

# The Application of Computer Aided Design and Manufacture in School-based Design

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## Abstract

The increased provision of digital media to facilitate design activity in commercial practice, Higher Education and schools, has led to the need to consider what the likely impact has been on design education.

The potential for Computer Aided Design (CAD) to impact the activity of 'designing' within an educational context is clearly established and it has been identified that many of the activities associated with project-based design could be undertaken using CAD technology. This paper aims to examine the extent to which the potential identified is being effectively implemented in design activity within education.

To do this, the paper reports further research on a survey distributed to design and technology departments nationally (Hodgson and Fraser, 2005) and describes the role and impact that CAD may have on aspects of design and technology education.

It reports both teacher and pupil opinions arising from interviews and analysis of student work. It provides relevant case studies to support any conclusions drawn. It notes that CAD/CAM is having a significant and positive impact on the activities undertaken in design and technology education and that, at the very least, this allows participants to make and manufacture items that would not have been possible either by more conventional means or within the time constraints of a modern curriculum. Despite this, the paper suggests the impact of Computer Aided 'design' and the role it can play in the activity of 'designing' is an area of potential not very well established or often recognised. It notes an increasing awareness of how the technology may be used to better facilitate 'designing' and that the use of CAD in design development activity could be seen as furthering the potential already well established.

## Key words

CAD, designing, making, manufacture

## Introduction

It is apparent that the changes in children's designing arising from the use of Computer Aided Design (CAD) in schools are sufficiently profound to warrant careful research (Kimbell et al 2002). Moreover, recent technological developments in both software packages and affordable equipment have enabled CAD/CAM not only to become a realistic but also a *compulsorily* part of the National Curriculum. Similarly, the increased provision of digital media to facilitate design activity throughout commercial practice, Higher Education and schools, has led to the need to consider what the impact has been on design education.

Previously, researchers assessing teacher perceptions of the technology have all advocated that the 'quality' of pupil's *outcome* is significantly improved when the use of CAD is implemented (Fullwood 2002, Hodgson 2006, Kimbell et al 2002, McCormick 2004, Prest 2001). However, the influence on both the quality of design and the activity of designing has itself, as yet, to be established.

It is clear that we cannot look to research within industry for the answers as the role of CAD in commercial practice is very different to that in education. MacMahone and Browne (2003) whilst identifying the role of CAD as rapidly becoming a necessity rather than a luxury described CAD as the more efficient, productive and competitive approach to product design by making significant contributions to company productivity and lead times. Despite these obvious merits, it is unlikely that any of these issues hold any relation to the capabilities developed by an 11 year old tackling the challenges of designing a 'one off coat hook' (to use an example offered by Breckon, 2001). It is, therefore, increasingly important to establish the effective role of CAD in design activity within an educational context.

### Computer Aided Design?

If, as advocates of curriculum advances have established (Norman and Roberts 1999 and Roberts 1990) the 'real' learning experience within design and technology is likely to occur whilst proceeding with design problems and within the activity of 'designing', it should be of concern that the role of CAD in this activity is subject to some scrutiny.

Kimbell et al (2002) whilst observing participants ability to use CAD as a tool to aid design suggested that despite pupils having the necessary capability to operate the software the use of CAD as a means of undertaking 'designing' was restricted. Similarly the authors (ibid.) describe the pencil/paper booklets typically produced within design and technology project work as far richer records of development than any shown through CAD modelling software.

The Office For Standards in Education (OFSTED) however, acknowledge that CAD holds inherent capabilities for the detailed development of design ideas but feels it does not provide an effective means of supporting conceptual designing and creative activity like that of pencil and paper. (OFSTED, 2001).

As a result, many believe CAD is unable to support aspects of conceptual designing and creativity that is common place within paper based folios and that, subsequently, many of the advantages of CAD seem to lend themselves more to project-based making and manufacture rather than any considerable contribution to 'design' and the early stages of 'designing'. Despite this, McCormick (2004) makes a point, often underestimated by design educators, that CAD/CAM systems employed within education enable pupils to achieve something they could not have done by more conventional means. By introducing new tools and methods with which pupils can engage in designing and making are pupils more likely to reach their full potential?

### Identifying the *potential* for the role of CAD in design

Hodgson and Fraser (2005) clearly established (by means of a survey completed by Heads of Design and Technology departments, nationally) a significant potential for the use of CAD in design and technology

education. This research identified that the large majority of project-based design tasks could be, and seemingly were, undertaken using CAD. The authors (ibid.) identified a predominant use of CAD as a means of generating outputs such as rendering and/or physical modelling. Despite this, the evidence to suggest participants of design and technology were able to develop design ideas and ultimately engage in the activity of designing within CAD was still inconclusive. There remained a need to distinguish what, if any, learning experience is synonymous with CAD in design. What skills and capabilities is its use perceived to enhance, de-value or replace and what are the perceived benefits to *education* and the activity of *designing* within an educational context are likely to be?

If we consider the complexity of design it is clear that any description of CAD's contribution to design and technology education, and its role in the activity of *designing*, must be based on a close description of actual activity in terms of the actions done and the decisions taken (Cross, 1995). It is apparent also that the individual *opinions* obtained from the previous survey data could not form a basis from which to make assumptions about *actual* concrete behaviour.

This paper aims to address the extent to which the implied *potential* for the use of CAD in designing is actually occurring by direct reference to work undertaken by a sample of schools generated from the previous research. Retrospective folio analysis and interviews with teachers and pupils were used to draw a more informed understanding of the impact CAD is having on design and technology education. More specifically where, if any, significant value is derived from integrating CAD modelling activity into designing. The use of retrospective interviews with pupils provided a useful insight into their project; granted them opportunity to justify the tools and processes used; and provided a deeper explanation of the project as they perceived it. This aimed to eliminate the 'static snapshots' of items *presented* purely for assessment and provided a more holistic view of the design activities undertaken.

Of the 342 respondents from the survey cited in Hodgson and Fraser (2005) a sample of ten schools were drawn based on *their* opinions about the level of

capability within their department. The survey data was originally structured within a series of measured hierarchical levels and asked respondents to express their opinion by rating agreement or disagreement with a set of attitude statements that related to their perceptions of CAD capability.

As a result of the scaling techniques employed it has been possible to further scrutinise the results and perform extended analysis to provide each respondent with a cumulated numerical score based on *their* perceptions of the departments respective capability. The attitude statements to be analysed were converted to a numeric value depending on their content (accepted content values include: strongly\_agree, agree, n/a, disagree, strongly\_disagree and these were mapped to values 5 to 1 respectively). As a result, values could be summed for each respondent and the cumulated value was deemed to provide a numerical indication of the respondents' opinions of CAD capability within their department.

These results enabled two distinct percentile groups to be identified and of the 328 respondents that could be analysed (as a result of anonymity of responses), the top and bottom percentile groups were established in order to better represent a range of CAD user capabilities and advocates.

As a result, the data for this paper is drawn from a series of interviews conducted with a sample of ten schools distributed throughout the UK. Within each of these schools and their respective departments, a group of pupils and at least one teacher from each of the key

stages taught (typically Key Stage 3 to 5) were asked to offer their opinions on a range of issues surrounding the use of CAD in school-based design. In total 48 students and 13 teachers were interviewed. The opinions, and project work to which they refer, form the basis of the findings and the case study examples provided within this paper.

Whilst the previous research paper (Hodgson and Fraser, 2005) established the need to consider in greater detail the role of CAD in design and the activity of designing, it also observed the need to better define the nature and use of CAD in schools and its implementation in school-based design work. This paper, therefore, highlights more general benefits to design and technology education as a whole as well as any specific contribution to the activity of designing.

## The role of CAD in school-based designing

It is clear that CAD/CAM is having a significant and positive impact on the activities undertaken in design and technology education and that, at the very least, it allows participants to make and manufacture items that would not have been possible either by more conventional means or within the time constraints of a modern curriculum. The example below shows a pupil's design for a sensory mood board for autistic children, which at over six feet in length would not have been achievable either in terms of the design or the manufacture without using CAD/CAM. It is clear that by introducing such tools into designing and making pupils are no longer constrained by their own physical capabilities in the workshop and are able to explore a



*Figure 1: Example of CAD\CAM based A' level project which would not have possible either in terms of the design or the manufacture within the time constraints of a modern curriculum*

wider range of possible outcomes to the design problems they attempt to resolve.

Interviews with both teachers and pupils identified that the introduction of CAD/CAM systems significantly reduced the time traditionally devoted to making and manufacture. Despite this, the perception of some CAD critics was that CAD replaced or significantly devalued time traditionally spent on what they perceived as 'better activities' such as resistant materials work. However, the majority of teachers and particularly pupils did not express any great concern over the apparent shift in emphasis. Teachers noted that pupils demanded a return on their ideas quickly and cited one of the main advantages of CAD as delivering just that. CAD, in the form of a high quality output, often motivated pupils to engage in design activity at the very least. In fact in some instances teachers went as far as to say that CAD/CAM inspired pupils to take an interest in making which would not have normally done so.

*"For whatever reason we now have generations of kids that have such sophisticated lives that making in a traditional sense is not such a strong part of that [their lives].*

*Traditionally, kids would have generally well developed making skills from things like Airfix models and trains...you talk to a kid about an Airfix model*

*today and they give you a funny look! It's important for me, as a D&T teacher, to use the skills these pupils have to engage them in 'making'."*

Despite noting the significance of CAM in this equation CAD takes an equally significant role.

*"CAD allows some pupils to access D&T that normally would not have done so... as we teach it [CAD] further down the school we are attracting those pupils at Key Stage 4."*

This notion that CAD has enabled some pupils to 'access' design and technology was one shared by a majority of schools in the same sample as teachers generally felt that CAD enabled some pupils to better communicate design thinking. Similarly, pupils often described CAD as a 'universal' language and recognised its importance as a effective format by which they could easily communicate and more importantly defend their ideas.

*"...You know before you start to make something that it will work...!"*

*"Its easier to explain what your products all about with CAD. With drawings you have to label what goes where and what connects to different things."*



**Figure 2: Examples of how knowledge of the helical sweep feature in Pro/DESKTOP has been independently learnt and shared amongst students which, in turn, were able to apply that knowledge to their individual design projects**



One of the most intriguing findings of the research and possibly one which has been significantly understated is the culture of use that surrounds CAD in design and technology education. Often pupils inadvertently acquired, swapped and shared knowledge, skills, tools and resources using CAD as a medium for communication. By developing a range of skills in this manner pupils autonomously developed the necessary capability to better use CAD as a design tool by which they could express ideas and ultimately begin designing within a virtual environment. Pupils explained how they would discuss how to achieve certain shapes forms and features sharing their knowledge and skills without reference to teacher or other obvious resources. The example in Figure 2 illustrates how pupils were able to share knowledge of a helical sweep and apply that knowledge to communicate design intent.

Teachers felt that CAD generally aided participants of design and technology to better meet assessment criteria imposed by GCSE and A' level syllabuses. Also, that CAD enabled pupils to consistently achieve a high quality of manufacture, accuracy and engineering drawings almost at the touch of a button, and as a result, were more inclined to teach CAD as an effective means of generating an output. It was clear that in this manner CAD was enhancing pupils *apparent* capability by allowing them to communicate their ideas more effectively.

It was also noted that, in some instances, CAD had lessened the time required for making and manufacture and it was felt important to establish what this time had since been devoted to. For example, did the decrease in time enabled pupils to spend more time designing and as a result produce better designs? In a minority of instances, some pupils felt that, as a result of a decrease in the time required for making and manufacture, they could *further* develop their design ideas.

*"The manufacture on a hand made project is weeks isn't it? Where as when you use CAD/CAM you can do it in a session... You can spend more time developing your ideas and that sort of thing, so the thing you come out with at the end is better developed."*

However, this was not always the case. The majority of pupils and teachers expressed a belief that any reduction in manufacturing time was not spent on *further* developing design solutions but instead invested in recording in greater detail the development *already* done.

*"With CAD...because the manufacturing is going so quickly manufacturing is not the meat of my project. It means I can go back over my work and catch up with my folio, finish off all my development and show a lot more stages of development."*

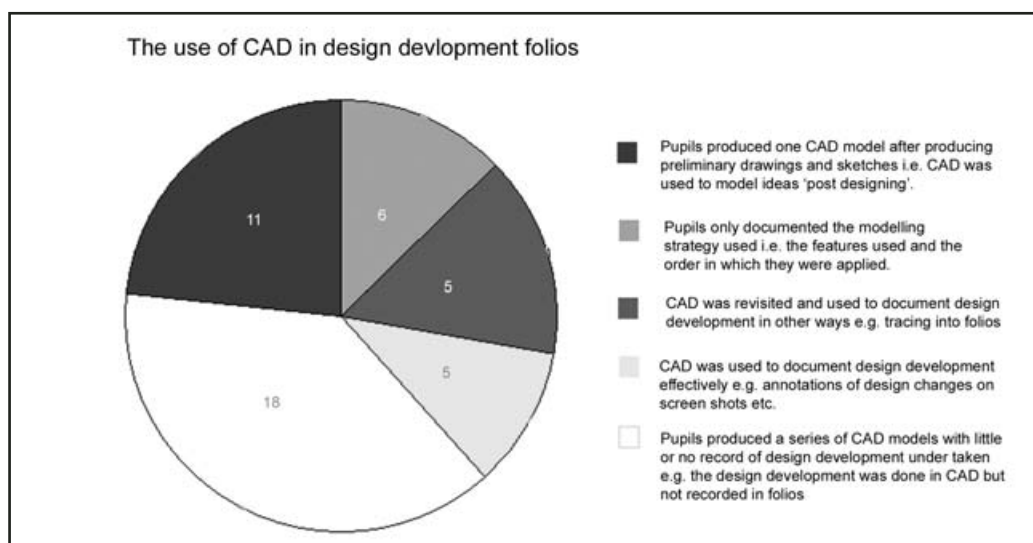


Figure 3: Chart showing number of pupils and their use of CAD to document design development in folios

It was clear that, despite the potential for the time created by CAD/CAM systems to contribute to pupils project work, it had made limited further contribution to designing and the activity of design development. In the majority of instances any additional time gained as a result of integrating CAD/CAM into making was not spent on 'designing' but more 'documenting'. The following use of CAD in design folios was observed (see Figure 3).

Generally, CAD played a significant role in the majority of departments sampled and allowed a significant proportion of pupils to not only be motivated to engage in design activity but to succeed in producing high quality outcomes in response to design problems. In this way CAD, as a means of generating such outputs, brought obvious rewards to making and manufacture within school based design work. Equally, these outputs strongly supported relevant assessment points by improving the communication of design work. CAD's ability to engage pupils in designing and making and allow pupils to realise and communicate not only their design intent but arguably their full potential can be seen as a clear case for CAD in the national curriculum.

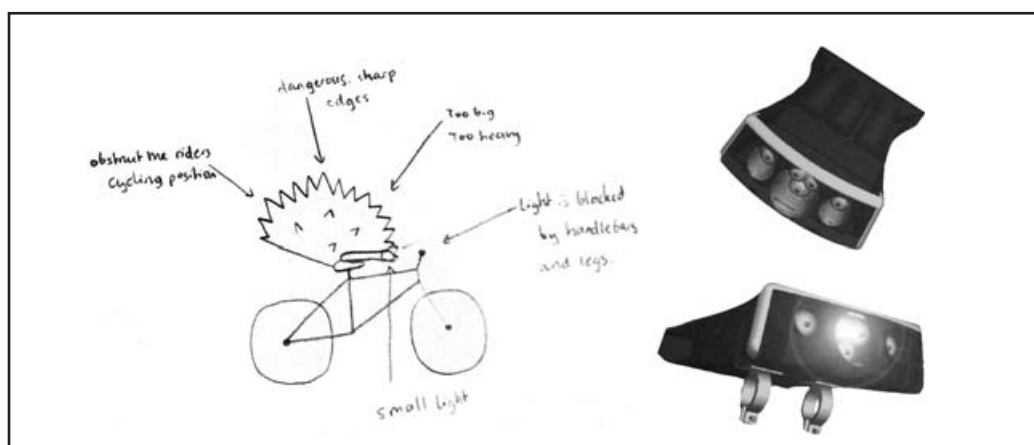
However, despite noting these positive benefits CAD is seemingly having on the nature of design and technology, the impact of Computer Aided 'design' and the role it can play in the activity of 'designing' is an area of potential not very well established or often recognised.

As suggested by Hodgson and Fraser (2005) the use of CAD within school-based design is predominantly output focussed and the technology is often exploited as a means to an end rather than a means to facilitate designing and developing design concepts.

The use of CAD therefore, to facilitate design and specifically the activity of 'designing', could be seen as furthering the potential already well established and promoting the 'real learning' experiences identified as central to achieving capability within design and technology education, albeit within a virtual environment. For these reasons the use of CAD in design and the concept of Computer Aided Designing are worthy of consideration.

### Genuine design?

Further investigation revealed that some pupils were using CAD in aspects of design activity as a means by which to communicate design thinking. In these instances the development of design ideas in CAD often remained entirely undocumented prior to the appearance of a rendered 3D model for assessment. For example, the image below (Figure 4) suggests a significant proportion of the development for the students' project has occurred within a CAD environment, yet the folio reflects little or no development at all, regardless of the use of CAD. The images depict the stages of design development exactly as documented within the pencil\paper folio



*Figure 4: Example showing significant leap from thumbnail sketch to fully developed CAD model with little or no development documented in the pupils folio. Is it possible to assume that a significant proportion of 'design' occurred within a CAD environment?*

and the leap from the thumb nail sketch to the fully developed CAD model occurred on adjacent pages of the submitted folio.

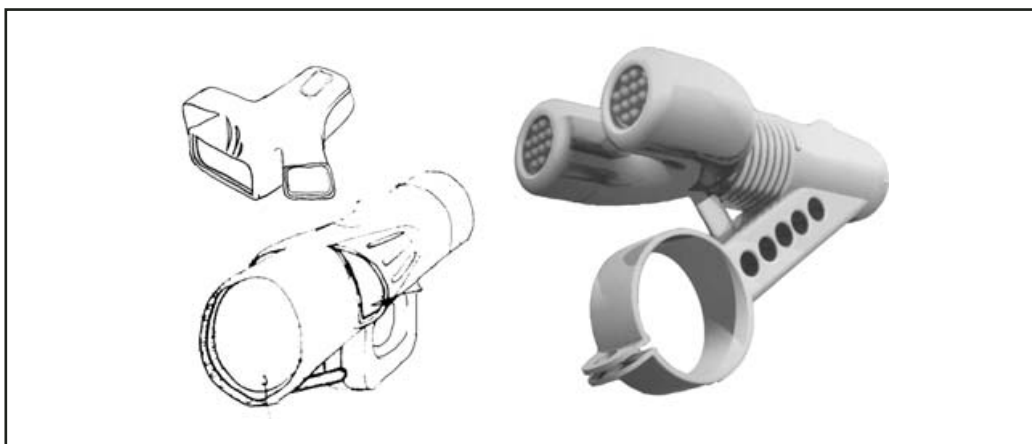
The next example (Figure 5) illustrates much the same point. Despite the transition from sketch to CAD being less dramatic it is clear that a significant amount of designing has occurred within the CAD model and that this development remains undocumented within the folio submitted. It clearly shows that given the opportunity to use CAD as a means to communicate design thinking the quality of the aesthetic and consideration of detail, at the very least, is improved.

What is of greater significance, however, is that typically the participants that made a significant use of CAD in designing either failed to record, or did not recognise, the activity as significant in terms of their design development. There are a number of reasons why this may be the case; lack of time, lack of motivation to continue to document the design saga or an inability to conceive the design development within a virtual environment as 'genuine design' worthy of submission. What is also worth questioning is if the pupils had not been given the opportunity to use CAD would they have been able to communicate design thinking as effectively, if at all? Also, would their

design have been as fully developed? Retrospective analysis of folios provided a limited insight, as they typically depicted a series of static snapshots that were not necessarily representative of the process of designing actually employed. The case can be sustained when consideration of further student work and interviews are included.

For example, in many of the cases where development was seemingly apparent, it was clear that the communication offered (typically done as screenshots) was centred around the knowledge applied in producing the CAD model in terms of the features used rather than any indication of the actions and decisions taken as a result of 'designing' in CAD.

Also, in a number of other cases, pupils who had sufficiently developed their ideas within a CAD system felt the need to record this development as sketches and annotations. The example that follows (Figure 6) shows a design for a camping stove significantly (if not fully) developed in CAD but traced back into folios to provide the relevant documentation of development.



*Figure 5: Example showing significant leap from thumbnail sketch to fully developed CAD model with little or no development documented in the pupil's folio. Is it possible to assume that the value of design development is not recorded or recognised?*

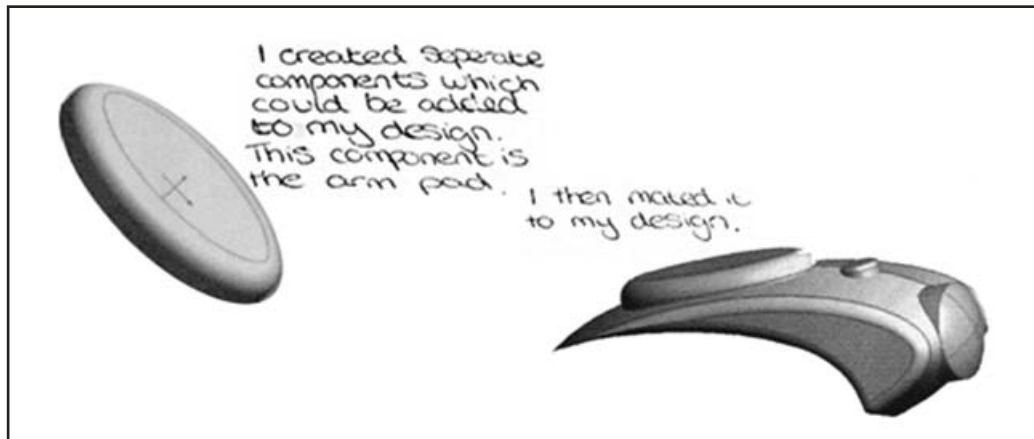


Figure 6: Examples showing how pupils annotations typically document the modelling strategy adopted (the features used and the order in which they were applied) as opposed to communicating design decisions

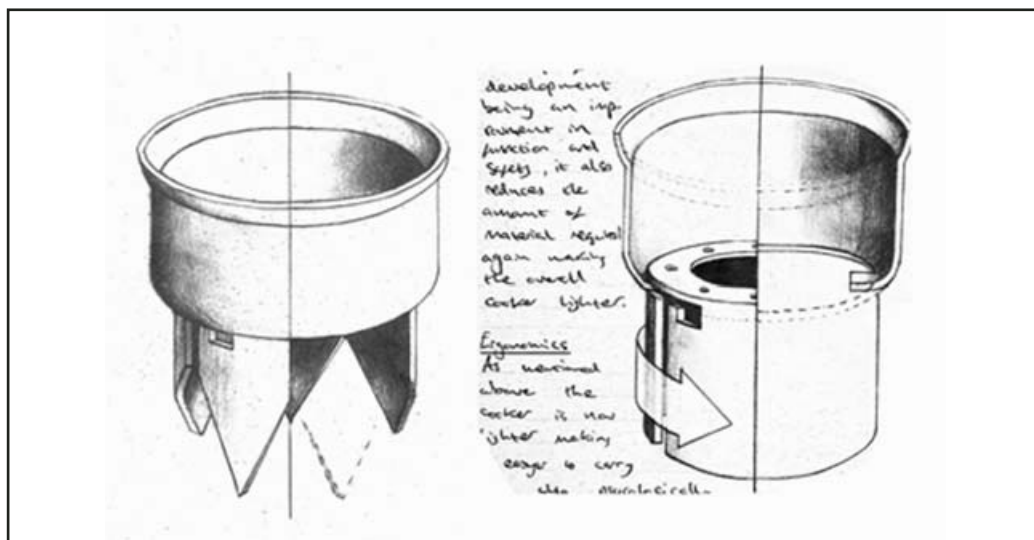


Figure 7: Example showing a student's use of a Pro/DESKTOP model traced back into a student folio to record the development undertaken in a CAD environment

Also, in a number of other cases, pupils who had sufficiently developed their ideas within a CAD system felt the need to record this development as sketches and annotations. Figure 7 shows a design for a camping stove significantly (if not fully) developed in CAD but traced back into folios to provide the relevant documentation of development.

It is important to make the point that in these instances pupils were capable of producing screenshots of work and often did so later on in project folios. However, one student offered an interesting account of his actions.

*"It's a real talent to be good at sketching...plus if you use drawings sketches that kind of thing your project looks like it has been designed properly...does that make sense?"*

It seems increasingly likely that pupils may not always conceive the development done within a CAD environment as 'genuine design'. This has implications for their project folios, and in the case illustrated by the example above regard sketching and other such activities as more worthy 'designerly' acts. Is it possible that the range and ease with which pupils are able to manipulate



their design ideas in the finest of detail makes documentation of design activity in a traditional sense largely impossible? It may simply be an inability of pupils to pick out the 'significant' design changes within CAD rather than a negative contribution of CAD to design development. Such issues are a part of our on-going research in this area.

## Summary

CAD/CAM is having a significant and positive impact on the activities undertaken in design and technology education and, at the very least, allows participants to make and manufacture items that would not have been possible either by more conventional means or within the time constraints of a modern curriculum.

CAD, in the form of a high quality output, often motivates pupils to engage in design activity and in some instances teachers felt that CAD/CAM inspired pupils to study design and technology and take an interest in 'making' which they would not have normally done so.

CAD generally aided participants of design and technology to better meet assessment criteria required by GCSE and A' level syllabuses, allowing pupils to consistently achieve a high quality of manufacture, accuracy and engineering drawing quality. Subsequently, many of the advantages of CAD were applied more to project-based making and manufacture rather than any considerable contribution to 'design' and the early stages of 'designing'.

Despite this some pupils were using CAD in aspects of design activity and as a means by which to communicate design thinking. Although it must be concluded that the impact of Computer Aided 'design' and the role it can play in the activity of 'designing' is an area of potential not very well established or often recognised.

It was noted that, in some instances, CAD had lessened the time required for making and manufacture but that it had made limited *further* contribution to *designing*. In the majority of instances any additional time gained as a result of integrating CAD/CAM into making was not spent on 'designing' but more 'documenting' and 'improving' folio work.

It was interesting to note that pupils may not always conceive the development done within a CAD environment as 'genuine design'. This has implications for their project folios, as in some instances pupils regarded sketching and other such activities as more worthy 'designerly' acts.

The potential use of CAD to facilitate design (specifically the activity of 'designing') was seen as promoting the 'real learning' experiences identified as central to achieving capability within design and technology education; albeit within a virtual environment.

CAD's contribution to the quality of outcome is not to be underestimated but it is felt important to establish what the impact has been on the quality of 'design'. That is to say, is CAD considered an alternative or more effective means of proceeding with design problems and designing? Does the ease at which pupils are able to make modifications and communicate design ideas enable them to produce 'better' designs as a result?

It is envisaged that further analysis of the teacher/pupil interviews, undertaken in the range of case studies, will provide some answers to these questions.

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