ProDESKTOP in schools

a pilot study of its impact on design & technology

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brief

In the 18 months since the DATA professional association launched the CAD-in-schools initiative with ProDESKTOP, 3000 teachers have been accredited for teaching CAD with their students in 2000 schools, and nearly 500 student teachers have been given the opportunity to explore CAD approaches in design & technology. Within a further twelve months, 95% of English secondary schools will be in a position to use ProDESKTOP (hereafter PDT), a sophisticated professional engineering design package. The changes that are being brought about in children's designing are sufficiently profound to deserve careful research. This project is a small-scale exploration of the impact of this CAD initiative on children's designing and on the standards of work that can be achieved. It's aim is not to produce answers to these difficult questions. Rather its purpose is to clarify the questions that might need to be asked in a full scale evaluation. Because of the timing of this project and the looming examination demands in years 11, 12 and 13, we were asked to focus on years 9 and 10.

methodology

rationale and data sources

We are concerned primarily with what design & technology demands of youngsters and how this is serviced by the capabilities of the software. Accordingly, we devised three modes of enquiry.

First, we devised a design activity (based on a former APU test) that could be presented to students *either* as a 'normal' paper & pencil design activity *or* as a CAD activity in PDT. We used a customised form of the 'developing solutions' APU test activity which prioritises students ability to generate design proposals (for the user and for manufacture), their ability to examine the value and consequence of their proposals, and their ability to communicate their ideas and outcomes. The activity was based on the design weakness of 'built-in' cooker timers, and invited students to design a portable cooking timer for the elderly, that can be set with a twisting motion and sound an alarm when the set time elapses. In either mode the activity was designed to take 90 minutes; the task was the same; the procedures were the same; and the assessment processes were the same. The difference existed in the fact that one was done on paper (with pencils) and the other was done (dominantly) in PDT. The exception to this ideal lay in the requirement for students working in PDT to save their work at intervals so that a developing record of it could be pasted into a paper booklet - in which the written (reflective) elements of the activity were also conducted. Each student undertaking the PDT form of the activity also created a disk record of all their work. The idea was to conduct the test activity in both modes (paper&pencil and CAD) but with different groups of students; to examine the nature and quality of performance; and thereby to identify some of the differences that arise in performance when operating in PDT format.

Second, we devised an evaluation questionnaire for the students to complete once they had undertaken the design task. This questionnaire was in three parts. Part one invited students to agree/disagree (across a 1-4 Likert scale) with five statements about the activity that they had undertaken and why they had liked or disliked it. Part two invited students to agree/disagree with 13 statements about the desirability of designing in PDT. Examples here included 'because its good for having ideas' ; 'because its good for visualising ideas' ; and 'because it helps when I make things'. Part three was a free-response section, where students were invited to identify the three BEST things and the three WORST things about working in PDT.

Third, we developed an interview framework for students who had been taught PDT and for the teachers who had introduced them to it. This structured interview was conducted in all the test schools and additionally in a school in which we had not tested the students but in which we were advised that good practice existed. Interviews were conducted with students from years 9-12 and included issues of familiarity with other software; experience with PDT; their pleasure and confidence in using PDT; what difficulties they have in using PDT; the benefits they perceive in using PDT; the advice they would give to others about using it; and how PDT might impact on the future of design & technology. The teacher interviews additionally included sections on their own experience in design & technology; about their training for PDT; and about their views of PDT as supporting students capability in design & technology

student samples

Student performance data was derived from two categories of students; those being given high quality d&t experience **without** use of PDT and those being given high quality d&t experience **with** use of PDT. Our aim was to portray 'best practice' in design & technology and to seek to discern the differences arising in students practice as a result of PDT use with year 9 and yr10 groups. The first challenge was to identify these target groups, and we took advice from DATA (about national centres of excellence) and from a south London advisory team (about local centres of excellence). From this advice we chose 3 schools in which to conduct the PDT activity and contacted the heads of design & technology. We sought groups of 12 students and asked the schools to compose a group of their very best PDT students in years 9/10. One of the schools was a single-sex boys school, which made it more difficult to achieve a gender balance across the whole sample. We had hoped to balance the sample by having more girls in the samples from the other two schools. In the event however, the teacher-selected groups of 'best PDT students' were also biased in favour of boys and, as a result, our overall PDT sample (38) was very biased towards boys (32).

The pencil and paper activity sample was much easier to arrange. On the recommendation of the south London advisory team, we went to two schools and tested 24 students (12 girls; 12 boys) in year 10. One of these schools was also one of the schools in the PDT sample. In this case we asked the school that (i) the student samples must be separate; (ii) that the PDT sample must take priority (ie having selected the PDT sample, those 12 students could not reappear in the pencil & paper format of the activity).

We gave considerable thought to the idea of composing the sample in a completely different way; by testing a group of students *both* in pencil & paper format *and* in PDT. This might have provided valuable data about the differences *within* individuals of working across the two formats. However, we rejected the idea for several reasons:

- we wanted *best* capability in both cases, and there was no guarantee that the best designers (on paper) would also be the best designers using PDT.

• this would also have required each student to do the test twice (once in each mode) and this raises many other technical difficulties. They might simply repeat the same activity (with the benefit of familiarity 2nd time round), or we might have composed a separate test (raising equivalence and hence reliability questions).

Since we were not looking to personalise the data to individuals - but to gather a picture of difference through ‘best practice’, we chose to examine best practice in each case - regardless of the students within which it resides.

In total therefore, four schools and 62 students have been involved in this pilot study; two schools using only the PDT format; one school using only the paper & pencil format; and one school using *both* the PDT *and* the paper & pencil format.

The student questionnaire was completed by all the students in the sample, and the interviews were conducted with a small group of students (usually 4) and with teachers (usually 1) in each of the schools.

data management

The test activity provided an immense amount of *performance data*. For the paper&pencil sample, the work existed in the APU style booklets. For the PDT sample, the same record existed in specially constructed booklets into which print-outs could be pasted from the disk records of students work. All the work was then assessed, using the same general categories as for the APU survey;

initially and primarily

• holistic score

and subsequently

- identifying & specifying issues
- generating and developing proposals
- evaluating
- communicating

In each case we used a 1-4 rating (1=poor; 4=excellent), but for finer grading we subdivided each into 3, so that (eg) a 2 might be weak 2, a middle 2 or a strong 2. This created in effect a 12 point scale. Within the marking team of four, initial samples of work were double marked and a moderation conference was used to calibrate standards. The resulting data were then entered and analysed in Excel.

The *questionnaire* responses (62) were also transferred into Excel for analysis.

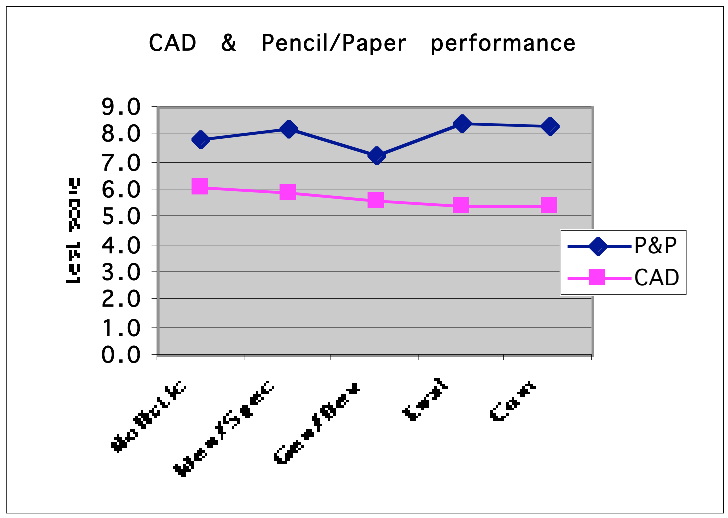
The *interviews* were not recorded, but were conducted by two members of the research team who took notes on a prepared booklet. These notes were subsequently compiled in composite form in an Excel spreadsheet such that all answers to a single question could be scanned at a glance. The interview comments that appear in this report are therefore not verbatim quotations - but are rather the interviewer’s encapsulation of the comments of the students and the teachers.

summary findings

Before launching into this section of the findings in the data, it is worth recalling that the group of students we were working with were selected by the teachers as their ‘best’ design & technology students. For the CAD test we asked for their very best students - the most proficient at using PDT. For the paper & pencil activity we similarly asked for the best designers.   These data do not arise from ‘representative’ students. They are the BEST we could find, and (in the case of PDT) the schools were similarly recommended to us as those in which the use of ProDESKTOP was best developed.

Furthermore, not only are the samples highly selected - but they are also small. Taken together, this renders the statistics irrelevant as predictive of national trends, but they are (we believe) illustrative of some factors that are worthy of more detailed examination.

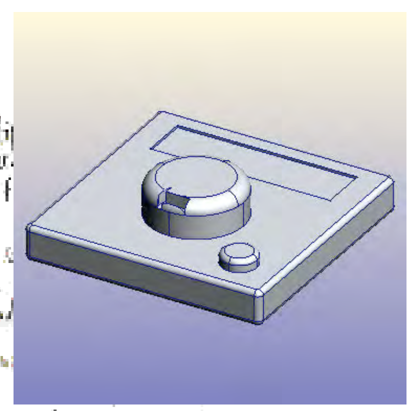
student performance data

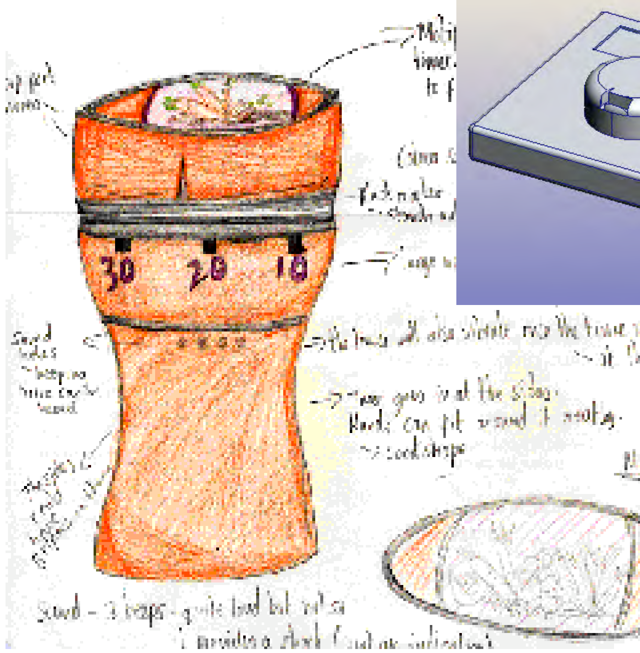


CAD / pencil & paper performance
Performance in the paper & pencil format of the test activity was better than in the CAD format by a factor of approx 15-20%.

The most marked differentials exist in the reflective areas of ‘identifying & specifying’ the task and ‘evaluating’ their work, as well as in the measure of the quality of ‘communication’ .

In reality, there are enormous qualitative differences between the PDT responses and the paper & pencil responses, and some of these differences are exemplified in the two samples shown here. The issues are teased out later in this report under the heading of ‘issues arising’ .





CAD (gender)

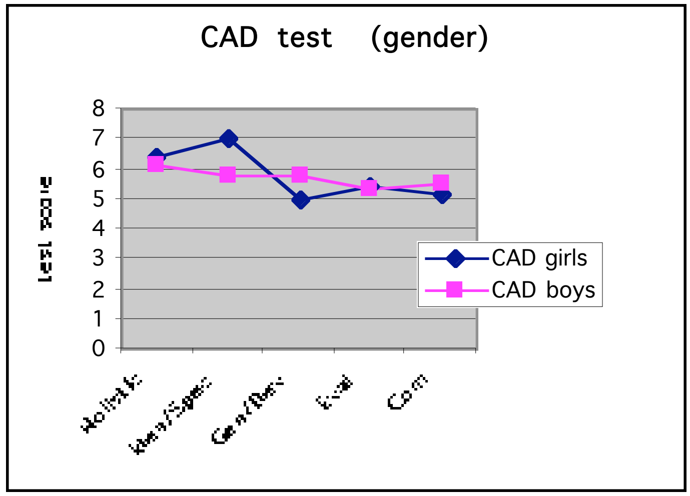
In the CAD format of the test activity there are some gender differences in performance. Most notably;

• holistically, girls marginally outperform boys

• girls significantly outperform boys in the reflective areas of 'identifying & specifying'

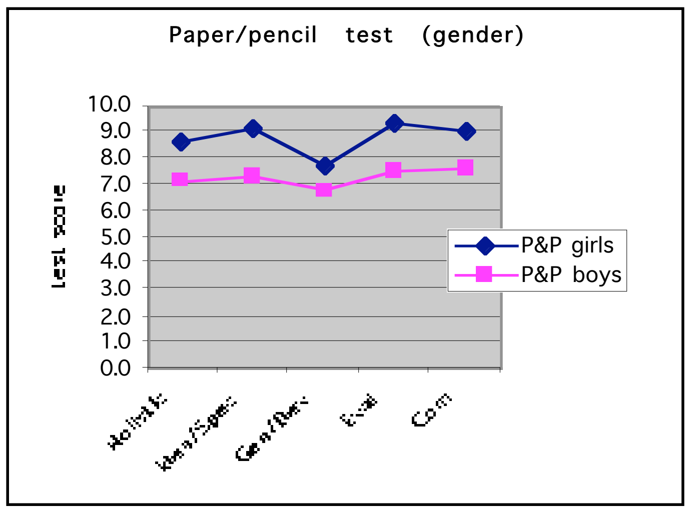
• boys outperform girls in the active area of 'generating and developing' proposals.

One interesting feature of the gender difference is that all the girls score a steady 6 or 7 (high 2 or low 3) whilst the boys range is from 2-10 (a mid 1 to an excellent low 4). We address this phenomenon later in 'issues arising'



pencil/paper (gender)

In the paper and pencil format of the test, girls outperform boys throughout by a factor of approx 12%. The boys level of performance is closest to girls in the active areas of 'generating and developing' proposals. The greatest gender differential exists in the reflective areas of 'identifying and specifying' the task and in 'evaluating' performance. The range difference identified above does not exist in these paper&pencil activities. Both girls & boys score up to 11 (mid 4). However, the lowest score for girls is 6 (a good 2), and for boys is 3 (a high 1).



pencil and paper performance over time

It is worth reporting that the performance of these students in the pencil / paper format of the test was of extremely high quality. We used exactly the same test and assessment devices as we had previously used in the APU survey of 1989. The performance of these students in 2001 was very significantly better than that which existed in the APU survey.

We attribute this improvement to 10 years of national curriculum development in design & technology, during which time teachers have become more skilled in developing students designing ability.

student evaluation questionnaire

Following the test activities, all students completed an evaluation questionnaire, reflecting both on the activity and on their use of CAD within it. On a 1-4 scale (1=strongly disagree, 4=strongly agree) there was strong agreement (3.7) that the activity was liked. The main reasons cited were ‘because I like working with computers’ (3.5) and ‘because we had to design something’ (3.2).

The specific evaluation of PDT involved 13 factors through which students might identify what they liked or disliked about working with PDT. The responses here are clearly gendered, with boys expressing greater general approval (3.1) than girls (2.7). However, the individual factors that they approve or disapprove of are not gendered. The students are very clear about what they agree as the real strengths of PDT:

- it helps me to present my work professionally (3.5)
- it helps me to visualise ideas/objects (3.3)
- it helps me to work accurately (3.3)

At the other end of the scale, they are equally clear about what they disagree with

- it has good instructions to follow (2.1)

The questionnaire also has a free-response section, enabling students to identify the three BEST things about working with PDT and the three WORST things about working with PDT. There is considerable commonality in student responses.

BEST things identified:	(No of times identified)
• it is easy to use	17
• it makes work look professional	16
• it is accurate	12
• it allows you to see what the product will look like	12
• it makes my work look better than my own drawings	10

WORST things identified	
• it doesn’t let you do what you want to do	18
• it is too easy to make errors	14
• it is stressful / annoying / confusing	13
• it is difficult to master	12
• the commands are hard to use	10

There is clearly something of an paradox here. How can all theses students identify the operational difficulty of PDT whilst at the same time a large group report it as easy to use? We return to this matter in the discussion of ‘issues arising’

student interviews

Many students had previous experience of CAD software (eg 2D Designer & Art CamPro). It was being used in graphics sessions and design projects, and most had installed it on home machines. The vast majority enjoyed using PDT (lots), particularly the quality of visualisation of 3D objects, but had not enjoyed the learning curve; ‘fiddly to use’ ‘difficult language’. But now, most felt confident with it. PDT was seen to have high value in project work;

> experimental work for AS - mixing paper with CAD
> seeing it on screen makes it easier to imagine on paper

it helps visualisation
fantastic virtual reality - you can ride through the maze or mechanism and see it working
sometimes it's difficult to explain what I mean, but PDT helps me to explain it

But it also had limitations;

time - you can always pick up a pencil and do a quick sketch
its not good to go straight into PDT - you need some roughs first
adding detail is simpler and quicker on paper
you can't undo mistakes except the last one. And its really hard to FIND the mistakes

When asked about the differences in projects when using PDT, students commented on the the different (graphic) effects and higher accuracy they could achieve, and on the speed of visualisation. It was generally thought to be 'more exciting', ' you have more ideas' and (interestingly) 'the teacher is more enthusiastic - more "with you" '. It was thought to have increased familiarity with technical terms and with computing skills. Equally however, they were (initially) frustrated by error messages, by slow machines, by lack of teachers, and the general fierceness of the learning curve 'it's a hard programme to learn - VERY hard at the start'

The benefits of using PDT were seen as several levels;
to students; it's where things are going; it's good for getting jobs in industry after; it makes you more confident; it improves you work
to teachers; they seem more enthusiastic; an alternative approach, adding options for projects; they love working with it, it's brought out a new aspect of d&t for them
to the school; it will strengthen d&t and make it a more favourable option; it shows that the whole school can do it.

When asked what advice they would give to other students about to learn PDT they comment as follows;
to students: try out ideas - don't be scared; be patient - don't be discouraged; don't panic - take time to figure it out; listen carefully to instructions; and get LOTS of mouse time
to teachers; get on a GOOD course; teach in smaller classes; get pupils involved in demonstrations; go slowly - then use us as teachers - some of us are already really quick and can help others.

And the future of design & technology?
It'll make it more exciting; you don't have to be good at drawing; it'll make d&t more popular; the course is more about designing - less making; it cuts out the models and mock-ups and goes straight to manufacture.

teacher interviews

Most of the teachers interviewed have responsibility in their departments for ICT and CAD/CAM and none of their ITE courses had involved CAD. Their PDT training was almost exclusively focussed on technical information about the package; 'mainly technical information' 'use of the software' 'set exercises based on introducing the tools'. All the teachers found the software very difficult to learn

- frustration at things that didn't go right
- instructions very difficult- trying to understand it was very off-putting
- some set exercises were OK - but it was more difficult when they moved to their own designing
- how to know where the kids have made a mistake?
- loads of gaps in the training and therefore in my knowledge
- problem solving - you can dig yourself into a deep hole very easily

None of the training had involved pedagogic factors - helping the teachers to build PDT into a teaching and learning experience for students. Most of the teachers felt moderately confident that they could now cope with teaching PDT. Several had reconstructed their normal teaching style to enable the students (who learned more quickly than the teacher) to see themselves as co-learners; 'I changed tack on teaching it.. away from set exercises to using a set of tools to develop their own ideas' ' working with kids as co-learners'. Most felt that the training should be different;

- more child-centred - the exercises are no good for pupils
- more examples of what to do in schools - support materials to take you through tasks
- more careful thought to introducing the activities - making the relevant and manageable
- too much was straight from the manual
- fault finding - more examples of using it in the classroom.

Reflecting on the changes that PDT creates in design & technology, there was much enthusiasm;

- most striking thing is the excitement for pupils
- it's turned designing on it's head - they work in 3D and the working drawing is now incidental
- seeing how pupils think in 3D - being able to rotate was like turning on a switch - fantastic
- PDT is another leap forward taking d&t to the next stage.

Commenting on the differences between teaching a normal project and one using PDT;

- instant accuracy - and students not inhibited by the poor quality of their drawing
- 30% love it, 30% cope and 30% resist it
- at present CAD is slower as we don't have enough contact time
- on paper pupils don't want to do another idea, on computer they are happier to play with ideas.

When we asked what the pupils most enjoyed, we were commonly told; 'instant accuracy' 'quality images from the start' ' constructing straight from the mind onto screen - perfect examples - playing with it - informal - intuitive' 'the less able enjoy the 3Dness as they aren't confident on paper'.

Gender differences were noted by several teachers; 'it's given boys more interest in designing' 'boys used to hate design (folder stuff) and just want to MAKE. Now they love designing' 'they ask so many questions and PLAY with it - they experiment' ' you have to stop them - but girls will wait for the next task'. 'boys are not more able - but will jump in with both feet. Girls are conservative, careful, take small steps - and can outstrip the boys with well worked out solutions - same as non-CAD work' 'girls are less willing to lose or change what they have got'. It was also felt that the gender differences were balanced with the use of ArtCAM Pro

Considering the benefits of introducing PDT, all teachers found it very beneficial; 'I was getting bored - now I'm off again' ' it has changed d&t in parents eyes - a more relevant, modernised subject' ' it has upped the image - it has been difficult to develop a culture of design before' 'good at promoting d&t' 'it has to be here to stay - completely changing the workshop environment' .

But equally there were many suggestions about improving it - particularly about easing the fierce learning curve. 'Make problem solving (error messages) more user friendly' 'configure it to introduce at different levels eg KS3 version KS4 version' 'better "help" - clearer instruction - easier to backtrack' ' the training needs to be sorted out' 'now I need an extension course' .

issues arising

state of readiness in schools

It is still very early day in the use of PDT, and practice is not yet well developed. Our schools sample was drawn from a short list of recommended schools since we were concerned not to reflect common practice but rather to identify leading-edge practice. Nonetheless, in the three schools in which we conducted the pupil design activities, we were somewhat surprised to find that it was the FIRST occasion on which the year 9/10 students had been required to use PDT as a design and development tool. Whilst in the same schools the year 12 students were using PDT on demand as part of design activities, in year 9/10 students were being guided through tightly controlled tasks that were dominantly seen as graphics (and during graphics lessons). PDT was not part of the normal designing experience of the students. This will inevitably have had a serious impact on students performance in our activities.

We have subsequently visited two schools where the teachers have given a great deal of thought to making PDT work as a design tool for younger students. This pedagogic planning was not part of their original PDT training, but has been worked out by the teachers concerned. This is a matter to which we return later in the report.

1. teaching & learning issues

enthusiasm & frustration

In our analysis of the student evaluation questionnaire, we drew attention to a paradox in the data; how can students identify the operational difficulty of PDT and at the same time be so excited by it? Data from the questionnaire suggests that the very same student will say apparently contradictory things when asked to say the BEST things and the WORST things about working in PDT.

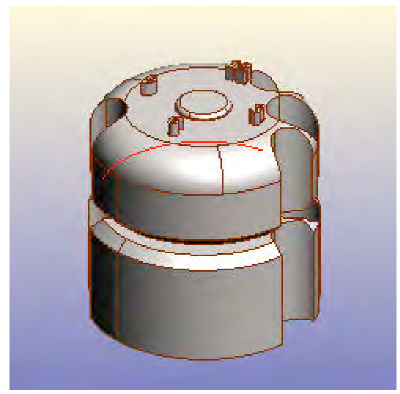
• it's fun & better than creating pen-paper	BUT	it's hard to use
• it's easy to use	BUT	it does not understand me
• it's better at seeing the final result	BUT	it can go wrong and clear the screen
• it's fun and easy to start again	BUT	it refuses to do something quite often

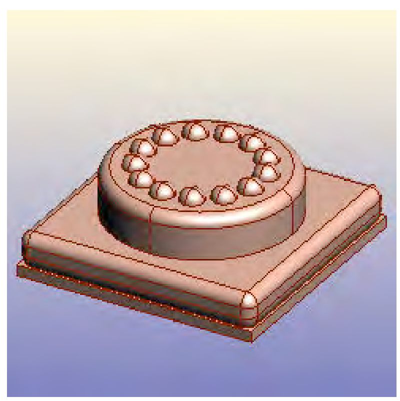
This paradox was equally evident in our visits to schools to conduct the test activities. On one hand we found enormous enthusiasm (from staff and students) for PDT in the design & technology curriculum, but on the other hand, in students work on the activities and in their interviews, we saw a great deal of evidence of their frustration at being unable to create the forms and images that they wanted.

Initially we had not expected to 'score' frustration as part of our assessment framework, but it proved very easy to do. Many CAD scripts have comments like "...I was trying to do x ..but I couldn't make it do it". The 'frustration' measure is a simple count of the times when students indicate that they are unable to show what they intend in their design. These indications exist both in the pencil drawings (in the P&P test) and in the CAD drawings (in the CAD test). Frustration is indicated in 50% of the CAD booklets and 8% of the P&P booklets. More interestingly however, in the CAD format of the test activity, the better designers have the highest frustration score, whilst the less able designers have a lower frustration score. There are 12 students with a low score of 2,3,4, or 5, and of this number only 4 registered frustration: ie 33%. By contrast, there are 16 students with a score of 7,8,9, or 10 and of this number 10 registered frustration; ie 63%. We believe that these differences can be explained in terms of able designers having more sophisticated ideas than they could manage to create in PDT. Students with less capability were more content with the images that they created. There is no gender effect in these data.

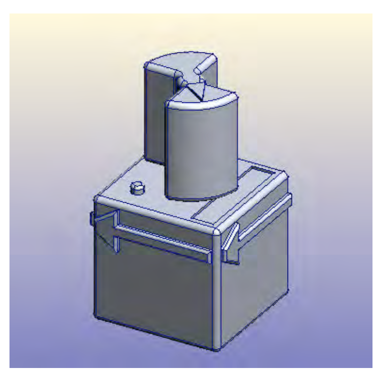
But we still have to try to explain the paradox; enthusiasm and motivation on one hand, and frustration on the other. It would be more normal for frustration to result in de-motivation and lack of enthusiasm. Yet it does not. How are we to explain this? We believe that part of the answer lies in the computer-game culture in which youngsters try time and time again to get past the evil goblin, but only succeed in getting eaten or squashed. Eventually - on the 53rd attempt - they find a way around the problem, experience the 'high' of success, and move on to the next challenge (the hairy spider). The early experience of PDT is not dissimilar, even to the extent of students having to 'go back and start all over again' because not only had they made a mistake, but also they couldn't see or find WHERE they had made the mistake.

We do not conclude from this that the frustration they experience with PDT is desirable. But we do suggest that it is made more tolerable (for youngsters) by its computer-based context. It is a paralogical phenomenon which is understandable only in terms of a powerful balancing motivational force, and there is no doubt about what that is. Students enthusiasm derives from the power of PDT for visualisation. All the interviews tell the same story. Students are very impressed by the amazingly 'real' images they can create.



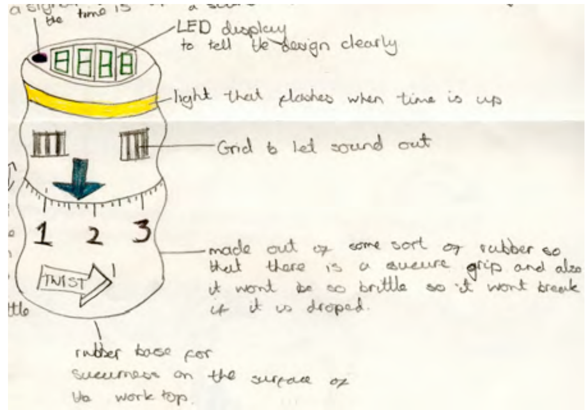


They can 'see' objects on screen in a far more realistic form than they could possibly achieve with pencils. The equally powerful advantage of PDT for computer-based manufacturing is hardly ever mentioned as a reason for student enthusiasm. We suspect that this is because they have not used it in that way - but have been introduced to it rather as a graphics tool. Nonetheless, our test activity provides ample evidence of students ability to create strong product images, and these provide the antidote to the equally evident frustration.

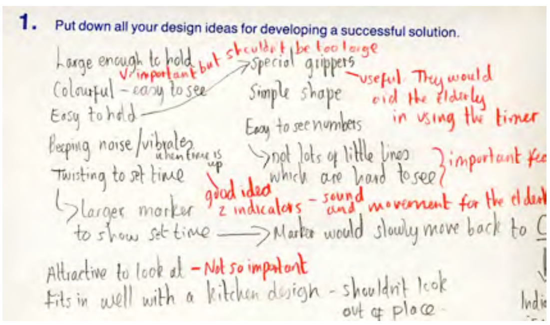


design iteration

There is a wealth of literature that has established the importance for designers of reflecting on proposals as they develop. Recursive action and reflection is the cornerstone of student capability in design & technology and in normal circumstances is evidenced through the portfolio.



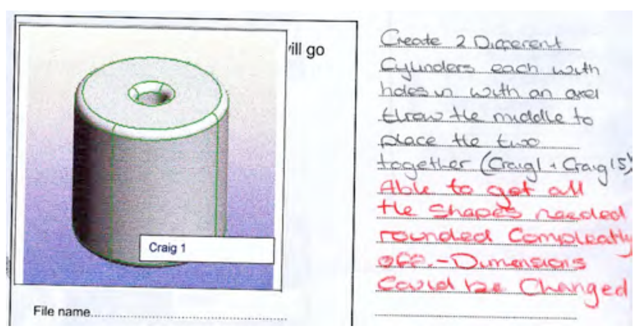
In the the test activity, the booklets have been deliberately designed to maximise the impact of this iteration - encouraging students constantly to reflect and comment on their developing proposal.

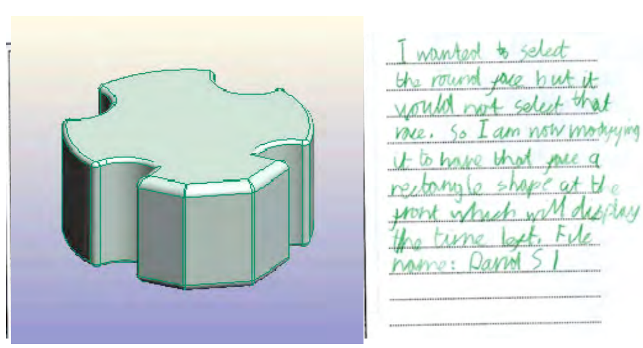


In the paper and pencil form of activity is was easy to achieve this iterative growth - both in terms of student reflection on their *drawn* proposals, and equally on their written thoughts. These booklets exemplify the kinds of student responses that exist in good design portfolios.

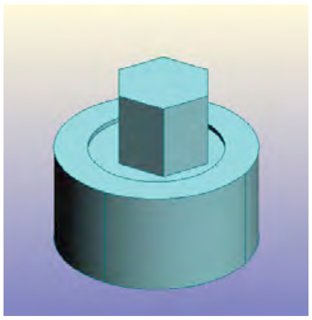
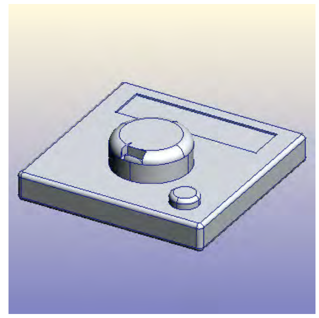
The challenge for us in this project was how to achieve this level of reflective iteration in PDT. We explored several approaches to creating a virtual portfolio - in Word and in Powerpoint - enabling students to save their work into them. Problems in both cases arose from the requirement to have another big software programme open alongside PDT causing some machines to 'freeze' or 'crash'.

In the end we created a paper portfolio (similar to the pencil and paper booklet) and encouraged it's use as a reflection tool linked to the point they had reached in their development on PDT. This was sometimes supported by printing out their work to produce a hard-copy for pasting into the booklet and for over-writing with reflective comment. This worked reasonably well in some cases, but was clearly less than ideal and frequently did not provide the critical information about WHY students were doing x, y, or z, and in what ways they saw it as being an improvement on the previous version of their proposal. Frequently students used it to tell us about the difficulties they were having making PDT do what they wanted it to do.





This issue is clearly illustrated in the following two images that a individual student produced in the activity. The lack of reflective comment associated with either drawing makes it impossible to understand what the student was thinking, and whether the move from (a) to (b) represented a sensible development.

(a)  >>>>> (b) 

Quite apart from the value to students of reflective comment - helping them to expose and clarify their thinking - there is clearly a related assessment issue. Where did the development in (b) come from? Is it a thoughtful development from (a), or was it simply copied from a neighbour?

There is a strong case for PDT to have an in-built 'portfolio' tool that will (i) allow the progressive development and recording of a *sequence of proposals* AND (ii) enable students to *overwrite comments* on them as they develop. The 'album' tool does not work in this way, and we have not seen a single school that has been able to create anything equivalent to the flexible iteration that is commonplace in paper-based portfolios. As evidence of this, one has only to compare the work that students produced for this project on paper and on screen. The pencil-paper booklets are far richer design records than are the ones linked to PDT. In the absence of such an in-built tool, teachers have to find effective ways of linking work in PDT with work on paper. We return to this issue below under 'assessment'.

gender

There is conflicting evidence about the impact of PDT on gender groups. In one school the teacher was absolutely convinced of a powerful gender effect. Girls - she thought - were quite prepared to follow the teacher through a set of instructions on a series of graphics exercises in PDT. But the boys were not. They wanted to play with it. Will it do that? What's that for? How does that work? Why can't we try this? The teacher was firmly of the view that the girls played safe while the boys played around. This resulted in the girls all achieving the desired end-point, but the boys having very variable performance. Some failed to get anything done - while others found things out that the teacher herself didn't know about. The teacher (female) described being bombarded with questions that she could not answer, and accordingly changing her approach to one of co-learner.

> I experimented with the boys and they helped me to learn it (Sch no.1)

This clearly gendered account is contrasted in our data with that from another teacher, who was convinced that all students managed it in much the same way "

> It's a real level playing field girls/boys/high ability/lowability/good drawers/bad drawers. Their background is irrelevant" (Sch no.7)

The evidence from the test activity suggests that performance is indeed gendered, at least in the three schools in which we conducted the CAD format test activity. As we reported earlier

- holistically, girls marginally outperform boys
- girls significantly outperform boys in the reflective areas of ‘identifying & specifying’
- boys outperform girls in the active area of ‘generating and developing’ proposals.

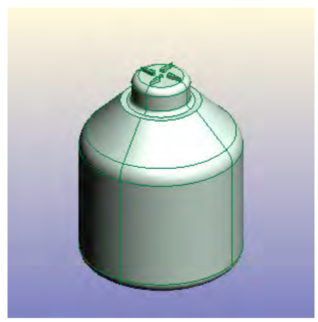
These data might be thought ‘normal’, in the sense that they conforms to the findings of the APU survey (1989) and are equally in line with what most of the literature since that time would lead us to expect. However, a particularly interesting feature of performance concerns the gendered spread of the test scores. All the girls score a steady 6 or 7 (ie, a mark range of 1) whilst the boys score from 2-10 (a mark range of 8). One explanation of these data would be that girls are indeed “playing safe” while the boys play around; taking more risks both with their proposals and (by extension) with the limits of their understanding of PDT. This could easily lead to the dramatic variability in performance noted in these data.

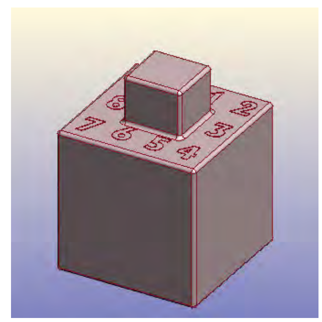
inside and outside

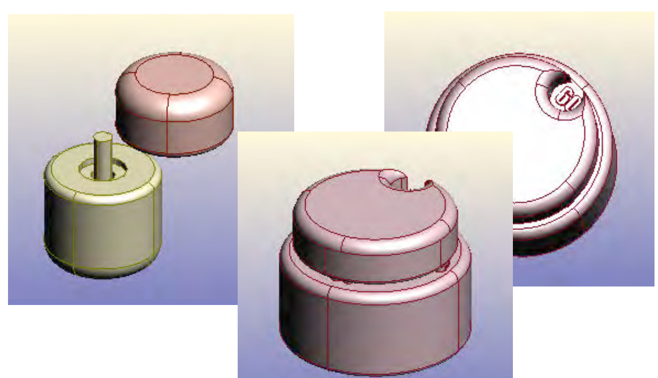
A noticeable feature of student performance in the activity concerns the kinds of design activity upon which students choose to focus. With students using the PDT form of the activity, in every case they focus on the outside form of the object. None choose to go inside and consider either the internal detail or the working mechanisms. Either the complication of this process, or students lack of familiarity with doing it, or the lack of time during the activity appear to have encouraged students to focus their energies on the surface form of the timer.

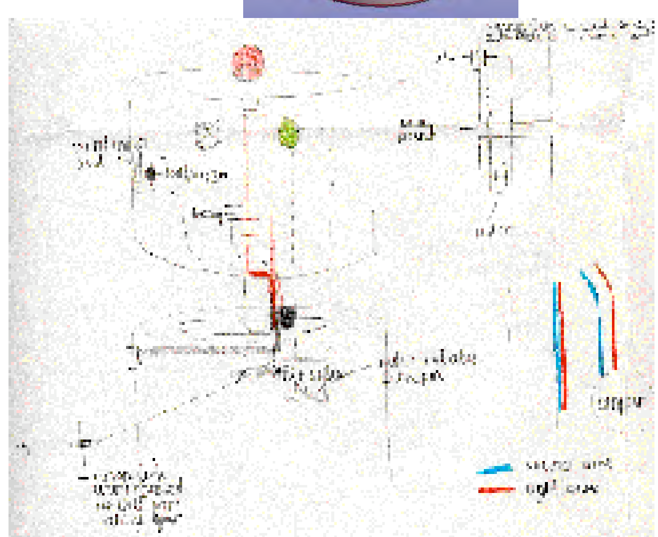
Several students did however focus on the idea of a two-part product; one revolving on the other. In one case this led to an imaginative arrangement in which the time setting on the alarm was revealed as the time was set.

In contrast with the CAD form of the test activity, in the paper/pencil format a student in school 1 chose to focus on the inner working detail of the electronic system and how it might be arranged in the overall form and operation of the product.



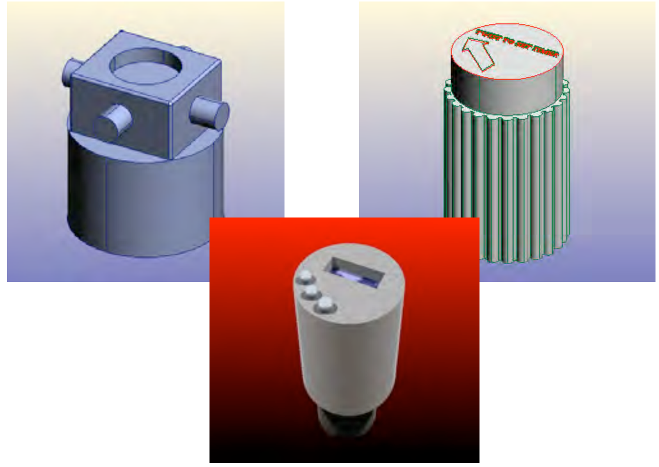




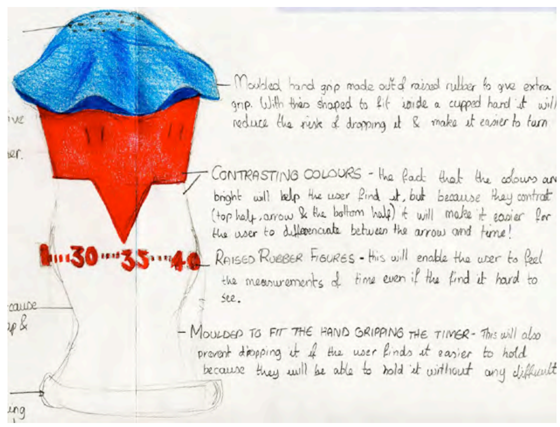


regular and irregular forms

A further noticeable feature of student performance is that all students working on the PDT form of the activity built their proposals around 'engineered' regular forms, typically cylindrical and cuboids forms.



In the pencil and paper form of the activity, several students move away from the regular and the engineered; exploring forms that, in terms of manufacture, would be achieved more through moulding and casting.



designing style

This problem may, in part, be one of initial unfamiliarity, but equally it may be that it is also a designing style issue. There is an accumulating body of literature that suggests that designing can be undertaken in very different ways, and that individuals display a preference for one style over another. Some students build up design solutions incrementally - working from small parts of it and gradually constructing a whole. Others conceive solutions as a whole and then 'take apart' their idea to explore how it might be composed. Some students are better at working with drawings, some with words, and some prefer to make models and mock-ups. There are many pathways to salvation in design. One of the problems of current examination requirements (eg GCSE), is the implicit assumption that designing only happens in one standard way. Since designing is such an individual process, the danger exists that those whose style does not fit with the examination requirement will be disadvantaged.

We suspect that this designing style issue is also raised by PDT, which lends itself to working in a particular way. The points we have raised above are indicators of this; for example its tendency to encourage external block modelling and the tendency for this to be based on engineered 'regular' forms. To use an extreme example, students whose preferred designing style was based on observation of organic forms, would (we suspect) find PDT a difficult and unsupportive tool.

This suggests to us that PDT, like every other tool in the designers toolbox, is good for some things and not for others; suited to some kinds of designing and not to others; appreciated by some students and not by others. We note from the interview data two samples that suggest the truth of this notion:

- two year 12 students were ecstatic about the power of PDT in their A level work - both were male and both had applied for engineering degree courses.
- a teacher commenting on the use of PDT with her year 10 group reported that about 30% love it, 30% cope with it, and 30% struggle.

In both these cases we suspect that preferred designing style underlies these reactions.

ProDESKTOP and design and technology capability

These issues above raise the question of what PDT is designed to do. Is it intended to be a *conceptual design* tool - or is it rather intended as a *development* tool (leading to manufacture) once the outline concept of the design has been broadly 'roughed out' by other means? If it is the former, then PDT could be used from scratch in a design exercise, using it to outline a design concept and take it through to manufacture. If however it is the latter, then PDT has to operate as part of the repertoire of tools used during the design & development process.   Our data is unclear on this point. One one hand PDT appears from the performance data to be more of a *development* tool than a *concept design* tool, and moreover it appears to be particularly appropriate in the sphere of engineering. But on the other hand some of our interviews suggest that students like to use it as a concept / visualisation tool. At this point therefore we can merely mark up the issue as unclear and in need of further clarification.

A related issue about d&t capability arises in our sample of schools, all of whom introduced PDT from the top down - ie starting with years 11/12/13. When this has been found to work, teachers have ventured to introduce it to year 10, then year 9, and several teachers were now convinced that it should be introduced straight away in year 7. Because of the evolving nature of practice in this new territory, it is understandable that in these early days teachers will be operating through focussed tasks, and - we observe - in most cases using PDT as a graphics package. Accordingly, whilst we have seen a considerable amount of real design & technology capability demonstrated by students using PDT for projects in years 11,12 and 13, we have not seen this in years 9 and 10, where the focus has been on skill-building in the use of PDT. In the circumstances therefore it is not surprising that many students in the PDT sample were preoccupied with the mechanics of making PDT work. In the process, they frequently lost sight of the design task - a portable cooking timer for the elderly - settling for what they could manage to draw rather than drawing what they thought the product should be like. An extreme example is provided by the student who rejected the computer, picked up his booklet and just drew (with a pencil) his ideas along with the scrawled comment "It's like THIS".

The evidence from looking at work in years 11,12 and 13 suggests that this may be a transitional phenomenon and that once students have developed their familiarity and skills with PDT they are able to demonstrate design & technology capability of a high order. This raises the central issue of how teachers build student experience and capability in PDT, and this in turn raises the question of how the teachers are themselves trained to do that.

3. training issues

In our sample of teachers, the evidence was overwhelming that their training in the use of PDT was focused exclusively on developing their technical competence to operate the software. No time appears to have been devoted to considering how best to introduce it to students - and in particular how to ease the gradient of the learning curve. Teachers approaches in schools have typically reflected their own training and focussed on the technicalities of the software.

In one school (in which we were not testing the students) we have observed a quite different approach in which projects have been planned specifically to bypass whole areas of the software, empowering students to get into designing from their very first lesson. The success of this approach suggests that teachers training should incorporate detailed consideration of *how students will learn* PDT, rather than merely how it works and what it can do.

learners as teachers

There is ample evidence that students learn the programme easier than do their teachers. This may be explained in many ways, but is clearly related to uninterrupted mouse-time (at home). We heard many accounts of students working whole evenings and weekends to create a particular piece of graphics.

The speed of assimilation by students is clearly something that teachers have to manage, and we applaud those teachers who rapidly recognised that the conventional teacher/learner relationship (teacher leading; student following) was not sustainable. Best practice here is clearly going to be based on a community of co-learners working together to understand it and make it work. The student mentor programme is another sensible response to the reality of this situation.

time

We have already suggested that the learning curve for PDT is fearsome. Teachers and students need lots of 'mouse time'. Accordingly, its availability for students to work on at home was frequently mentioned as a really important factor. Typical school timetables (45 mins and then clear up) are hopeless for PDT. Just as they get started it is time to stop, and moreover, if one of the frequent problems arises anywhere after the midpoint in the lesson, there is the temptation to think that it's not worth starting all over again in the final 20 minutes of a lesson. Schools which allow big blocks of time will be far more successful in getting students up the learning curve. Another element in this will of course be the perseverance of the students. As in so many areas of design & technology, stickability is an important quality.

4. assessment issues

The principal issue here is the extent to which the use of PDT changes the normal rules of engagement for the assessment of project work in design & technology. The issue appears to us to present itself once again as the old problem of process vs outcome. Are we looking at the *process* of development and resolution or are we looking at the quality of the final solution? We are firmly of the view that the quality of the development process must be at the heart of student assessment. Since PDT does not have a built in portfolio facility, all kinds of development may be undertaken by a student on a project and lost unless the student goes out of his/her way to create a continuous series of hard copies that illustrate their pathway of development.

This takes us back again to the 'tracking' issue that we discussed earlier in the context of design 'iteration'. In normal design and development, the paper portfolio serves a double function:

• it allows the student continuously to develop ideas and reflect on them - thereby encouraging further development

• it allows the teacher/examiner to 'see' the development of a student's thinking - it is a manifestation of the thought processes in action

In principle we see absolutely no reason why a portfolio should not be submitted on a disk, BUT this carries the proviso that it must equally be a requirement to be able to see (on screen) the progressive development of the student's thought processes on the product. Capability assessment is not changed by the transition from paper to screen. In either environment it must be possible to 'see' the student's development process. If that is not currently possible in PDT, then other approaches must be used, but it would be major step forward if a portfolio tool could be developed within PDT.

5. technical issues

For the reasons mentioned above, we are firmly of the view that PDT would be a far more valuable tool for design & technology if it had a built in portfolio facility not just to record snapshots of the developing object - but also to enable the student to overwrite comments on that development process. There are good *learning* reasons for this and equally good *assessment* reasons.

recommendations

As we pointed out at the start of this exercise, its purpose was to clarify the questions that might need to be asked in a major research project into the use and development of CAD in schools. We believe that we are now in a position to make suggestions as to what some of these questions should be.

There is no doubt that PDT is a valuable tool for use in schools. But its effective use is limited by a number of factors, particularly its fierce learning curve that currently disables a significant proportion of those who embark upon it. Even outstanding teachers with PDT comment on its complexity and note that after a holiday it takes them a couple of days to get back into it. Its adoption may also to be gendered.

Taken together, our study suggests that there are several areas of activity that would enhance our understanding of how PDT affects students designing (research questions) and equally there are areas of activity that would enable schools to transform this understanding into better curriculum (development projects).

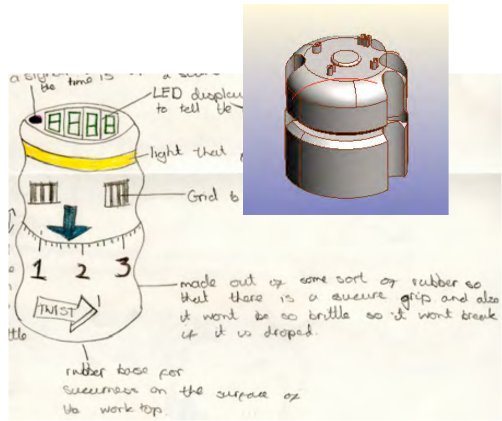
research questions

There are three principal research questions that are all tied together and that cry out for immediate research and development.

RQ1 *concerning iteration*

How in PDT is it possible to improve the design iteration between active and reflective features of the process, in order to enhance the *learning* potential of PDT. Currently it is possible to see WHAT students have done - but not WHY they did it; what they think about what they have done; what are its strengths and weaknesses; how they might want to improve it; etc etc. To be an effective tool for design & technology, students *thinking processes need to be made explicit*.

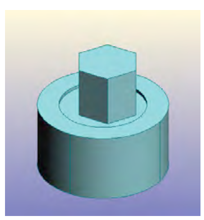
The student developing work in PDT is effectively 'silent'. You cannot hear or see what they are thinking about. All you can do is infer their thoughts from the objects that they create



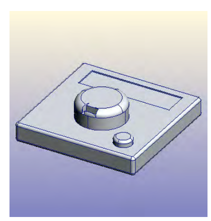
RQ2 *concerning portfolios*

Flowing directly from 1 above, research is needed into how to create a 'portfolio' facility for tracking the development of a student's design. When we were building the test activities, we tried to do this with Word and with Powerpoint - and both systems proved inadequate for our purposes. The final paper-based system that we used also had difficulties as is evident in the 'silent' transition from (a) to (b) in a student's work shown below. We have no idea what was going on in the mind of this student - and accordingly we are unable to make sense of this transition

(a)



(b)



From a series of discussions with interested parties, we believe that it would be possible to create a portfolio system (possibly using a web-browser as the medium in html) that could run alongside PDT and act as the 'voice' of the student.

RQ3 *concerning assessment*

Related to 1 and 2 above, our third area of enquiry is assessment. In principle we believe that it would be possible to create an authentic but 'virtual' portfolio that would allow complete product development - and equally allow the student to manifest this development for the benefit of examiners. But we need to build it and try it in a big enough research exercise that can validate the approach to the satisfaction of examining bodies.

Our pilot study suggests that the interrelated issues of active - reflective iteration; a portfolio 'voice' for the student; and the resulting possibility of assessment are the keys to unlocking the school-based potential of PDT. Taken together, these three research questions probe the heart of the educational value and importance of ProDESKTOP in schools. We strongly recommend that they form the basis of a major research endeavour.

RQ4 *concerning d&t capability and designing style*

This research question is not immediately tied to the first three - but it is important. It concerns the issue of design & technological capability and designing styles. The question centres on two related issues;

• the extent to which students with particular designing styles are supported (or not) by PDT in developing their capability,

• the consequences of this for teaching and learning and the development of students capability

We have noted in our discussions with teachers that they have an informal view about the complementary nature of different CAD systems, and that whilst 'x' is good for this, 'y' is good for that.

We recommend that these questions (RQ1-4) be the subject of a significant research study. The first three should be tackled as a group in a targetted project that would allow the proper research and development of an iterative portfolio and the exploration of appropriate assessment strategies. The fourth research question requires a longitudinal study, tracking the performance of groups of students from their early experience of PDT through to the point at which they become accomplished in using it. It would need to be a big enough sample to provide a range of teacher approaches, a range of school settings, and a variety of project interactions with *other* design and development activity, ie NOT within PDT.

development activities

DA 1 *reducing the fierce learning curve*

The evidence from this small study suggests that most students have been taught PDT through a similar approach to that adopted by the trainers who trained their teachers. This has presented students with a very steep learning curve. We have also observed that it is possible to present PDT to students in ways that are more accessible. We recommend that development activities be undertaken (by DATA or others) that facilitate a reduction in the severity of the learning curve, eg.

- *by switching off features.* In the early stages, in addition to simplifying tasks this might also help to overcome (or at least greatly reduce) the major problem of error messages (for the student) and fault tracking (for the teacher)
- *by developing cut-down versions or customised sets (KS3 kit?).* Most students in our design activity used only 4 or 5 tools (workplane; draw tools; rub-out; extrude; rotate)
- *by creating a simple 'front end' draw facility* (virtual sketch pad) possibly using ready-made elements.

DA 2 *pedagogic development*

Developing from 1 above, when students have made inroads into PDT, it is important that teachers understand how to built progressive demand into the activities they undertake with students. In particular it is important to develop good practice in relation to the connections between the power of visualisation and the capability for manufacture. We recommend that careful development work should underpin the dissemination of good pedagogic practice, and furthermore that this good practice be embedded in any further training for teachers.

.....end.....