Beyond Pro/DESKTOP Computer Aided Design (CAD) : the transfer of CAD-based design modelling skills from schools to Higher Education

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Beyond Pro/DESKTOP Computer Aided Design (CAD): the transfer of CAD-based design modelling skills from schools to Higher Education.

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Abstract
Most secondary schools in England and Wales now include the use of three-dimensional (3D) CAD modelling skills in their secondary design and technology curriculum and the majority of those employ PTC Pro/DESKTOP as the software that is used to develop and implement 3D CAD modelling skills. The use of CAD, and other digital media, is a key part of the Industrial Design and Technology programme at Loughborough University.

This paper reports on investigations into the ways in which Pro/DESKTOP software has been used in A’ Level work, from the perception of 120 students in their first year of the undergraduate Industrial Design and Technology programme. It draws distinction between being able to use CAD modelling features and being able to model products in CAD. The need to move from Pro/DESKTOP to Pro/ENGINEER is clearly underpinned by the need for graduates to have capability with a sufficiently complex and appropriate CAD modelling system that the design intent is not compromised by their ineffective use of the software.

A seamless progression from CAD work at A’ Level to that at undergraduate degree level is unlikely, in part because of the range of effective CAD capability across A’ Level students and also because the different CAD software packages employ some differences in style and approach. The paper considers some issues concerned with the transfer of generic CAD skills between school and undergraduate level at university, and draws conclusions that have implications for the teaching and learning of CAD.

Keywords
modelling, Pro/DESKTOP, Pro/ENGINEER, A’ Level, CAD, teaching

Introduction
Design and technology activities in schools are making increasing use of 3D CAD software as the DfES CAD/CAM in Schools Initiative enters its fourth year. This initiative, launched in 1999, saw the introduction of CAD software following the training of teachers and provision of free PTC Pro/DESKTOP and other software. ‘The success of the scheme to date can be judged by the number of teachers registered for Pro/DESKTOP software (over 6000), together with the overwhelming demand for places at the CAD/CAM conference held at Warwick Manufacturing Group at the University of Warwick in 2001’ (DATA, 2003). The effective use of this newly-developed capability has, as yet, to be objectively measured. The need to make use of CAD/CAM in schools is identified in the National Curriculum, which states that ‘Pupils should be taught to … use graphic techniques and ICT, including computer-aided design (CAD) to generate, develop, model and communicate design proposals’ (QCA, 1999: 23). The need for CAD/CAM is now also highlighted in A’ Level specifications. For example, ‘Appreciation and understanding of the use of CAM for industrial production. … CAD (computer aided design) product modelling’ (AQA, 1999: 29) and ‘Computer-Aided Design, Manufacture and Testing (CADMAT) … e.g. for: creative and technical design, modelling and testing, … integrated and concurrent manufacturing’ (Edexcel, 2000: 39).

The Industrial Design and Technology programme at Loughborough University includes an information and communications technology (ICT) intensive approach towards the rapid development of products in a commercial context. It has made use, over many years, of a range of 3D CAD systems, together with other software, to develop, illustrate and simulate product design development. The use of CAD and other digital media is a key part of the course programme, enhancing the quality of student design work together with their prospects of employment in an industry that expects graduates to have a high level of CAD capability in addition to the more traditional skills of industrial design and design engineering. The level of CAD capability required in such a context is high, particularly if design intent is not to be compromised by a designer’s inability to model the...
shape, form and detail of their product using CAD. To this end, core modules of ‘Computing for Design’ form a part of the first two years of study in the course programme, supplemented by focused activities that aim to exploit the advantages of using CAD in design development. One example of this approach is illustrated by an injection moulding project undertaken early in Year 2 of the course programme. Injection moulded products and tools are designed, manufactured and presented primarily through the use of CAD/CAM (Figure 1).

Figure 1: Film cassette clip. Example of injection moulded products and tools from the Year 2 ‘Computing for Design’ module.

Final year students are expected to have a high level of CAD capability and are able to make effective use of solid, surface and interactive design modelling tools to represent and develop their design ideas. As a test of their CAD modelling capabilities students are required to ‘reverse engineer’ a relatively complex and ‘sculptural’ product. Whilst this is no measure of their ability to generate design concepts, if a student is able to represent this product accurately, it is likely that they can also represent their own designs accurately (Figure 2).

Figure 2: ‘Reverse engineered’ electric sander using Pro/ENGINEER software. Final Year student coursework.

In order to model complex products accurately and to exploit that model in many different ways, it is necessary to use more complex CAD modelling systems than Pro/DESKTOP. Whilst the software used in schools and university is similar in many respects, the greater range of features and options in Pro/ENGINEER software can make the new system difficult to learn, even for students with previous experience of CAD.

The aim of this study was to identify how Pro/DESKTOP software had been used in A’ Level design and technology work and to consider the impact of that use on how effectively students developed CAD modelling capability with the more complex Pro/ENGINEER software.

Student use of Pro/DESKTOP at A’ Level

During the summer period prior to entry, before starting their programme of study, students entering the first year of the Industrial Design and Technology programme were sent questionnaires about their general use of CAD at A’ Level. All students had studied design and technology at AS and A2, gaining at least a B grade at A2 before being accepted on the programme. Of the 120 questioned, 79 replied, providing information about the software used and some initial description of their use of CAD in the context of design and technology project work. This identified the different software applications that had been used and the actual use of the software within their A’ Level work.

In general terms, approximately 40% had not used a 3D CAD system in their work, 40% had used Pro/DESKTOP and 20% had used a variety of other 3D CAD systems (Figure 3).

Figure 3: CAD modelling software used in A’ Level design work.

These students had been asked to describe their use of the software, partly by identifying the use made in actual support of their final project work and partly through their general comments about its use at the end of the questionnaire. By far the greatest use of the software was to provide rendered images (23%) with only 14% suggesting that they had used 3D CAD modelling to aid design development (Figure 4).

Many students had only used the software in simple exercises and did not feel confident to use it in their design development. Whilst this survey had provided
useful information to help with the development of the teaching and learning of Pro/ENGINEER in the first term of study at undergraduate level, it was decided that it would be necessary to explore in more detail the nature of the CAD use in school. It was decided to concentrate on a single CAD system used at A' Level (Pro/DESKTOP) and to focus on issues concerned with the move from this system to the more complex Pro/ENGINEER. Therefore, further questionnaires and interviews were targeted at Pro/DESKTOP users within Year 1 of the course programme. They identified those students who had made significant use of the software and those who had not applied it in a design context. This generated quantitative data regarding their depth of Pro/DESKTOP use at A' Level, the results of which can be seen below (Table 1):

**Difficulties encountered learning Pro/ENGINEER 3D CAD software**

Initial one-to-one interviews were conducted on a weekly basis with a number of the respondents who had stated that they used Pro/DESKTOP at A’ Level, as well as a number of students who had not. The primary objective for these interviews was to highlight issues concerning problems experienced by students as they first learnt Pro/ENGINEER. It was important to interview both Pro/DESKTOP and non-Pro/DESKTOP users to establish a correct representation of the year, as indicated by McCrossan - ‘…it is essential that the survey sample is carefully designed so as to represent the population’ (McCrossan, 1991: 5).

<table>
<thead>
<tr>
<th>Factor:</th>
<th>Percentage of Pro/DESKTOP Users (%) (n=36):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student's Pro/DESKTOP model of major project was either complex or very complex</td>
<td>41.7 (15)</td>
</tr>
<tr>
<td>Student had been taught Pro/DESKTOP by a teacher</td>
<td>47.2 (17)</td>
</tr>
<tr>
<td>Student had taught Pro/DESKTOP to themselves</td>
<td>30.6 (11)</td>
</tr>
<tr>
<td>Student had taught Pro/DESKTOP to themselves and been taught by a teacher</td>
<td>22.2 (8)</td>
</tr>
<tr>
<td>Student had used Pro/DESKTOP near the end of their A’ Level studies</td>
<td>58.3 (21)</td>
</tr>
<tr>
<td>Student believes that they developed good skills in terms of using Pro/DESKTOP</td>
<td>69.4 (25)</td>
</tr>
<tr>
<td>Student feels quite confident or very confident in relation to using Pro/DESKTOP</td>
<td>38.9 (14)</td>
</tr>
<tr>
<td>Student believes that they have picked up Pro/ENGINEER quickly</td>
<td>52.8 (19)</td>
</tr>
</tbody>
</table>

*The sample of Pro/DESKTOP users hereafter is different to the sample used for the data above, due to the fact that access was available to the whole year [120 students], instead of simply the 79 who replied to the previous questionnaire over the summer period. It must also be noted that some students had left the course, or were not available to interview, which, again, results in this slightly different sample for the rest of the paper. Compared to the current assignment (modelling a stapler, hole punch, calculator or mobile telephone).*
• at the earlier stages of the assignment, the Pro/DESKTOP users had made use of more complicated features and the students who have not used Pro/DESKTOP before seemed to have undertaken more preparatory sketch work beforehand.

This could indicate that the students who have used Pro/DESKTOP were more confident of their abilities to work straight onto Pro/ENGINEER.

At this time, the Pro/DESKTOP users were asked what part(s) of their previous experience with Pro/DESKTOP had helped them to use Pro/ENGINEER. The responses included:

• having used similar features/tools before
• being able to visualise how they had combined features on Pro/DESKTOP before they started using Pro/ENGINEER for modelling
• knowing how a CAD system works generally had helped them to learn specific methods in Pro/ENGINEER
• prior use of Pro/DESKTOP helped them to visualise how they were going to model their product on Pro/ENGINEER.

Through initial interviews, several issues emerged concerning the preliminary stages of learning Pro/ENGINEER. The information collected was used to design another questionnaire which was distributed to 120 Year 1 students. The questionnaire related specifically to the move from Pro/DESKTOP to Pro/ENGINEER and was used in addition to a wider study into their use of CAD modelling. The questionnaire was designed to be interesting and impartial, as Oppenheim states ‘Another way of maintaining the respondents’ co-operation is by making the questionnaire and the answering process more attractive’ (Oppenheim, 1992: 122).

The results from the new questionnaires, as mentioned previously, now showed that 36 respondents (30% of the year) had used Pro/DESKTOP during their A’ Levels. Of these 36 respondents, 27 had used Pro/DESKTOP significantly (to model their major project). Therefore, for the following statistics, the sample of 27 people who had used Pro/DESKTOP to model their major project were used. A substantial percentage (70.4%) of these respondents indicated that prior use of Pro/DESKTOP had helped them to use Pro/ENGINEER or that it had helped them to work out how they were going to model their product using Pro/ENGINEER.

### Advantages and disadvantages of using Pro/DESKTOP at A’ Level

In terms of whether using Pro/DESKTOP at A’ Level has had an effect on a student’s achievement at undergraduate level, a comparison of the marks for an assignment which was given to the entire year was undertaken. The comparison was made between students who had used Pro/DESKTOP to model their major project at A’ Level and those who had not. The assignment was uniform across the whole year and the mark itself took account of the tools used on Pro/ENGINEER and how well the product had been modelled. The mean marks for this Pro/ENGINEER assignment differed significantly ($t(118)=-3.83$, $p<.01$) depending on whether the student had used Pro/DESKTOP at A’ Level or whether they had not. The students who had used Pro/DESKTOP to model their A’ Level major project achieved a mean mark of 70.7% whereas the mean mark for the students who had not used Pro/DESKTOP for their A’ Level major project was 58.7%. This suggests a 12.0% difference in respect of the mean of the marks between groups.

However, it was found that there is no advantage in simply showing A’ Level students how to use Pro/DESKTOP. In fact, the data would suggest that this results in a disadvantage compared with those who have applied Pro/DESKTOP to their A’ Level project, and even compared with those who have never used Pro/DESKTOP before, as can be seen in Table 2.

### Pro/ENGINEER assignment

In addition, the students had been asked to make

<table>
<thead>
<tr>
<th>Significant Pro/DESKTOP users (i.e. Pro/DESKTOP has been applied to the student’s design work):</th>
<th>Non-significant Pro/DESKTOP users (i.e. Pro/DESKTOP has not been applied to the student’s design work):</th>
<th>Non-Pro/DESKTOP users:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average mark for group (%):</td>
<td>70.6</td>
<td>54.3</td>
</tr>
</tbody>
</table>

Table 2: Comparison of prior Pro/DESKTOP use and marks achieved in the first.
general comments regarding their use of Pro/ENGINEER at undergraduate level. Some of the students commented that it was initially a disadvantage to have used Pro/DESKTOP before they used Pro/ENGINEER. For example, LH (Year 1), states ‘Pro/DESKTOP is a lot different from Pro/ENGINEER. Once you have used Pro/DESKTOP you have difficulty adapting to Pro/ENGINEER because you are used to doing things a certain way’. CC, a Year 1 student, also supports this comment: ‘Pro/ENGINEER complicates a lot from Pro/DESKTOP so it isn’t much of a benefit to know about Pro/DESKTOP’.

Conclusions
It might be expected that some prior use of 3D CAD modelling software would be of benefit before studying similar areas of ICT at undergraduate level. This was confirmed in the case of the programme at Loughborough University, though the nature of the prior use of CAD and its context at A’ Level is highly significant.

The results suggest significant benefit for those students who have developed enough CAD capability to enable them to use it in their A’ Level project work, both in terms of design development of the project work itself, but also in terms of their subsequent learning of more complex CAD modelling systems in Higher Education. The implications are that teaching and learning strategies for A’ Level students should be developed to provide students with substantial CAD capability, sufficient to provide the expertise and confidence that encourages them to integrate its use in design development and project work. Anything less appears to have no significant impact on either A’ Level project work or subsequent learning in CAD. Indeed, the results suggest that students who do not move beyond simple exercises find it more difficult to learn new CAD systems than those students who are learning CAD for the first time.

Whilst this was a small sample at just one university, student perception and comment suggests that whilst some elements of their work with Pro/DESKTOP was of benefit, and transferred easily to their work with Pro/ENGINEER, some elements were not and might even have been a barrier to their initial learning of the software. The reasons for some students not making full use of CAD at A’ Level were varied, but all students interviewed in the second sample were ICT literate and had used other software in their project work. However, it was felt that further investigation of these reasons should be considered in subsequent research.

The generic nature of 3D CAD modelling systems aids transfer of skills from school to undergraduate level university. Whilst students found some difficulty with the more complex nature of Pro/ENGINEER, they also commented on the similarity of extruding, revolving and rounding features. Of greater significance is the transfer of CAD modelling skills, as the analysis of Computing for Designers assignments suggested. Although rarely taught overtly, the way in which CAD modelling features are combined to accurately reflect design intent is likely to be the most significant skill that transferred and might be better considered in the implementation of CAD in schools and university. The implementation of CAD modelling strategies is currently the subject of further research at Loughborough University.

New releases of both Pro/DESKTOP and Pro/ENGINEER are anticipated and as their user interface and modelling philosophies converge, it will be interesting to consider, again, the transfer of CAD skills from school to undergraduate level at university.

References


