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CAD and Creativity – A New Pedagogy

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Abstract

In 2007, the Design and Technology (D&T) national curriculum for England suggested: ‘In design and technology pupils combine practical and technological skills with creative thinking to design and make products and systems that meet human needs. They learn to use current technologies and consider the impact of future technological developments’. Consequently in England, the use of Computer Aided Design (CAD) packages has become a significant part of the teaching of D&T to students from the ages of 11 to 16 years but often using a teaching strategy that concentrates on the functionality of the CAD package.

In contrast, this paper presents findings from a three-year intervention study. The programme investigated how 11-14 year old students can develop their creativity at the same time as learning complex 3D solid modelling computer aided design programmes through an improved pedagogy.

The study was broadly an ‘action research’ programme in five phases in which the researcher was also the teacher in the secondary school in which four of the five phases were conducted. This paper provides details of the construction of a new approach to the teaching of CAD, and evidence that the novel teaching methods have improved the students’ and teachers’ confidence to take risks when using the CAD software, therefore leading to more creative and complex outcomes.

Introduction

In school in general, and in Technology lessons in particular, teachers need to prepare students for a working life in environments which will often have evolved by the time they reach the work place. Fisch and Mcleod (2007) stated this quite succinctly when they wrote that as teachers ‘we are preparing students for jobs that don’t exist yet, using technologies that haven’t been invented yet, in order to solve problems we don’t even know are problems yet’.

Teaching students to be creative is seen as an essential foundation in preparing them for this future (Robinson, 2001: Cox, 2005). We need to encourage them to seek novel solutions to problems, to take risks and make links they may not have previously thought of (Cropley

2001, Best and Thomas 2007, Rutland and Barlex 2008). Isaksen *et al.* (2001) recognises a nine dimension model for establishing a working environment to encourage creativity. 1) Challenge and involvement, 2) freedom, 3) trust and openness, 4) idea time, 5) playfulness and humour, 6) conflict, 7) idea support, 8) debate and 9) risk-taking.

These facets are particularly concerning when teaching Computer Aided Design (CAD) within Design and Technology lessons. The programs used to teach CAD, particularly 3D solid modelling CAD, not only evolve rapidly but are also complex and difficult to learn and therefore allowing younger students the freedom to also be creative can be seen as virtually impossible. This concern is further compounded by the lack of confidence shown by many teachers when teaching CAD. Teaching CAD is only one small part of the range of lessons needing to be taught, and teachers often do not have the time to become experts in using the program especially, as previously stated, the software used changes rapidly.

Current methods of teaching CAD in classrooms tend to centre on the teaching of “command knowledge”. This provides students with the knowledge of sequences of commands to create a feature on the screen but often do not teach “strategic knowledge”, which is knowing the best features and the best order for the features to create the desired model (Lang et al 1991, Chester 2006). Bhavani et al (1993) write that ‘students are so busy learning the commands that little time is available for acquiring other kinds of information such as procedural (strategic) knowledge’.

Adopting the traditional step-by-step method of teaching CAD commands to students does not allow them to take ownership of their work or develop it in their own way, which is essential to encourage the student to become creative when using the more complex CAD programs.

Below I describe classroom studies conducted in five phases that examine what students actually need to know and understand when learning a program that evolves as frequently as CAD software, and furthermore suggest a suitable pedagogy that would support teachers and learners to achieve successful and, most importantly, creative outcomes.

Potential issues when learning to be creative when using CAD

The literature reveals a range of possible factors that may affect students’ progress when learning CAD software and in their ability to be creative when using it. In summary:

- Students’ attitude to learning when using computers varies considerably, with particular concerns being raised over differences between the attitude and approach presented by males and females. (AAUW, 2000. Siann, 1997. Clegg and Trayhurn, 1999)

- Using CAD involves mentally rotating and manipulating images. Varying levels of *types* of intelligence may result in difficulties being able to create new models with CAD software. (Gaughran, 1996)
- Creativity has been reported to be an essential part of education on a personal and professional level and several initiatives have been instigated by the UK Government. These may have resulted in improved creative ability in students however the impact of this on learning CAD programs has been unclear. (DfE, 2003)
- Different approaches by males and females to using technology may require different methods of teaching CAD to each gender.

Phase One

To provide a clear understanding of which of the issues highlighted above most significantly influenced the students' ability to learn and use CAD creatively, a pilot study was undertaken involving 254 students of 10 years of age (124 girls and 130 boys). Over a two day period groups of 25 students experienced a 40 minute activity intended to introduce them to both 2D and 3D CAD programs. The activity was part of a programme of events provided for primary (elementary) school students who would be starting at the secondary (high) school the following year. As such the school, teachers and equipment were new to the students.

The activity started with a demonstration of a 2D, then a 3D CAD programme. This was taught by the same teacher, in the same room throughout the two day period to maintain consistency. The students then completed a short questionnaire. Most of the questions in this involved the use of a Likert scale. This was considered to be the most appropriate method due to the large number of students and time constraints, in addition as the Likert scale was used most of the data was quantitative and could be compared to results gained in later studies. The students also completed a short spatial awareness test consisting of range of problems which asked the students to mentally rotate shapes. Finally, prior to the event the students had submitted a design for a key fob, which was assessed for its creativity by a panel of experienced teachers. These designs were transferred to a 2D CAD programme and the students were able to watch these being made and could take their product home with them thereby completing the students understanding of the design and make process.

The study revealed that 93% of the student participants have access to a computer at home with 60% of these students who do have access to a computer at home using it between 1 and 5 hours a week. The remaining 40% use the computer between 6 and 16 plus hours a week. In contrast to earlier studies, gender appeared to make little difference to the amount of time spent on the computer although the study did not investigate what activities the computers were used for. It may be that males and females participate in different activities, which may change the way they approach designing with a computer. 83% of students expected the 3D solid modelling software to be more *difficult* to use than the 2D program. 68% of students expected to *enjoy* using the more complicated software compared to the 77% who expected to enjoy the 2D CAD programme. Both of these findings are reasonably

high suggesting that students were looking forward to both types of CAD even if it presented a challenge. Spatial ability appeared to make little difference to the students' expected enjoyment or difficulty or either programme or to their ability to be creative. The spatial ability test was short, however, and was not completed under strict test conditions. Overall the designs produced were considered to be not very creative, with only two of the students producing work that was placed in the top level when judged against the usual D&T criteria.

Phase Two

Once the students aged 10-11 had enrolled at the High school, the students took part in three Design and Technology lessons lasting 50 minutes per week as part of their normal lessons. The students rotated around different aspects of D&T every six weeks on a 'carousel' of various activities including a CAD unit following the traditional command-led teaching method. This consisted of the students all completing similar products using a 3D solid modelling CAD programme in a step-by-step fashion as the teacher demonstrated a step then the students completing that step. In the last few lessons the students were asked to use the knowledge they had learned to create a model of a robot using the software. At the end of this unit the students were given the same questionnaire as they had been given in the previous study; however questions that had been identified during the previous study as being irrelevant were omitted.

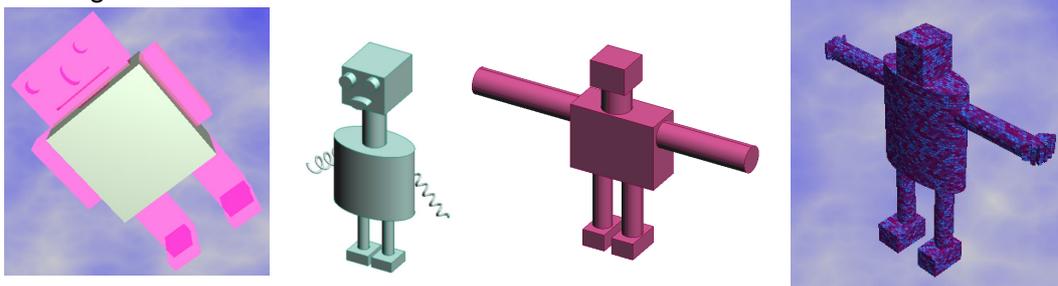


Fig. 1 Students' work in phase two

From this it emerged that 42% of students had indicated that their actual level of enjoyment had matched their expected level of enjoyment. 14% of students had enjoyed using the programme slightly more than they had expected and 10% had enjoyed using the programme significantly more than they had expected. 21% of students had enjoyed using the programme significantly less than they had expected and 12% of students had enjoyed using the programme slightly less than they had expected. This appears to indicate that if students *expect* to enjoy using the programme that they will actually enjoy using it.

To gain a deeper understanding of the students' feelings when using CAD, those students who either had the most extreme opinions of ease of use or enjoyment when using the program - or whose opinion had changed the most - were invited to attend a group interview of around 5 students at one time. The interviews were semi-structured in that some questions were prepared, however it was important that the interview was not so structured that the students weren't able to express themselves.

Findings from the interviews suggest that many of the factors shown to promote creativity may also be relevant to learning CAD programs. Students stated that they liked challenge and problem solving, although when taking risks the outcome had to be achievable as students who had not managed to complete the work were those who had enjoyed using the program least. Most students wanted to work at their own pace but also liked the idea of working in pairs as this appeared to reduce the risk as they could work through problems together.

Phase Three

Building on the results of the phase 2 study an alternative teaching method was created that focused on methods of promoting creativity. The resources for this method were presented to the students as a computer game in which the students needed to use CAD to create items in order to work through various levels and ultimately rescue a 'village elder'. The students were asked to work in pairs with one student in control of a set of information video clips and the other operating the CAD program. The students could work at their own pace and stop to review any points that they found personally difficult. The students were also awarded points both for getting it right or solving their own problems and also for attempting a creative design regardless of whether it worked or not. The intention was that this would encourage the students to take risks. Even if the final design didn't work, the pair would still gain points but more significantly would begin to develop an understanding of what CAD commands would or wouldn't work through play and exploration. When the students had finished the task they switched over roles and repeated the task and could improve their marks from their first attempt. Finally the students were provided with a booklet of common problems that they may encounter in each task to reduce the dependency on the instructor.

To test the effectiveness of this 'strategic' method of teaching compared to the traditional 'command-led' method, the game-based resources were used with classes of students who enrolled in the following school year. To maintain consistency, the students attended for similar activities as elementary school students as those had in phase one prior to them starting at the school. As before, by completing this task the students' answers regarding how they *expected* they would feel about using a CAD program could be compared to how they *actually* felt about using the program. The new teaching method was then used over a six week period involving three fifty minute lessons per week. At the end of this period of study the students were asked to complete the same questionnaire that had been given at the end of the phase two study and, as before, those students who either expressed extreme views or whose views had changed most dramatically were invited to attend semi-structured interviews.

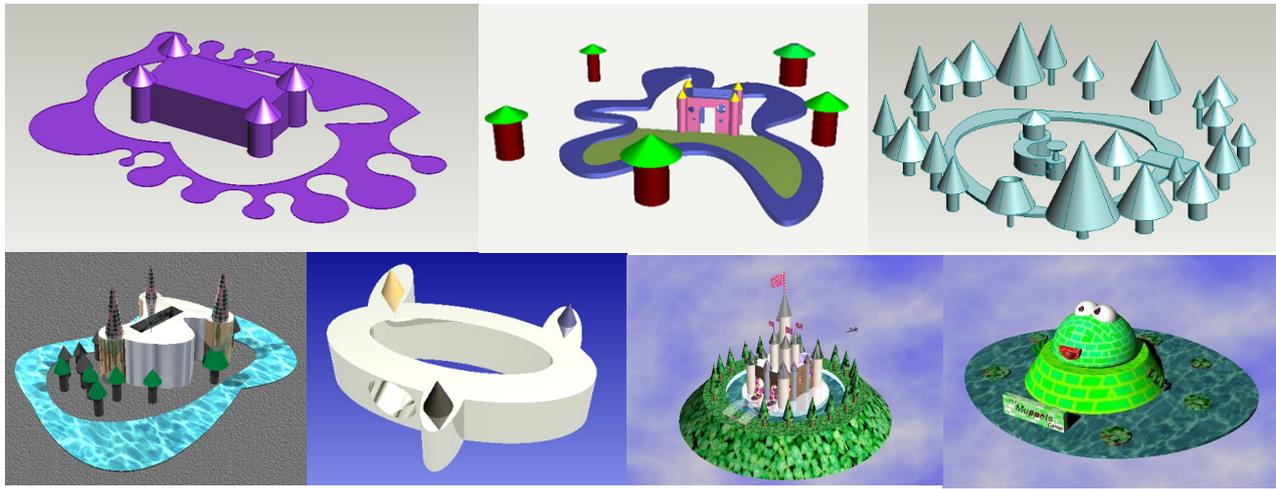


Fig. 2 Students' work in phase three

The results of this study again highlighted that student attitude to using the program made a difference to how the students approached the tasks. Those students that had expected to enjoy using the program most often did then enjoy the program when they had used it. Those students who had expected the program to be difficult to use, but had also enjoyed using it, had seen the tasks as a challenge that they needed to work through. Those students who had thought the program would be difficult to use, and had not then enjoyed using it, had seen the challenge as a barrier that was just too hard to get through. Most students, even those that hadn't enjoyed using the program, had enjoyed the game aspect of the learning. Almost all of the students enjoyed working in pairs and had liked being able to work through problems together. This aspect had also been pleasing to the instructor who had enjoyed listening to conversations between the students in their pairs and felt that the students had learned far more from this experience, and by making mistakes, than by getting it right first time but by just following instructions. All students enjoyed being able to work through the tasks at their own pace; most students liked being able to revisit parts that they had found difficult, but others liked that they did not feel held back by weaker students and they could progress to the more difficult challenges. Most importantly the work completed by the students displayed far more variety and creativity either through the tasks with help from the explanatory video clips, or in the final task of the game by creating 'a castle' without a specific explanatory teaching video to follow.

Phase Four To further test the alternative 'strategic' method of teaching CAD to students, the previous study was repeated with the next year's intake of students soon after they had enrolled at the school, but this time the students were taught by a different instructor who was equally experienced as a teacher but was far less confident in teaching CAD. A difference to the previous studies is that the study was undertaken with only one group and the new instructor was asked to keep a diary of their experiences after each lesson. The introduction and initial questionnaire was also completed at the start of the first lesson rather than before they had enrolled at the school.

Interestingly, more students had indicated at the beginning of the study that they expected to enjoy using the program, but fewer students had actually enjoyed using it. This perhaps

confirms Pektas and Erkip's findings that instructor confidence may influence the students' attitude to the task (2006). The instructor also reported problems with some of the students working in pairs that had not happened before, although she also believed that this could have been due to the ability level of the class. A few of the students had some level of learning difficulties and this may have caused some problems with the pairings. Concerns raised by the students were that their partner wasn't following the instructions properly or that the students felt they weren't spending equal amounts of time on the program and the instructions. The instructor stated that she would use the method again but this time she would teach the students who struggled to work in pairs separately and guide them more closely. Again, however, the students produced a much better quality of work than others had when taught using the traditional 'command-led' method of teaching, and the work displayed a greater level of variation and creativity.

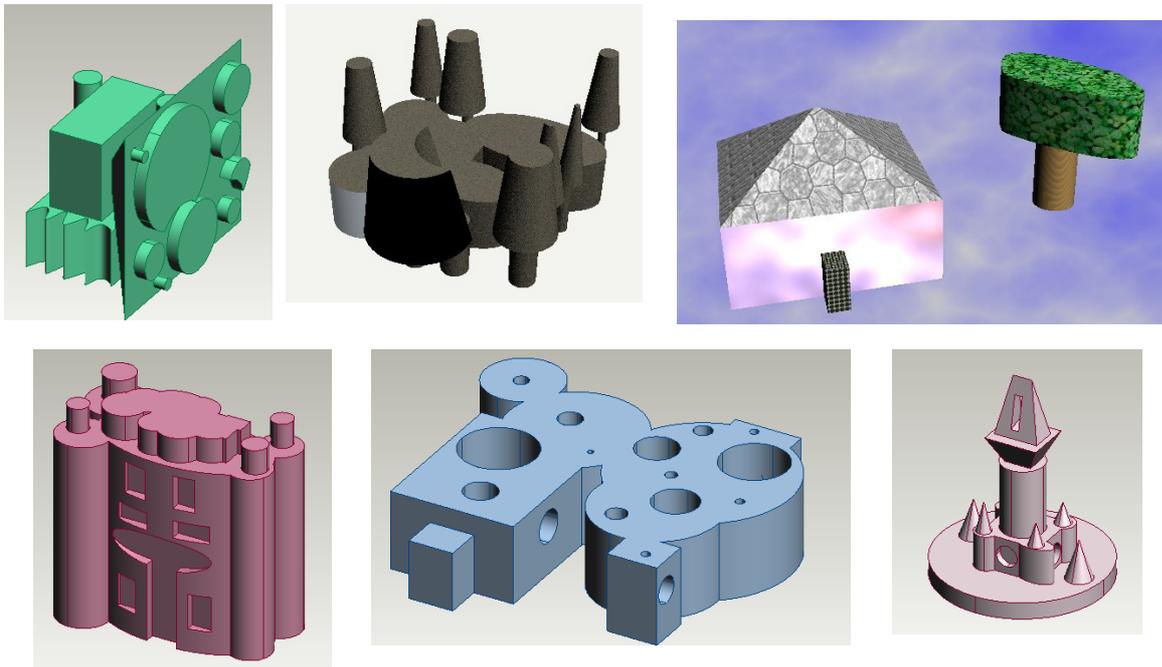


Fig. 3 Students' work in phase four

Phase Five

The final phase in this program of research tested the alternative 'strategic' game-based method of teaching CAD to students in a different school with a different instructor. The school had fewer resources for teaching CAD and only had one room of computers and no data-projector in the department. The instructor chosen for the study had also voiced a passionate personal dislike for the CAD program used in this study. Again a questionnaire and a demonstration of CAD were given to the students at the beginning of the first lesson and a second questionnaire was given at the end. The instructor was also asked to write a diary at the end of each lesson. In this study the diary was written in a more conversational tone and gave a deep insight into the level of concern, and even fear, which can be present when trying to teach using new and ever changing technologies.

Once the instructor had become used to the resources and how they should be used, a marked difference in tone became evident in the diary and the instructor reported that he had enjoyed some of the lessons and even looked forward to the lessons at times. One change from the previous studies is that when the instructor was stuck or saw the students getting into difficulties he reverted to old methods of teaching CAD for short periods. This made little difference to the study as the important aspects were adhered to and it made the instructor more comfortable.

At the end of the study, fewer students than in previous studies said that they had enjoyed using the program, however the instructor felt that this was due to the last task, which involved creating 'a castle' without the aid of specific instructional video clips to help. He believed that this had over taxed the students which had changed their final opinion as during previous lessons the students had stated they had looked forward to the lessons. The instructor reported similar experiences as the instructor in phase three when considering paired learning. The instructor had enjoyed listening to the conversations between the pairs, particularly when the students were trying to solve problems. When asked whether he believed the students had been creative he replied, 'creative, - try gay abandon!' Once the students had realised they gained higher marks if they made their designs different to the designs in the video clips, they had worked hard to make their work novel and so the result was more creative. The instructor concluded that the method was valuable as it removed much of the pressure from the instructor, and by working through problems themselves provided a far more valuable learning experience for the students. He said that the students could see the point in what they were doing and didn't get bored as he had noted when teaching using the traditional 'command-led' method. He believed the game resource could be adapted to suit other CAD programs, and he would certainly use the resources again.

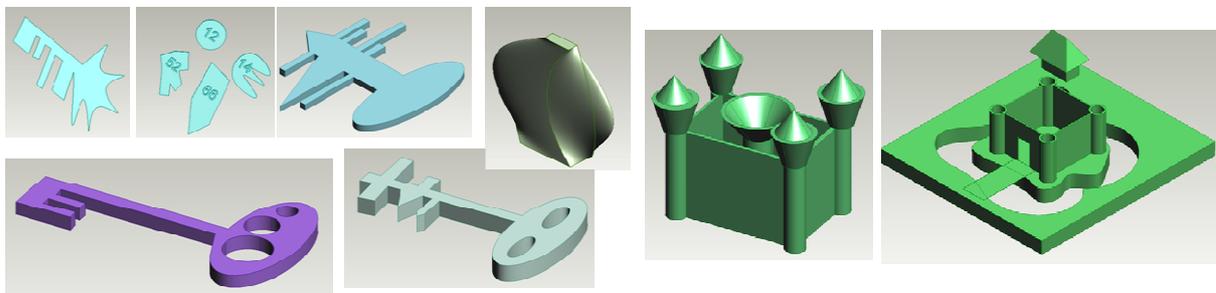


Fig. 4 Students' work in phase five

Conclusions

Some of the concerns raised in a review of the literature were not a significant factor. These included a possible difference in the way males and females approached using technology. Throughout these studies this was less of an issue than previous research has suggested. Male and female students gave similar levels of response to all parts of the questionnaire, and produced work that was of equal status and demonstrated similar creativity levels to each other. Spatial awareness also appeared to present little concern throughout the studies.

The issues that appeared to be more relevant to the studies were of instructor confidence, student attitude and lack of ability by the students to be creative. Surprisingly whether the student enjoyed using the program or not made little difference to the work outcome. Those that did well generally had the attitude that it was something they needed to do and get on with. By putting the work in a context, and through aiding the student to achieve even small goals, improved the students' confidence. Paired learning was pivotal to helping the students work through their own problems and the students gained an improved learning experience through discussion of their work as it progressed. By using known methods of encouraging creativity by providing rewards for taking risks, and not just for the actual final outcome, the students work showed a higher achievement and creativity level. Instructor confidence also appeared to be an important factor in influencing the students' confidence. By providing strategies for dealing with mistakes and solving problems the instructor's confidence improved, and through this the instructor was more confident to allow the students to take risks and work independently. The instructor was able to work through the problem with the student rather than giving them the answer each time, or not being able to help the student at all.

In short, the alternative 'strategic' teaching method based on a computer game is far more beneficial to both the students in terms of quality and creativity of outcomes, and also the instructor in terms of improving teacher confidence.

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