Strategies for the Transition to CAD based 3D Design Education

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Ertu Unver[1]

[1]University of Huddersfield, e.unver@hud.ac.uk

ABSTRACT

In the proposed paper, our experience in managing the transition from traditional design education to CAD based design as a case study for comparison is documented. Use of CAD technologies on both undergraduate and Master level is also discussed.

This document outlines the necessary details to prepare a paper for the journal Computer-Aided Design and Applications. Authors are requested to follow all formatting instructions encoded into this MS Word file. To simplify the task of paper preparation, simply type in your paper into this document.

Keywords: 3D, CAD, design education, curricula development.

1. INTRODUCTION

This paper presents a comparison of methodologies used by CAD practitioners in industry and education. The purpose of this research is to provide a commentary on recent models of commercial design methodology and to explore their relationship with current educational practice in Computer Aided Design in the School of Art & Design at the University of Huddersfield.

New technology has had a profound effect on the three-dimensional design professions. Processes, such as rendering, prototyping, or basic stress analysis, can now be completed by an individual designer without the support of a variety of specialists. An experienced designer can now be informed on the implications of any design decision with greater speed. The optimisation of the design process has clear advantages in an industrial and commercial context. Development time and costs can be reduced while retaining quality and reliability. Finite element analysis enables an accurate prediction of performance prior to production. Prototypes can then be constructed by rapid prototyping or CNC machining in appropriate materials to allow performance testing.

The particular approach to designing consumer products called industrial design has a relatively short history, being principally a discipline created in the 20th century. It has roots in the philosophy and practice of the Arts and Crafts movement and the Bauhaus in Europe, and in the USA through the introduction of overt styling as a way of increasing product sales. It is called 'industrial' because of its concern with products manufactured by industrial processes, and has tended to have an emphasis on vocational effectiveness and practice. The education of industrial/Product designers has been mostly the responsibility of Art schools, particularly in the UK. The various changes in higher education in the UK in the last 25 years have resulted in the discipline at degree level being located almost exclusively in the new universities. However, because of both its relative youth and its roots in the art school approach it has lacked any traditional form of research. [7]

Industrial/Product design and Engineering design terms sometimes are taught the same by researchers or academics but there are differences between them. The term Industrial design was traditionally associated with styling and ergonomics to later become Product design, where designers are more aware of technical issues of materials, manufacturing processes, and assembly. The objective of educating product design students is to train graduates who could practice professionally in conceptual product development. Product design has much in common with architecture and engineering design. Within its Art school tradition, product design is regarded as a specialization in three dimensional design. It has a stronger relationship with furniture, ceramics and interior design. It has some common structure with graphic design, textiles and fashion design. Product designers design the things we use in our daily lives from vacuum cleaners to cars. They consider how to make items easier to use, more efficient, cheaper to produce or better looking. This means looking carefully at what is required, researching and developing ideas and coming up with a design, which might be for a completely new product or to improve an existing one. The process involves, taking a brief, making initial sketches, creating detailed drawings, renderings, making samples or working models and testing the design. Designers work with other skilled people such as engineers and model-makers.

In education, the advantage of rapid development must be carefully balanced against the need for clear and effective discussion between the student and tutor. In an educational environment, creative thinking must be explored, discussed, and challenged to direct the development of the student as well as the design brief. The use of CAD technology can deepen the student's understanding of final form, structure and performance of a product. However, the student and teacher do not have access to a simple overview of all the development process (traditionally, a set of drawings in a layout pad with a complimentary range of sketch and appearance models). This has been the essential evidence, which has underpinned both the design process and the educational dialogue. In this paper our experience in moving from traditional drawing board type to CAD based design education is presented.

2. CAD IN INDUSTRY AND EDUCATION

High-end CAD systems, which was until recently solely in the domain of larger companies' IT development strategies, are increasingly available to Colleges and Universities. The change in availability is a consequence of the inverse relationship between the power and cost of computers. Although these programmes are now more affordable it must be recognised that they still remain not only more difficult to learn but are also more expensive in comparison to mid-range software. This is, in part, because of the performance increase of mid range software, driving the high-end players towards improvements in their packages to stop the drift to mid-range alternatives. The introduction of facilities, which are not available to the mid-range vendor, enhances the high-end product, but inevitably increases the learning curve. Crucial among these is the smart hybrid modeller, which allows geometrical relationships of a product to be defined and automatically retained when design changes are made. 3D CAD packages generally allow users to specify functions and generate functionally compliant variants quickly. If these new features offer the trained designer a better understanding of the design process, they also introduce a new set of educational objectives for the uninitiated new designer. As a preamble to an evaluation of the impact and future developments of computer aided design in the curriculum, it is necessary to consider the present structure of design education in the context of the recent past.
Although there are good research on Engineering Design and use of CAD, there are limited number of research papers on the use of CAD in 3D Art and Design education. [3,5,12,13]

3. CAD CURRICULA IN 3D DESIGN COURSES

In this respect, the courses in 3D Design at Huddersfield will have many similarities to many other universities in the UK. Most UK degree courses in design will have moved towards a modular system of education using the credit accumulation and transfer system (CATS) to define the content and level for each element of the pathway to the degree award. The system specifies the teaching/learning content of the curriculum as self-contained units or modules. This offers a method of close examination of the outcomes in which it is relatively simple to map the influence of Information Technology as an aid to design education processes. The description given here, although specific to the University of Huddersfield will be familiar to many practitioners in design education.

The University of Huddersfield first offered Product Design course in 1987. During the following years, staff and student experience in working with and in industry highlighted the need for a broader range of design practitioners.

In response, two additional pathways, in Product / Transport Design, Industrial Design and later Product/Transport Design with Animation were validated, completing the current suite of courses. From the planning stages of these courses, the need for improved CAD skills was recognised, and three modules in CAD were validated as elements of the degree programmes, designed to equip students with experience of 2D and 3D software.

Fig.1 Use of image based CAD by students

During the early years of the new degree pathways, CAD was primarily viewed by students as a useful method of improving 2D renderings or of combining text with graphics. See Fig.1. Since then, the continuing development of affordable, powerful, and rapid processors has created an opportunity for the University to give increased access to CAD technology. As a result, CAD has moved, from a peripheral component of design education, to a central tool in the design process. In particular, the introduction of a middle range CAD software in 1998 changed the role of computer technology in the curriculum. Students were equipped with a tool to explore the 3D properties of their designs. The clearest evidence of this sea-change was the number of students putting in extra hours in the CAD lab, not only producing final presentation visuals, but also, developing and exploring form in the early stages of design projects. Clearly, the focus of design activity has moved. This movement, while welcome, has continued to offer a challenge to studio-based, modular design education. For example, CAD has empowered students with weak visualisation skills. The technology has improved these students understanding of their designs. Traditional drawing skills, which have been essential in the evolution of form through analysis and development of sketch visuals, have not yet been completely supplanted. However, the technological alternative has already removed the drawing board from the industrial setting and certainly will change the landscape in design education. Traditional studio teaching and assessment methods will also change if the more CAD based student is to be given equal access to staff advice during the development phase of their design projects.

Recent progress in communication technology allows a high level of remote interaction on product development via the Web. Using this medium, progress can be reviewed, parts inspected, tolerances checked, or even 'fly-through' assessments can be made of complex assemblies. In education, live project briefs can be arranged with companies operating on a global scale, via Internet connections and video conferencing links. This development is particularly significant as it exposes the student to a much wider cultural and industrial experience than can be gained through contacts with largely local or UK based companies. (See Fig.2)

Fig.2 3D CAD works by design students

In managing the education of new designers in the rapidly changing field of information technology, it is comforting to know that other Art and Design courses in different Universities started using at least one middle range 3D design package and rapid prototyping.

At the present time, however, especially the cost of larger size Rapid Prototyping hardware is beyond the reach of most schools of design for undergraduate teaching. The typical run time to produce a model would create a logistical nightmare. It is not difficult to imagine the scene as the final submission date approaches and students jockey for priority access to produce their rapid prototype on what will most probably be a single and very costly machine. For the moment our experience is that RP generally used as part of some modules on second year student as groups and also majority of final year students.

The movement of computer technology, into the areas of visualisation and 3D modelling, are the most immediate changes we experienced at the University of Huddersfield. We have extended the role of CAD to include mid range stress analysis software, which enables students to assess especially the structural properties of their designs. This development impacts on the syllabus of the technology modules by presenting graphic evidence of better understanding of constraints without the need for an extensive knowledge of applied mathematics for Art and Design students where math is not one of the requirements for the entry to the course although drawing skill and design A level or similar is. Technology and mathematics, which have often been viewed by Art and Design students as the poor relations in the design curriculum have become a more accessible dimension of the degree programme and the design process. Engineering design courses are traditionally known for their technical, mathematical and scientific approaches for design problems compare to visual, aesthetic and ergonomic approach from 3D courses in the Art and Design schools.

The University has also invested in an additional CAD laboratory. This facility runs high-end surface modelling software on Silicon Graphics and high spec PCs.

As we move into a virtual environment, we must look into requirements of consumer product design industry. Leading designers acknowledge that the way they work is moving increasingly towards integration. [6,9] Through the medium of CAD the broader parameters of design can be integrated, moving designers from just stylists to a more effective role in the development of products from concept to manufacture. A similar integration of the various strands of design is mirrored in education. The increasing use of computer technology is evident, not only in the CAD and practical design modules, but also in the theoretical and cultural aspects of education.

The course diagram Fig.3. compares the modular structure of a typical degree programme of the mid nineties with the same programme this year.

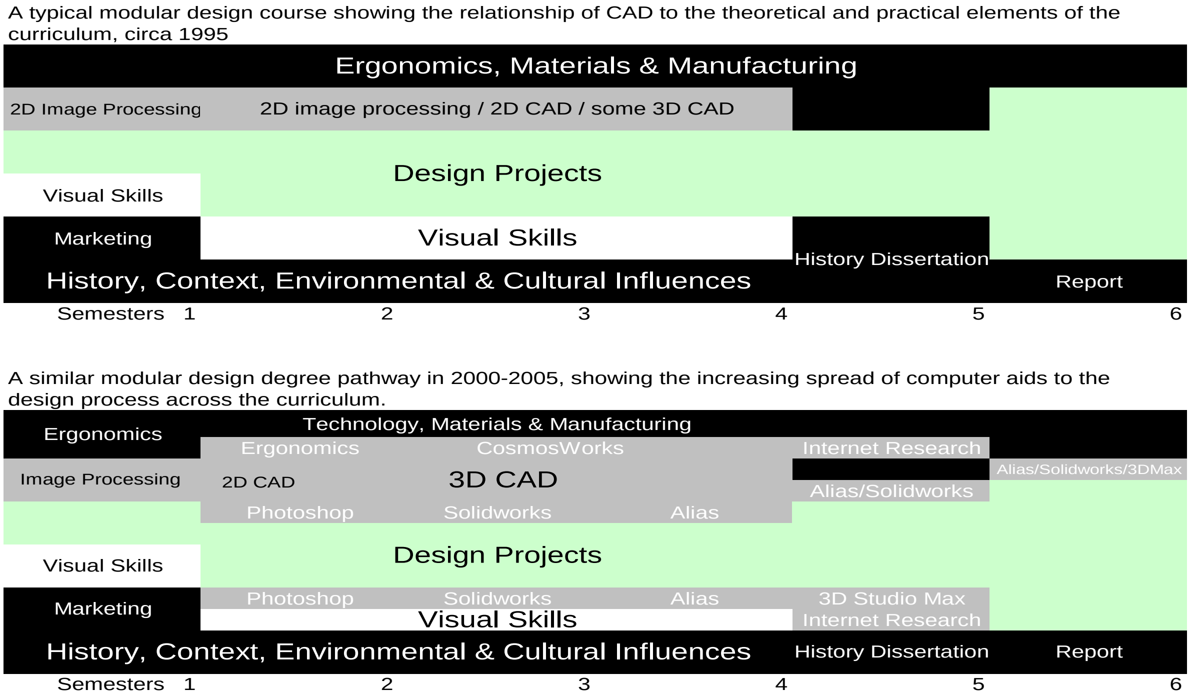

Fig.3 Product design course structure

Drane claims a tremendous change in using CAD system to develop design interactively before plunging into CAD modelling and companies when developing new products spend too little time talking to customers. Designers need to reflect customers needs, in the near future, the Internet will play a major role during product development. Stevens offers a contrasting view of the significance of CAD believing that computers are expensive tools, which can only respond to the quality of the original concept, enhancing rather than significantly changing design skills. [9] At the present time, there is substance in the argument that traditional concept and visualisation skills still form the basis for most design projects. CAD software can streamline and enhance several aspects of the design process, but as we have found at the University of Huddersfield, the initial stage of concept development still benefits from a thorough understanding of a range of traditional design techniques.

CAD developers have produced an excellent suite of programs, which allow a high degree of integration of a variety of technical and aesthetic parameters within the design process. As Stevens noted, computers can only enhance a good concept, and in a commercial environment, it can be expected that the CAD user has already developed a sound grasp of these basic conceptual skills. CAD software, therefore, does not address the earliest stages of concept development. There are good attempts from software developers though e.g. Alias sketching. The simple checks and balances, centred on the question of 'what makes a good product?' are not directly integrated within the structure of the package.

Although generally mid range 3D software has been found to be easy to learn and use, it has limitations, for example, modelling a shoe or a car exterior organic shapes are either very difficult or the shape generated is not the one designers wanted. Therefore a surface modeller Alias Wavefront Design studio was implemented, especially for BA Product Design with Animations and BA Transport Design students. Some example of students' work shown in Fig.4.

Fig.4 3D Organic shape modelling

Another area needed exploring was to use 3D animation as part of overall design process and presentations. Although Alias Wavefront Design Studio has limited animation features, 3D Studio Max software was chosen due to its easy learning and ease of use. Character Studio, and Reactor software are now part of the same suite and works well with Poser 3D Model software. Recent introduction of these software enabled student to create interaction between their 3D design and moving human and other characters. See Fig.5.

Fig.5 Use of character modelling and animations

The School of Art & Design has recently been making progress in the development of postgraduate provision. The vast majority of ongoing Master courses in the School have an emphasis towards practice-based activity underpinned with relevant theory, which differentiates them from provision in many other areas of the University.

A common feature of this provision is an acceptance of less defined discipline boundaries and an exposure to a wider range of creative activity from a number of discipline areas. This reflects the nature of creative activity at high level in the workplace, and is a positive benefit to students on these pathways.

The MA/MSc 3D Digital pathway recently started which share common academic and theoretical structure of study and facilities and the exchange of ideas and practices across disciplines. The MA/MSc 3DDD requires the designer to gain a broad understanding of theoretical and contextual issues while simultaneously addressing the current and emerging technological and methodological possibilities available. Theory and practice inform each other as much in this technological domain as in any other, and this dialogue characterises committed study at Master's level. The course structure promotes a sharing and potential cross-over of creative practices that are converging as are the technologies in use in society at large. The course is characterised by a broadening awareness of interdisciplinary practice arising through the adoption of new technologies, and the questioning of traditional disciplinary boundaries. The pathway develops practitioners to engage with emerging digital technologies at a level beyond that of conventional design techniques. [4,10]

4. CAD TRAINING METHODS AND APPLICATIONS

All the software used in the design department include training materials and tutorials. Design students often find tutorials difficult to follow without a tutor introducing the software first. During the early years when the first mid-range software was introduced, only some students used the basic functions of the software for their design. Shapes of products created were restricted due to limited knowledge of their CAD skill. Then University employed a new tutor and trained other tutors for the effective use of available software. The following new methods were then used for teaching.

4.1 Computer based training

CBT is a very basic method to train staff or students. Software developers, third party companies and staff from different institutions develop online training materials. There are drawbacks though. When users have previous 3D CAD skills in other areas, these tutorials are then easy to follow. For example if a student already has experience on a mid range software then learning other similar software is easier using this method. But if a design student has 3D animation and character animation skills on one software, this is not as useful when he/she want to learn a mid range 3D CAD software.

Some high end surface software were supplied with video CD/DVD training materials. During the early stages of transition to CAD based delivery, although students completed these tutorials, the majority of students were struggling to apply their new skills to other projects. Because majority of software has many features, and various ways of creating models, assemblies. Especially first and second year students, they just want to finish these tutorials and start their own projects. They do not spend enough time to analyse why they do certain tutorials and how these might be used later. Another problem is students are not informed whether his/her training part is right or wrong and why. Due to these deficiencies, the computer based training is not widely spread, but the development of the CBT technique is progressing.

4.2 Virtual Learning Environments (VLE)

Blackboard is piece of VLE software with an integrated online learning environment, bringing together functions including content delivery, communications facilities, assessment, student tracking and links to other systems such as registry, student database etc. at Huddersfield University Although some modules were effectively delivered using VLEs for teaching and learning there are modules in which VLE used very little. Generally reasons is limitation of this tool for a spesific module requirements or reluctunce of learning, using it by lecturers and difficulty in managing for registering new, failed, part time, or other students to a spesific course. Part of CAD module is delivered using this tool, including all written materials, briefs, video training materials and other necessary files, maps, textures, etc. Blackboard or similar VLE tools are believed to revolutionise how an institution delivers curriculum especially delivering entire courses to distance learning students and support to complement face to face classes as well as to provide support through the communications facilities to classes delivered entirely face to face. VLE is a useful tool for support for CAD teaching. But neither CBT nor VLE can replace face to face teaching in design education in the near future. While internet speed develop further, they might be used more though.

4.3 Face to face teaching
Although this method requires more resources, students have direct feedback from the tutor. Tutor can oversee the progress of individual students. As an academic institution our responsibility is to train all the registered students to a certain standard where they can generate their own design after the CAD teaching is over.

Students come from diverse background, some with basic computer skill others with good graphics and CAD skill. Some students learn very fast and others slow and numbers in each groups changes from one year to another and from one course to another. Fast learning students generally help the class to create higher standard work. Face to Face teaching enables tutor to oversee individuals learning progress. In the design department 3D courses CAD modules consist of three hours a week CAD teaching with students numbers are limited to maximum of 25. For the first 1.5 hours students are taught to use of the CAD software using a data projector and another 1.5 hours they were given computer based training for the first six weeks of their twelve weeks a term education. Second six weeks, students were given supervised projects to improve their CAD skill. These projects might be a lego car modelling for mid range software, a car exterior and interior modelling for surface modeller, and 3D Animation and interaction with 3D characters for the animation software.

4.4 Non-contact 3D Laser Scanner
Recent year a 3D non-contact laser scanner is implemented in the school for capturing 3D data from physical objects. The use of 3D laser scanned data for building 3D models is not as widespread in education as the use of 3D modelling software. The ability to integrate 3D scan data with 3D software and technology gives users in all design fields the potential to construct complex organic shapes. It appears that a significant advantage of laser scanning technology may lie in its use as an alternative tool for reaching design solutions where especially complex surfaces are an important part of the project. The study has shown that in particular, laser scanning can be used cost effectively, for surfaces difficult to model such as transport vehicles or organic forms [10]. The current scanning process, however, would appear to be far less suitable for the modelling of basic objects such as tables, desks, or other objects consisting of geometric forms which are straightforward to create using existing CAD modelling techniques.

Although 3D scanning process is easy and scanning takes very little time, integrating this process for daily use of students proved to be difficult. Problems areas are: learning another software to use only few times a year, individual technical support requirements by technicians and by tutors, resource sharing by different departments, and limitation of scanned objects, (moving, colour, details, thickness etc.) and, necessity to use hardware and software at the University. Laser scanners are beginning to be used by people who would not be considered experts in that type of hardware niche. It is possible that in time, a consumer market for 3D digitising may evolve to be easy enough for designers to use them effortlessly. See Fig.6.

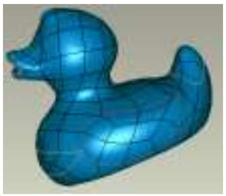


Fig.6 Laser scanning work

4.5 Rapid Prototyping
There are few new technologies that have impacted on product design and development as much as rapid prototyping. This impact continues to increase as organizations discover new, creative uses for the technology. As rapid prototyping further develops, additional applications will be discovered, and it will continue to expand into industries that have largely ignored or resisted it. An impressive number of R&D projects are underway in organisations of all sizes around the world. This demonstrates the commitment to and viability of rapid prototyping technologies. With some of the funding for these efforts coming from private investors and government agencies, it is clear that those outside of the rapid prototyping industry also believe in the technology. These investments in rapid prototyping development promise to yield dividends well into the future.

The advantages of CAD modelling as a result of its links with rapid prototyping technology will eventually have an effect on the model-making workshops of most universities. Increasingly students are using more and more rapid prototyping technology with external companies, recent years two different type stereolithography machines purchased with powder and resin technology. See Fig.7.

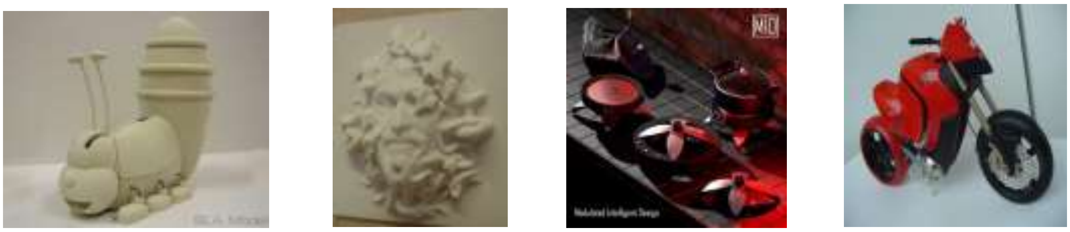

Fig.7 Stereo lithography works

4.6 Introduction of a Stereo-view system and 3D interactivity

Due to its capability of visualising object in 3D with depth, evaluation of different systems are completed and soon a 3D stereo view system will be deployed in our studio for both undergraduate and master students' usage. Creating of 3D character animations even using Character Studio etc. have difficulties. A motion capture hybrid system is also evaluated for easy character animations with MotionBuilder software. For virtual reality and interactive media creation Virtools software is already implemented. Students started using this software not only multimedia pathway but also Product and Transport Design courses for interactive presentation.

A stereo image works because it consists of 2 images that are separated at the viewing point by the eye separation of the viewer. Since the eyes are offset from each other the scene in front of them is shown from a slightly different perspective for each eye. This binocular disparity is the dominant depth indication in the human visual system, but isn't the only one to determine depth. There are a number of 2D cues that are used that are interpreted by the brain and so can be used to generate conflicting depth information.

5. CONCLUSION

The introduction of affordable, integrated, 3D CAD systems in recent years have changed the design process especially in small to medium size companies. CAD now enables the creation of accurate rapid prototyped models much closer to the beginning of the process. 3D CAD data can be easily shared on-line with the client and manufacturers. The combination of integration, communication and visualisation through the medium of CAD has allowed product development to become increasingly designer centred.

The use of CAD has had a dramatic impact on the time to market for new products. Where ten years ago there was a high probability that costly design changes would be required before a design got into production, these can now be rectified much sooner and at lower cost. In the next few years, even this approach will face competition from virtual reality systems. Computers now dominate design activity in industry in much of Europe and the US. However, it is clear that there is still a place for more traditional design techniques both in industry and in education. Some designers still favour marker renderings or foam models for the early stages of concept realisation; the 'hands on' approach bringing a more intimate understanding of form. For the moment, it could be argued that some principles in education are better appreciated in a low-tech format. A basic introduction to most topics will require some form of definition of terms and first principles for the foreseeable future. Although advances in the graphical presentation of a range of hitherto complex analytical processes continues to move the threshold of computer intervention ever sooner in the design process and consequently, earlier too in the educational curriculum. Traditional skills are not irrelevant, but the interface between them and technology has already impacted on the structure of design courses.

There can be little doubt that industry will continue to develop increasingly powerful tools to aid the design process. If vocational design courses ignore these changes, it will be at the risk of teaching a range of increasingly redundant skills. At the same time, the cost of investment in new hardware and software will possibly reduce the number of centres, which can afford to fund such degree pathways. Those institutions that invest in technology will have access to industrial partnerships on a potentially global scale, which would have been impossible only a few years ago. This same technology will offer opportunities to integrate many of the various strands of expertise, which inform the design process. Appropriate management, investment and CAD teaching in education will produce design graduates experienced not only in product aesthetics, but also in the broadest technical and cultural implications of their designs.

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