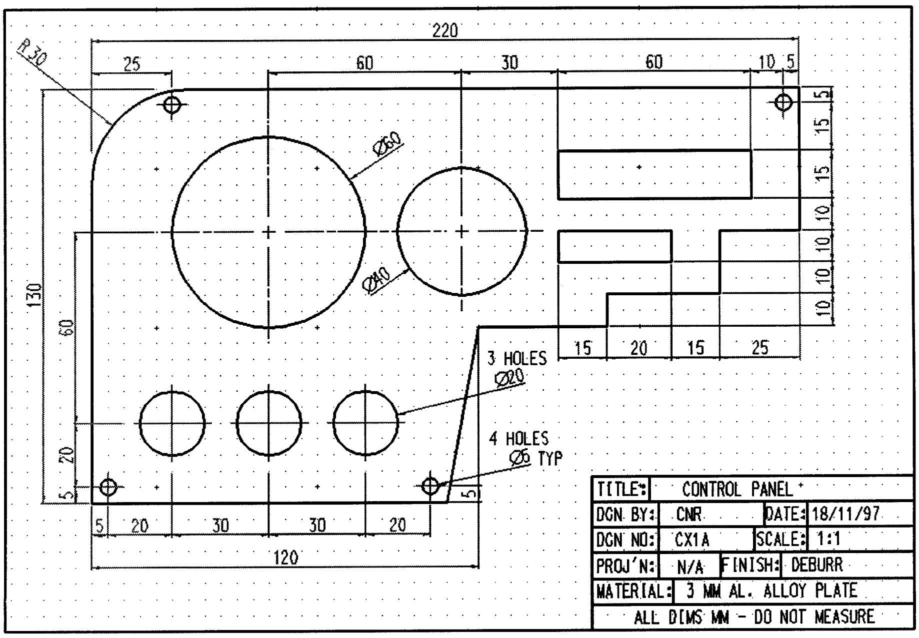

Fig. 3. The first CAD coursework.

contact with instructors and about the same amount of time on their own.

The student is given a copy of the drawing in a disk file and is asked to produce a section view and a 3rd angle projection side view. The test is designed to ensure that the student understands the principles of projection and can manipulate and edit sufficiently well quickly to produce the outlines of the views required. They are given 1 hour 15 minutes to complete the task. Few will complete the task but credit is given for making a sensible approach to producing outlines before detailed work is attempted.

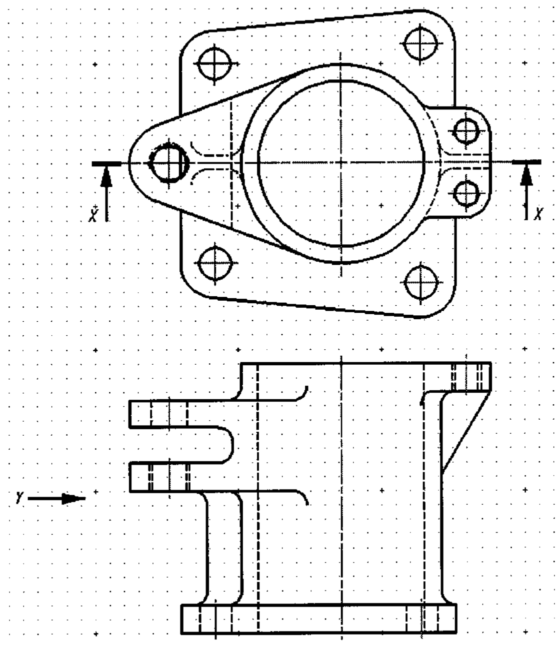

Fig. 4. The first CAD test.

ASSESSMENT OF CAD

Assessment of CAD work is not simple. Marking schedules can be set for the coursework since, frequently, the point of each exercise is oriented towards a principle of engineering drawing (for example, accurate orthographic projection). It has proved very much more difficult to grade the progress test, however. This is because, by that time the student should have learned the basics of engineering drawing but may have difficulty with workload. A good test, it is felt, should be a challenge to complete in the time available. The student may have trouble in deciding which parts of a drawing to do first and how much of each part to do. However, violations of major rules of engineering drawing can be flagged as a major marks deduction whilst details might be judged more subjectively.

Ultimately, we aim to train our students in engineering drawing to the stage where they exercise some judgement in their drawing work. A good example would be in drawing layout, the distribution of dimensioning and the use of auxiliary and section views. Thus, some differences in the final drawing might be quite substantial but not necessarily wrong.

DESIGNING A CAD LEARNING ROOM

The design of a CAD facility is not a trivial task; the design of a CAD teaching facility is even more demanding. The author, having had no training as an Information Technology administrator, sought advice from a wide variety of sources. It was found that potential suppliers were very keen to give free advice. Most of that advice was sound and has been successfully implemented.

The key requirements for the CAD rooms were:

- Students should have an unrestricted view of the teacher and the projected display. This means that the student's working station should not be oriented so that the student's back is to the teacher. Furthermore, where network-wiring pylons are required, their position should be carefully planned to ensure that they do not restrict visibility.
- Teachers should quickly be able to go to a student to give help.
- Teachers and technical staff should have good access to the wiring at the back of computers. Students should not! Considerable effort was made to keep the focus of student attention away from wiring and equipment. Rigorous attention to detail of safety rules was of key importance.
- Groups of computers need to be physically contiguously linked to allow wiring links for networking. This is particularly important so that each group could share printers and plotters.

Many drawing office layouts tend to be 'open plan'. This encourages people to enter and leave freely. This was the case with the RMCS facility and the positioning of the main teacher's display was carefully considered to minimise the distracting effect of pedestrian traffic.

As in all engineering design, compromises had to be made. Figure 5 shows the final layout of the facility.

Note that the original focus of the students (Fig. 1) had been along the long axis to a chalkboard and screen at the narrow end of the room. This was changed so that all students were closer to the teacher. Also, a potentially distracting pedestrian route is now behind the students. A false ceiling was also installed which allowed contemporary IT lighting and diffusers to be installed. This enabled selective darkening to minimise distraction and enhance visibility of the projected display. Also, Fig. 5 shows the position of the wiring columns and the lines of view which have been constructed to ensure that all students can see the central display.

An important consideration in all design work is the aesthetic as well as the functional appeal of the finished work. We were fortunate to have available funds to decorate the new facility with appealing and harmonised colour schemes (with the aid of specialist consultation). We also were able to hang some appropriate abstract pictures and to put on display engineering components and artefacts.

The comments of students (especially postgraduates) on entering the facility for the first time is very satisfying. They show appreciation for the contemporary feel of the asymmetry of the layout as well as the, obviously, expensive decoration. In an age where the students perceive themselves more and more as customers, it is important that they should feel that they get 'value for money' with the facilities we provide.

CONCLUSION

During 1994, Cranfield University at the RMCS, decided to start teaching engineering drawing on computers using computer-aided drawing programs. This involved substantial expense (including a new academic staff post) and much hard work but has been successfully implemented.

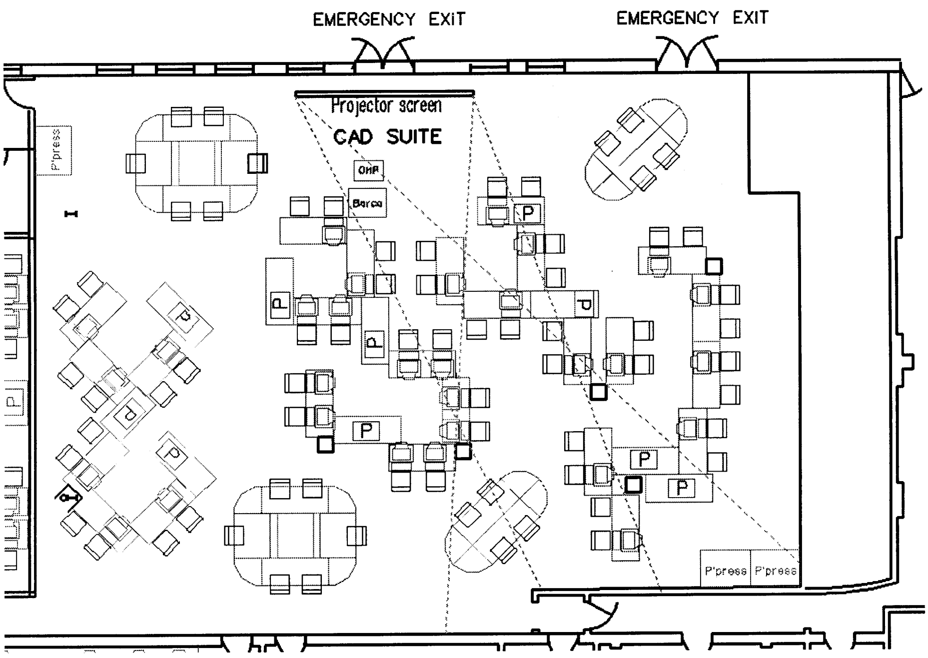

Fig. 5. The CAD suite.

There was much discussion amongst teachers on what it is that we should teach, how we should teach it and what tools to use for the job.

It was decided to scrap existing drawing boards and use the space for a large CAD facility based on PCs in a networked environment.

A new course of instruction in 2-D engineering drawing was designed after consideration of 3-D as an introduction to engineering drawing. The course is now delivered using an in-house developed self-learning text (by the author) supported by teachers in contact hours. The students express their enjoyment of this mode of learning and are achieving good standards of work.

The software used is MicroStation 95 from Bentley Systems.

The design of a CAD teaching facility was more difficult than would have been the case for an industrial facility since we had to ensure that the room allowed focus on a central position for the teacher. This complicated the issues of how to position and lay out the hardware and wiring pylons.

The design and implementation of the solution was not an easy task but is now running successfully and is appreciated by students.

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C. N. Reffold served as a Royal Airforce fighter navigator for 15 years before retiring through invalidity. Since leaving the RAF, the author taught engineering at Coventry University, specialising in design, experimental methods, computing and applied mechanics. He was latterly course tutor of a BEng course in Aerospace Systems Engineering. Mr Reffold joined Cranfield University at the Royal Military College of Science in January 1994 as a lecturer in computer-aided engineering. He currently works in the Engineering Systems Department and is responsible for teaching stress analysis, engineering design and engineering computing.