CAD/CAM in Schools

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Abstract

This small scale research project examines the use of Computer Aided Design and Manufacturing (CAD/CAM) in schools in England since the introduction of the new National Curriculum Order in September 2000, which set out specific programmes of study to include the use of this type of equipment. This research focuses on work in Key Stage 3 with a view to increasing knowledge and understanding of how CAD/CAM can be used effectively in schools. Research data has been collected in a number of ways: A media search; visiting five schools using a variety of CAD/CAM equipment; and by a questionnaire sent out to a random sample of 32 schools across England, of which 23 replies have been received and analysed.

Introduction/Rationale

CAD/CAM has only relatively recently been introduced into schools. The school in which the author teaches, Ashfield School in Nottinghamshire, gained Technology College status in 1998. Part of the bid included funds for new design and manufacturing equipment for design and technology. As a member of the design and technology staff at Ashfield, the author has been instrumental in the introduction of CAD/CAM into the school curriculum and the generation of projects and units of work, supported by this technology.

The introduction of the National Curriculum document for design and technology in September 2000, which set out programmes of study including the use of CAD/CAM, made it necessary for schools to provide equipment to meet these requirements. Research into this area is important because although CAD/CAM has been used in some schools in the past, the increases in technology over the past few years have shown that it can now be used in the classroom as a teaching and learning aid.

Defining CAD/CAM

The National Curriculum for design and technology at Key Stage 3 sets out requirements as a programme of study for teachers to follow, where pupils should be taught to:

- Use graphic techniques and ICT, including computer-aided design (CAD), to explore, develop, model and communicate design proposals [for example, using CAD software or clip art libraries, CD-ROM and Internet-based resources, scanners and digital cameras].
- Select and use tools, equipment and processes, including computer-aided design and manufacture (CAD/CAM), to shape and form materials safely and accurately and finish them appropriately [for example, using CAM software linked to a cutter/plotter, lathe, milling machine or sewing machine].
- Make single products and products in quantity using a range of techniques, including CAD/CAM, to ensure consistency and accuracy.

(The National Curriculum for England (1999), DFEE & QCA)

The above sets out the compulsory requirements for the use of CAD/CAM in schools. Due to the many variations of equipment available at the time of writing, the research presented in this paper concentrates on the use of CAD and CAM with regards to its use linked to a cutter/plotter, lathe, milling machine or sewing machine and related CAD software packages, appropriate for delivery of the National Curriculum.

Methodology

The approach to this research project is pluralistic, with evidence gained from a literature search, a questionnaire and the use of a number of visits. The methods described include both qualitative and quantitative methods. The methodology employed in this project included completing a literature search, a teacher questionnaire and a series of school visits enabling triangulation of findings. The tentative conclusions drawn, may enable my own and other schools to gain a greater understanding of the use of CAD/CAM in design and technology. The research methods identified allow a provision of relevant research materials for this small scale research project. The increases in speed of the new technology has made it possible for classes of pupils to use CAD/CAM within a normal classroom setting, instead of it being used by individuals on rare occasions. Research in this field is of importance to design and technology as current curriculum changes and trends show an increase in the use of computer technology.

Literature Search

It is apparent that over the last few years, the technology behind CAD/CAM in schools has significantly increased with the development of more powerful software packages, the lowering of equipment prices and an increase in manufacturing speed.

'These machines (CNC devices) are often very time consuming and quite difficult to learn how to use. The very idea of getting a large class of pupils to write programs and manufacture even the most basic 'widget' in

six weeks, seems too much to ask.' (Thomas, 1996)

In very recent years, technological developments have enabled CAD/CAM to be integrated into Key Stage 3 and Key Stage 4 work with relative ease.

David Prest, of the Cornwall Education Advisory and Improvement Service, sets out his own rationale for the teaching of CAD/CAM. He maintains that key features of good CAD/CAM work include:

- use to facilitate and enhance design and technological capability
- empowering students to be creative and innovative
  - unrestricted by the acquisition of hand skills etc.
- provides the opportunity for students to:
  - design, model, adapt, develop ideas as an interactive process, understand cause and effect
- encourages a greater emphasis on designing, research, planning
  - i.e. the development of thinking
- enables pupils to develop the ability to think three dimensionally
- develops an appreciation of precision
- provides value in terms of time
- encourages teachers to reassess notions of pupil ability
- enhances pupils' GCSE examination performance
- provides a fresh start for design and technology with:
  - head teachers
  - pupils.

(Prest, 2001)

Using this as a starting point, I decided to research the opinions of a completely random sample of design and technology teachers in schools across the country by using a series of random statements, some of which were taken from the Prest lecture and others added from my own experience of CAD/CAM in schools, an analysis of which is provided later.

It has been demonstrated by previous research (Robertson, S.I. *et al*, 1995) that attitudes between boys and girls differ when using computers, with boys expressing more favourable attitudes than the girls. It should be noted, however, that there are no differences in computer anxiety and computer liking between the sexes (Robertson, S.I. *et al*, 1995). The findings of this research would tend to agree with those resulting from observations in classroom settings in the five schools visited. Although no formal student interviews took place, it soon became clear from observation that boys and girls were equally confident in the use of the equipment. In some circumstances, particularly when converting designs into machine readable form, it was obvious that the staff felt more anxious about using the equipment than the students. If CAD/CAM is to become universally accepted in the design and technology curriculum, this anxiousness must be addressed.

Technology Acceptance Model (TAM)

Davis, Bagozzi and Warshaw (1989) have developed a theory called the Technology Acceptance Model (TAM), based on the work of Fishbein and Ajzen (Davis *et al*, 1989). This theory, shown in the TAM diagram, was developed following research into the use of computers by those occupying managerial positions in industry. The findings showed that an individual's computer use could be predicted by their actual intention to use it. It poses the question: Does an individual really want to use

Figure 1.

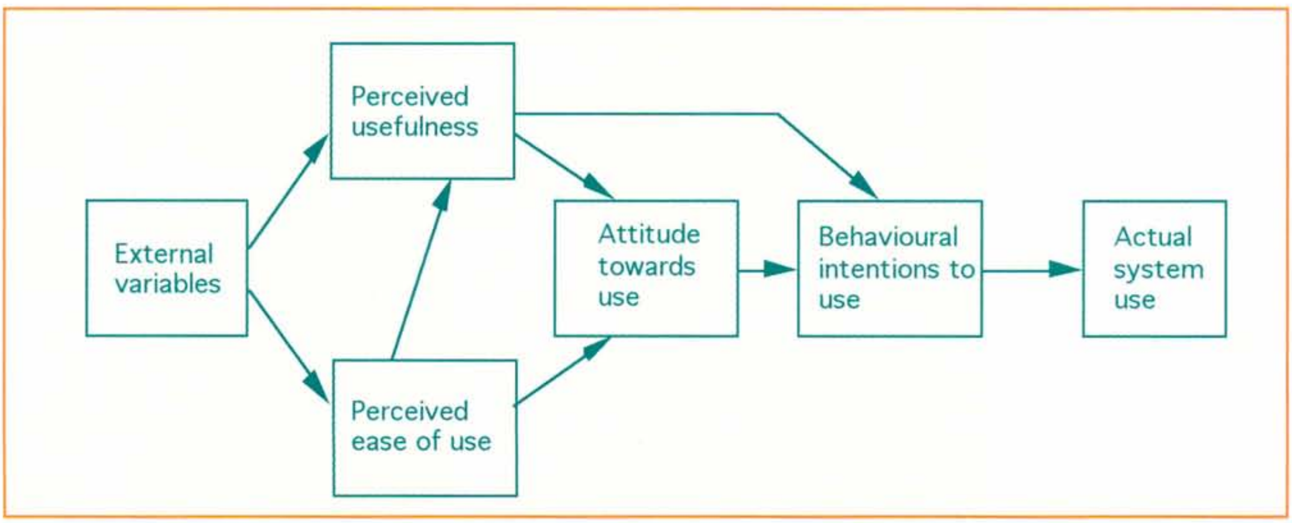

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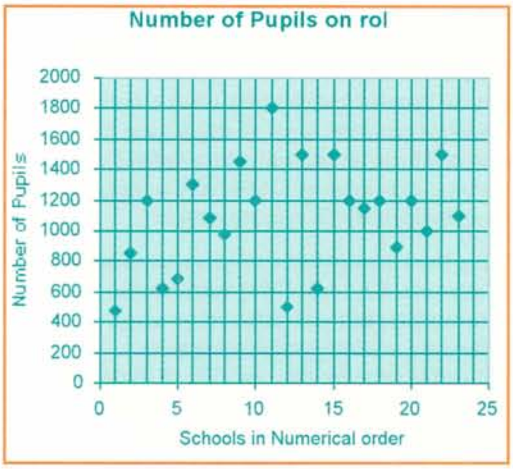
Figure 2.



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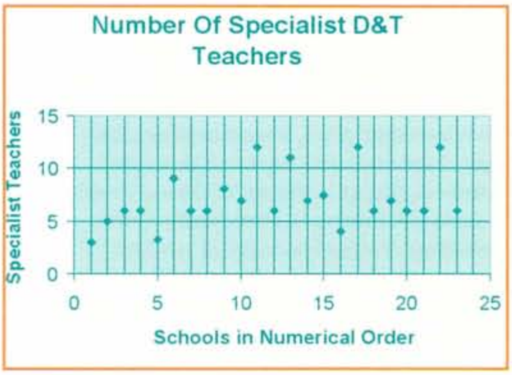

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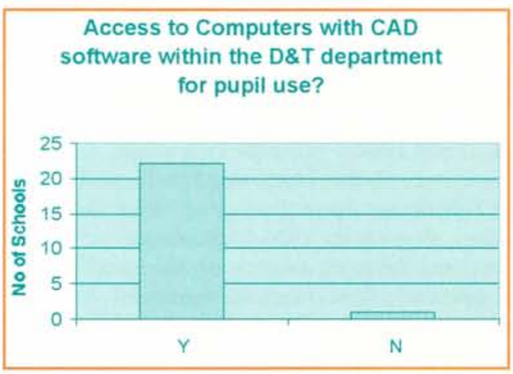


a computer to complete the task which they have been set? This theoretical model can be used to gain an insight into the use of computers within a school, by teachers. Staff may be reluctant to use computers for two reasons: firstly, they see the use of computers linked to specific activity, as being of limited value; secondly, they do not find the resources easy to use as a result of lack of training which subsequently affects confidence. Time pressures on staff in schools mean that they may not always have the time to learn a complex computer system or program.

The DATA CAD/CAM in Schools Initiative aims to provide schools with industrial quality design software, supported by training. This has had a major impact on the perception and use of CAD/CAM in schools. The provision of courses that accredit teachers in the use of design software (Pro/DESKTOP), has significantly increased the motivation of some teachers and gone some way toward bridging the gap between schools and industry. Problems have been noted with regard to resourcing, as some computer networks have struggled to cope with the complexity of this software. Other schools just have not got the facilities to use it, reducing the overall impact (Breckon, 2001). The introduction of The New Opportunities Fund (NOF) training into schools, is beginning to have an impact on staff training in the use of basic computer systems. Whilst still in its relative infancy, this initiative could go some way to improving the motivation of some staff to use computers, improving ICT usage throughout a school, not just in the design and technology environment. The major issue to be addressed is one of confidence. If a teacher is confident in the use of a computer system or program, this confidence is related to the pupils in his/her care, therefore improving the quality of education in the classroom/workshop.

Analysis of Data

As part of my research, a questionnaire was sent out to a completely random sample of 32 schools. 23 schools responded, the results show a varied level of response to each question.

The first few questions were general questions about the school and department, such as number of pupils on roll and number of specialist design and technology teachers. This was done in order to improve understanding of how different sized schools are coping with the requirements of CAD/CAM. It should be noted that the horizontal axis indicating the number of schools is consistent in each graph, therefore, school number one in the first graph is the same school as school number one in all other corresponding graphs.

The results shown, indicate the varied nature of the sample from schools with 1800 pupils and 12 specialist design and technology teachers to schools with 475 pupils and three specialists. The significance of this data will become clear when looking at the size of the school compared to the amount of CAD/CAM equipment it has.

Out of the 23 sample schools, one school had no access to computers within the design and technology department whilst the other 22 all had a number of computers within the department itself. It was not the largest schools which had the most advantageous computer/pupil ratio within the design and technology faculty. No correlation has been found between size of a school and the provision of CAD/CAM.

The greatest variation in results came from asking the schools if they had access to CAM equipment within the faculty.

A surprisingly large amount (21) of the sample schools did have access to CAM equipment (peripheral CNC outputs, including millers, lathes, vinyl cutters, sewing machines and routers), whilst the others did not. This leads to a percentage of 4.6% of schools in my sample which did not have access to CAM equipment. In order to substantiate this figure to the country as a whole, a larger sample would need to be taken.

Figure 7 shows the number of machines available for use by pupils from each school in the sample. Machines include Computer Numerically Controlled (CNC) millers, lathes, routers, vinyl cutters and sewing machines. The average number of machines per school works out at 4.04.

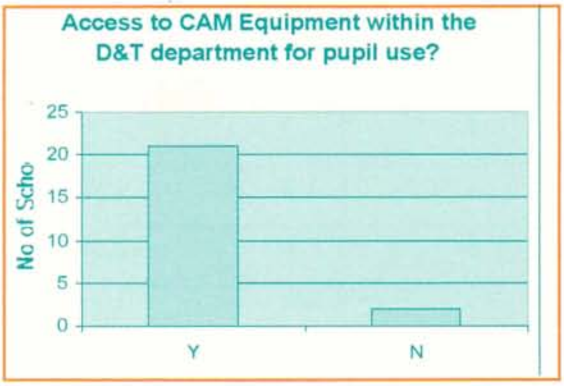
Figure 8 shows the number of schools in the sample which have specific CAD/CAM projects at Key Stage 3 or 4. No reference is given here as to which subject area the projects are used within.

The general nature of these questions provides an indication of the amount of provision of CAD/CAM equipment in the sample schools.

Reaction to the 'key features' identified by Prest was also sort. A list of these statements were added to my questionnaire with a reply grid of 1 to 5 (1 Strongly Agree to 5 Strongly Disagree).

The results of this survey of opinion are analysed and discussed in figure 9.

A list of the statements used are provided at the left of the table. The maximum and minimum columns indicate the highest and lowest score given by teachers in the survey. The Mean column provides statistical evidence of agreement or disagreement with the statement generally. A score close to 3 indicates a difference of opinion with the statement. The lower the mean score, the higher the agreement and the higher the mean score, the higher the disagreement. The responses show a wide range of opinions from the sample schools. The most important findings from the above are that in general, people surveyed agree that the quality of pupils' work is improved by using CAD/CAM and that pupils enjoy using it. It should also be noted that CAD/CAM should be used as an enhancement to, and not a replacement for, traditional skills according to the survey. Whilst it is deemed important to use CAD/CAM as a crucial component to modern making, key benefits of learning through making spring from the use of materials to



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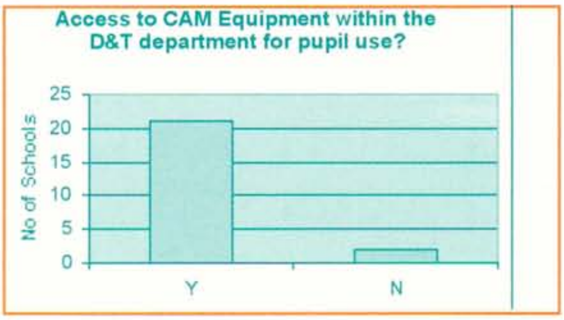

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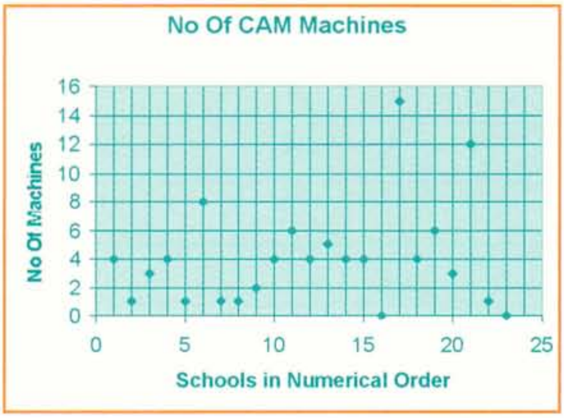

Figure 7.

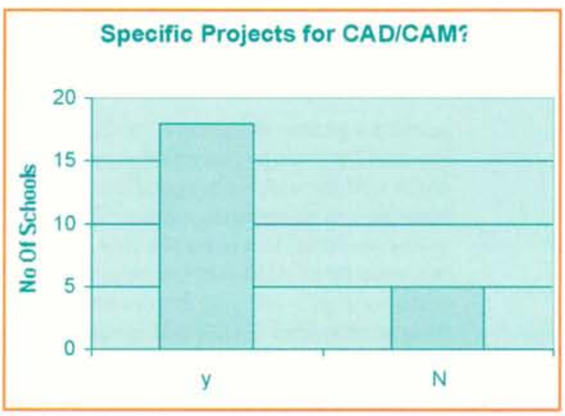

Figure 8.

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Table 1. Agreement/Disagreement with Statements (A Mean score above 3 indicates disagreement with the statement. A Mean score below 3 indicates agreement).			
Statement	Minimum	Maximum	Mean
The quality of pupils' work is improved by using CAD/CAM	1	3	1.78
Pupils enjoy using CAD/CAM	1	4	1.82
Pupils enjoy using CAD/CAM more than traditional methods	1	5	2.30
Pupils are easily bored when using CAD/CAM	1	5	3.47
Teachers find CAD/CAM easy to use	2	5	3.26
Teachers require a lot of INSET time on the use of CAD/CAM	1	4	1.82
CAD/CAM is used because it is new	1	5	3.17
CAD/CAM is used because it mirrors industrial practice	1	4	2.04
When using CAD/CAM pupils are unrestricted by the acquisition of hand skills	1	4	2.30
CAD/CAM develops an appreciation of precision	1	4	2.08
CAD/CAM provides a fresh start for design and technology	1	5	2.74
CAD/CAM enhances pupils' examination performance	1	5	2.48
CAD/CAM develops pupils' thinking skills	1	4	2.69
CAD/CAM enables pupils to think three dimensionally	1	5	2.61
CAD/CAM is frustrating to use due to software/machine faults	1	5	2.78
I feel that I use CAD/CAM to its full potential in school	1	5	3.34
CAD/CAM should be seen as an enhancement to and not a replacement for traditional skills	1	3	1.69
CAD/CAM is the future of design and technology in schools	1	5	2.65

Figure 9.

generate a product (Eggleston, 2000). The National Curriculum indicates that pupils, whilst working with tools, equipment, materials and components, must produce quality products. This being the case, and the indication that CAD/CAM improves the quality of pupils work, the importance of using at least some CAD/CAM in schools is fundamental to achieving success for pupils of all age ranges and abilities.

Whilst analysing the questionnaires, it came as a surprise that so many schools surveyed had access to machinery and equipment to carry out successful teaching of CAD/CAM, even though a large financial burden is placed on schools. Further work must be done if the figures gained are to be seen as accurate for the whole country. The current research done in this project provides a snapshot of the provision in the sample schools.

A series of visits were made to various schools around the country in order to gain a greater understanding of the use of CAD/CAM in other establishments. The visits provided information concerning schemes of work and projects undertaken. This, together with the questionnaire, provided a substantial list of CAD/CAM projects carried out by these schools:

Food packaging design (Nets designed on computer and cut out on vinyl cutter.)

CAD cake (Aesthetic designs produced on Pro/DESKTOP.)

Weather vanes (Letters and pointers profiled on CNC miller.)

Logo/emblem designs (Designed on computer and printed out.)

Electronic product containers (3D shapes designed on Pro/DESKTOP and cut out on CNC miller.)

Engraving circuit boards (Designed on computer and engraved using CNC miller.)

Embroidery work (Designed on computer and produced using CNC embroidery equipment.)

Design and working drawings (Pro/DESKTOP and Techsoft 2D design packages used to produce drawings.)

Maze games (Simple line drawings cut into plastic on a CNC miller.)

Broach designs (Jewellery, cast in pewter mould which has been cut into medium density fibreboard on a CNC miller or router.)

Relief letter cutting (Drawn on computer and cut out using a CNC vinyl cutter.)

Vacuum forming moulds (See Electronic Product Containers.)

Advertising (Designed using Desktop Publishing software.)

Computer control (Logicator software used to design flowcharts with power controllable models connected to a computer and the programming of Programmable Interface Controller (PIC) Chips.)

Pro/DESKTOP graphics (See Design and Working Drawings.)

Pop up cards (Designed on computer and cut out using CNC vinyl cutter.)

AS/A2 individual projects (dependant upon needs of individual pupils but can include techniques mentioned in this list.)

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Engraving (Production of room door plaques designed on computer and engraved using a CNC miller.)

Modeling (Including virtual modeling done using Pro/DESKTOP and limited amounts of CNC work usually done on either a miller or vinyl cutter.)

Pen racks (Nets of shapes designed on computer and cut into acrylic using a CNC miller.)

Stencils (Designed on computer and cut out on CNC vinyl cutter.)

Travel games (Designed on computer and cut out using combinations of equipment dependant upon the type of game.)

Clocks (Designed on computer and cut out using a CNC miller.)

Mobile toys (Profile shapes designed on computer and cut out using a CNC router or miller dependant upon material used.)

Helping hands for electronics (Component parts cut out using a CNC lathe.)

House signs (Designed on computer and cut out using a CNC Router.)

The projects listed here, show the varied nature of CAD/CAM projects across the subject. It is impossible in this paper to give in-depth information on the schemes of work for each project, but they are listed here to give examples of the sorts of outcomes being achieved by pupils and teachers in my sample at the time of writing.

From observations of pupils in my own school and others, a differing approach is used by the pupils towards their work when done in an environment such as a computer room, rather than a traditional design and technology workshop, due to the nature of the exercises taking place. As design and technology teachers, we have the benefit that in general, pupils like design and technology and are well motivated for the subject. We must, however, be very careful that the changes which take place in our subject do not destroy pupil motivation, but enhance their learning experience. It has been a pleasure talking to pupils about CAD/CAM as they have put across genuine enthusiasm for the work. Teachers have a duty to motivate students, encouraging learning in the most appropriate ways possible. Where such motivation is lacking, we must also try to ensure that existing motivation is not undermined by the teaching itself (Moore, 2000). Including the use of CAD/CAM in the design and technology curriculum has undoubtedly further improved students extrinsic motivation towards design and technology work in general.

It has been accepted by the schools in my sample, that CAD/CAM should be seen as an enhancement to, and not a replacement for, traditional skills. This being the case, it is important that we do not lose sight of what we are trying to achieve in design and technology, which is to increase the designing and making skills of pupils, encouraging and developing a problem solving approach.

Approaches to the use of CAD/CAM vary across different schools, mainly due to access to computer equipment. Some schools have specialist computer rooms specifically for design and technology, whilst others share a central computer suite with other faculties, which must be booked out. Design and technology faculties in the envious position of having their own computer rooms, are clearly at an advantage to those that do not. Considering the schools in my sample, CAD work is mainly carried out within the design and technology faculty, but can be done in non-specialist computer rooms around the school. CAM work, on the other hand, is restricted to the design and technology faculty due to specialist machines being required. Some schools employ the use of regional hubs to complete CAM outcomes, but this has been found to be a long process due to the increasing burdens being placed on these hubs.

Within design and technology faculties, the use of CAD/CAM has increased significantly over recent years. This increase in CAD/CAM use has seen an improvement in the use of computer technology within the subject area. Whilst this is deemed to be positive, this increase in use has also seen an increase in problems. These problems have occurred for two main reasons:

- the equipment and software can sometimes exhibit faults
- machines still only work relatively slowly.

Either multiple machines are needed, or simple projects are undertaken in order to give each pupil in a class the opportunity to use this technology. Machine faults are unfortunately beyond the control of the classroom teacher, but strategies can be employed to overcome high numbers of students waiting for work to be cut out on machines. At Ashfield School this year (2001), as a result of my research, I developed and trialled a unit of work, which was placed alongside one of our main CAD/CAM projects. The unit of work consisted of exercises in computer control and developed

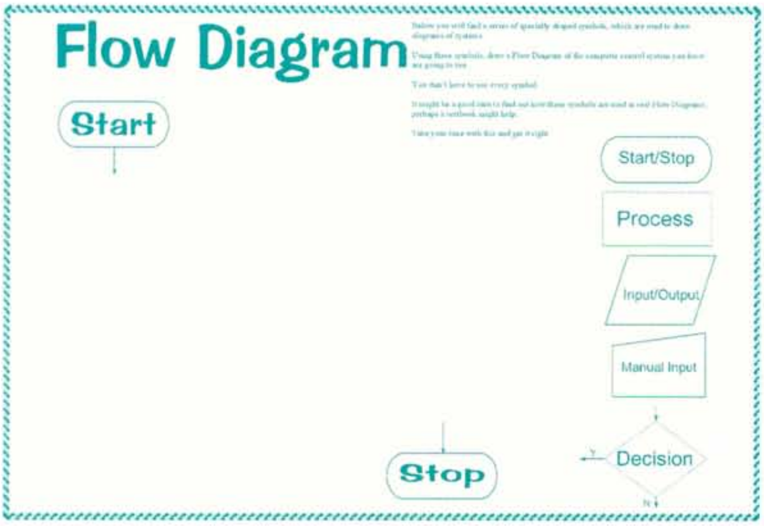
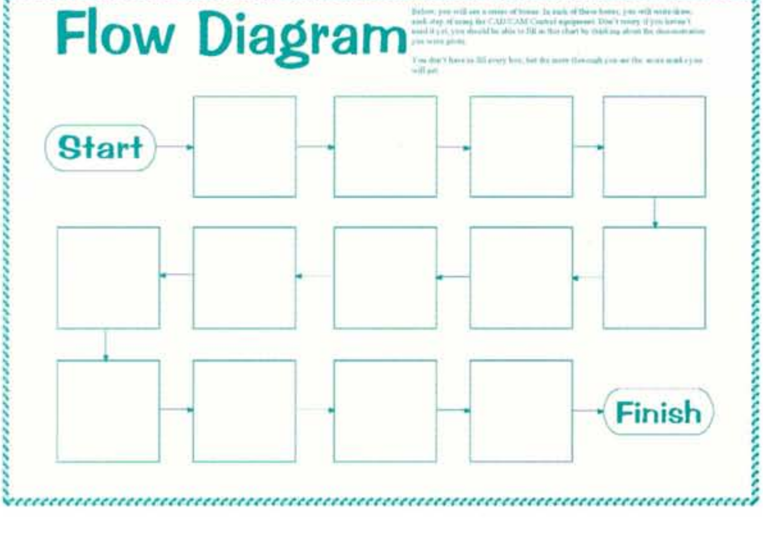


Figure 10.

the pupils' knowledge of machines, which are controlled by computers.

Examples of the sheets used are shown above and below. These pages were printed back to back on A3 sized paper. The sheets worked extremely well and involved Year 7 students in relevant work towards CAD/CAM at all times of the project. I have recently developed other sets of these sheets for Year 8 and 9 pupils which will be trialled in the 2001/02 academic year. The exercises and questions given in the sheets can be used in conjunction with any CAD/CAM project in schools with access to this type of equipment. These sheets have also been used to teach section 5 of the Key Stage 3 programme of study for design and technology (knowledge and understanding of systems and control). This unit of work has helped relieve some of the pressure on our school's CAD/CAM suite. It is presented here as an idea which may be undertaken by other teachers in order to give pupils a set of meaningful tasks to perform which were relevant to the project and topic being studied, in order to improve pupil knowledge and understanding – which was the initial aim of this piece of research.

Figure 11.



Due to the problem of the CAM machine bottleneck, there is a danger of using this technology to do simple and mundane tasks in order to get more pupils through in a shorter amount of time. This could prove to be a great problem for this technology unless more strategies can be found to alleviate the problem, or the speed of the technology can be increased. The other solution to is to reduce the sizes of individual classes to improve each pupil's experience of CAD/CAM, but this again is problematic due to monetary and logistical difficulties faced by schools.

Conclusions/Recommendations

In conclusion, this research has been successful in highlighting the many positive aspects in the use of CAD/CAM in schools. In particular, it has brought to light the tremendous amount of work being done by teachers around the country to make this section of the curriculum successful. Findings have shown that both teachers and pupils are gaining a remarkable amount of knowledge and experience from its use to forward their education and training. The most interesting results were put forward from the survey of opinion:

- The quality of pupils' work has improved by using CAD/CAM.
- Pupils enjoy using CAD/CAM.
- CAD/CAM should be seen as an enhancement to and not a replacement for traditional skills.
- Successful adoption of the use of CAD/CAM by teachers and their pupils requires the investment of time in INSET.

The above statements were the most widely accepted statements from my survey of 23 schools, although others did have positive responses but to a lesser degree. The project has shown that the issue of staff training is probably the largest limiting factor. Initiatives such as New Opportunities Fund (NOF) training and the DATA CAD/CAM in Schools Initiative are perceived to be a step in the right direction. Research findings from observations and school questionnaires, have also concluded that this technology is well used across the design and technology subject areas by members of school staff from a multitude of design and technology backgrounds. It has become increasingly clear that pupils gain a valuable learning experience when using CAD/CAM and are well motivated towards the tasks. It is also apparent

that problems still exist with the use of this technology, but with work and determination from the people involved with CAD/CAM, and the people using it at the cutting edge, CAD/CAM can become one of the most exciting and challenging parts of the design and technology curriculum for many years to come.

It is clear from the findings that CAD/CAM is being used in the majority of schools surveyed. Further research to determine how much time is devoted to teaching CAD/CAM skills, in contrast with other design and technology activity, would be a useful future project in order to ascertain whether or not this technology is being used to its maximum potential, increasing pupil awareness and knowledge of current design and manufacturing techniques.

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Special thanks must also go to the schools which took part in the survey and to Sarah Galloway of Hanson School in Bradford for allowing access to schemes of work.