The role of higher education in nD modelling implementation

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Introduction

University education is no stranger to change, but the rapid development of today's information technology (IT) is posing great challenges to academics who have to consider its appropriate integration into carefully designed curricula to meet the expectation of students and the requirements of industry. Since the advent of computer aided design (CAD) into academic programmes in the early 1990s, there has been ongoing debate and concern relating to IT implementation within students' education and whilst there have been many advances over recent years, CAD for many still means electronic drafting. The majority of construction organisations throughout the world are still working with two-dimensional CAD (CIRIA, 2005), and although there is growing evidence of three-dimensional CAD, many companies use 3D primarily for presentation and marketing purposes. Nonetheless, leading researchers and executives, attempting to predict likely developments in the 21st century, forecast more widespread acceptance of three-dimensional modelling and the ability to describe the look, sound and feel of an artificial world, down to the smallest detail (Gates, 1996). Built Environment higher education has an important role to play in enabling this vision. The emergence of today's easier-to-use 3D modelling software, rapidly advancing computer hardware combined with an increasingly computer literate student population is beginning to result in an increase in the adoption of 3D CAD for built environment applications. This increase is likely to continue alongside industry's adoption of new tools and the emergence of a generation of students with the IT skills required by their profession. A more widespread acceptance of 3D modelling within organizations is seen as a significant milestone in advancing the adoption of nD modelling technology and furthering the vision for a single integrated project model shared by the key participants in the design and construction process.

The need for a strategic approach

In order to successfully implement and evaluate any new technologies into the academic curriculum of students, several strategic approaches have to work alongside each other. IT implementation cannot work in isolation of teaching and learning strategies and the overall business objectives of a School. Embedding new technologies into built environment programmes involves preliminary discussions with employers and professional institutions. There is a need to raise awareness of the importance of incorporating new technologies into undergraduate programmes. Processes of software selection and evaluation have to be set up alongside training workshops to inform academic staff about the availability and development of new materials. Programmes of evaluation and feedback should enable reflection on decisions taken and plans for future direction.

Traditional approach to introducing IT into the academic curriculum

The initial inclusion of computer-related subjects as stand-alone modules in the structure of academic programmes is an established technique within the School of the Built Environment, Northumbria University. The School endeavours to introduce students to IT applications appropriate to their subject discipline. Undergraduate students are introduced to industry-standard, commercially available computer programs and not to computer programming. Academic staffs feel it is important that students understand the theory that lies behind computer applications and not just the use of the software. Students' education still promotes the theory of architecture, materials and construction, planning, costing as well as traditional representation techniques. Thus, students learn about real buildings and current practices alongside the appropriate application of IT for their profession. It could be argued that students are now producing some of the highest quality designs, and some of the most interesting projects, ever to come from University Schools.

Modular Approach

When a new technology emerges that is of importance to built environment students, an adopted approach for integration has been to develop a stand-alone IT module to be included within the modular structure of an academic programme. The potential of IT to become an integrating factor in the curriculum has been discussed by Asanowicz in the context of computer implementation in the architectural curriculum (see Asanowicz, 1998). A stand-alone module provides opportunities to assess the stability of new technologies, raise staff awareness, and appraise potential applications for other subject areas. Lead users (or 'champions') of software liaise with academic staff, software suppliers and technical support services to ensure efficient management of such modules. However IT modules, such as 2D CAD, are one of several subjects competing for time in the academic curriculum. Students are taught many subjects within a programme and often these subjects are not connected with each other. Figure 1 illustrates how an IT module may initially sit alongside other different subjects.

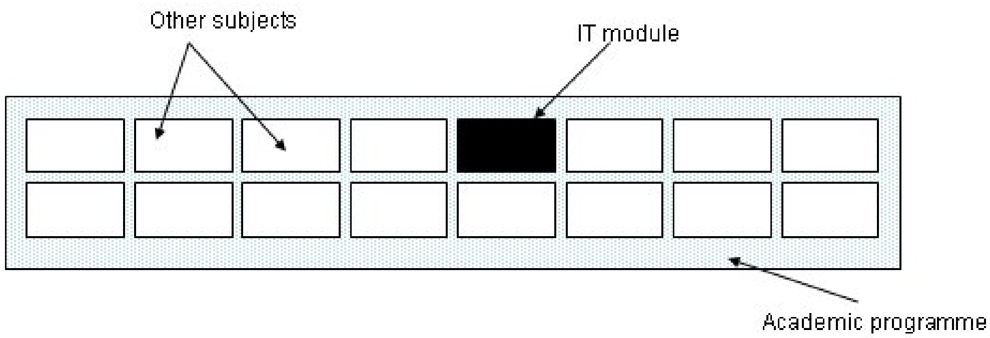


Figure 1. Traditional approach of IT as a separate subject of an academic programme

Software Selection and Progression Strategy

In addition to placing an IT module alongside other taught subjects within a programme, some consideration is necessary to place new technologies into the appropriate year of study. Students are entering universities increasingly computer literate and continual adjustment is being made to the IT components of programmes to acknowledge this. The chronological approach, adopted by the School of the Built Environment, introduces CAD/ visualisation as follows:

- Year 1 — 2D CAD (AutoCAD) - to provide accurate 2D representation of project design.
- Year 2 — 3D CAD (Revit) – building information modelling used for purposes of design, spatial assessment, visualisation, energy analysis and costing.
- Year 3 — Year in industry – to experience current practice.
- Year 4 — Virtual Reality (3dsMax, VR4Max, Stereoworks) – to enable interaction and depth perception when viewing design.

One of the criteria for software selection in the School of the Built Environment is that software is commercially available and used by industry. Software recently selected to introduce the factors of interactivity and immersion into 3D modelling is 3ds Max and VR4Max, selected as being suitable for VR for AEC applications. This strategic approach ensures that students are introduced to the underlying theory in each subject area, as well as developing knowledge and skills in applying the software. Having acquired this IT knowledge, students are encouraged to apply it in other subject areas, and demonstrate appropriate integration into their modular programme.

IT integration

Once students and staff develop familiarisation and confidence with a computer application, further integration into other subject areas evolves, and, to date, elements of IT appear in many modules throughout the School. Hence many IT applications develop from being introduced as subjects in their own right into component parts of other subjects in the curriculum (Figure 2).

This phased approach to the adoption of IT applications can lead to a change in the teaching methods of subjects, but it does not lead to a change in the curriculum as a whole, because in both of these models there still may not be any connection between separate subjects of the curriculum.

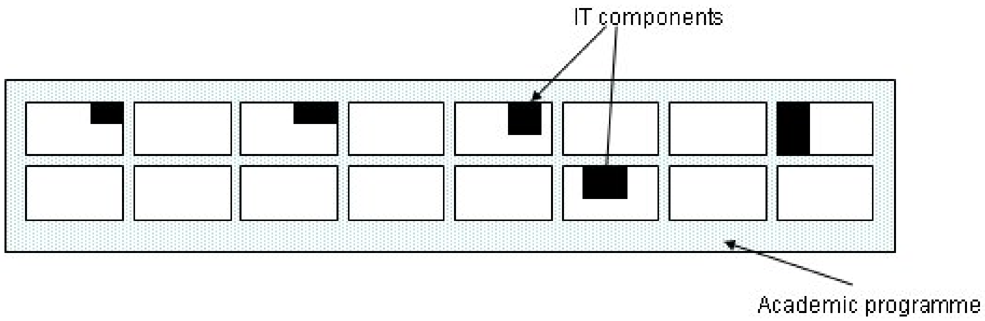


Figure 2. IT integrated into other Modules

An increasing demand for 3D computer modelling is one example of an application of IT being integrated across several disciplines in the School and some interesting applications are emerging.

Case Studies

Case Study 1: 3D Modelling for Design

Students on the final year of the BSc Architectural Design and Management programme are given an opportunity to apply 3D computer modelling to a design project. Figure 3 illustrates a student project with a chosen location of Forth Bank, Newcastle upon Tyne. This site has witnessed, over the centuries, a continuing process of industrial renewal and decay.

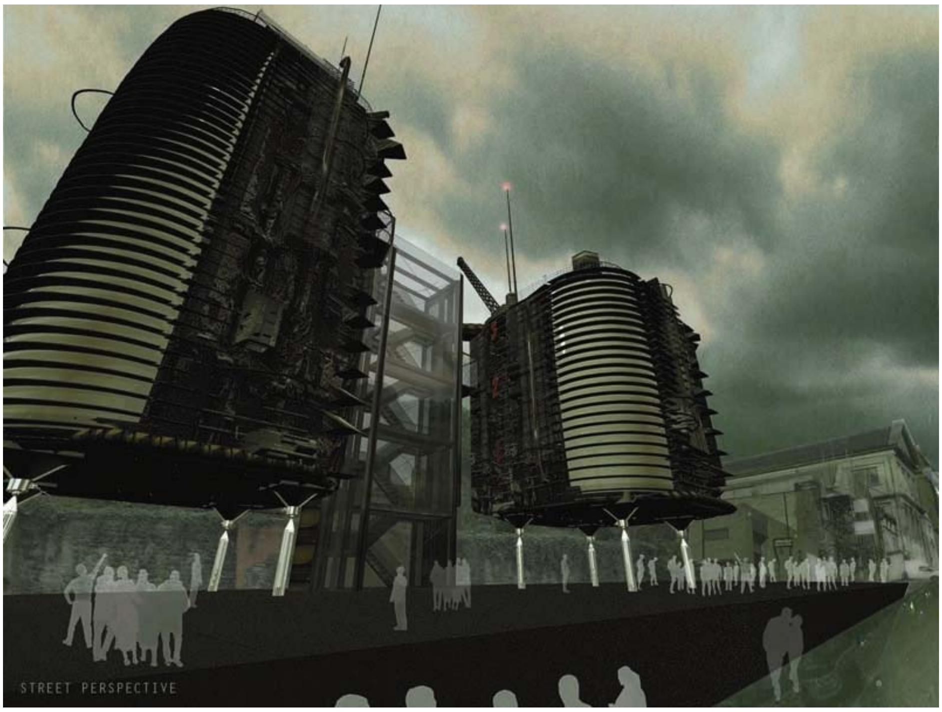


Figure 3. Forth Bank Gallery (Student: Oliver Jones)

The project was a physical narrative of this process: two post-industrial monuments, clad in a thick external crust of devices and services, stand defiantly in the face of the area's latest phase of decay and pending gratification. The crust preserves pure interiors from any external forces; the galleries only exhibit progress, in the form of exemplar products displaying technological and design advancement from around the world. The student visualised this project using traditional 2D representation as well as a 3D computer model developed in 3ds Max. The model was then imported into VR4MAX to enable interactivity and further design exploration.

Case Study 2: 3D Modelling for Construction

The role of the architectural technologist is emerging as the profession which can 'bridge the gap' between design and construction. Figure 4 illustrates a student project which created a fully interactive 3D model of a timber frame house. The end results communicated the technology of modern platform floor methods of timber frame construction. Students of architectural technology need to be able to 'analyse, synthesise and evaluate design factors in order to produce design solutions, which will satisfy performance, production and procurement criteria' (CIAT, 2005). CAD and VR are key subjects for the architectural technologist who needs to visualise and analyse new technologies and communicate options to various design teams and clients. The student imported files from AutoCAD into 3ds Max and then imported these into VR4Max to enable interactivity within the model. This model was also viewed in a semi-immersive passive stereo facility (Section 4 of Figure 4) which enabled a feeling of being immersed in the building.

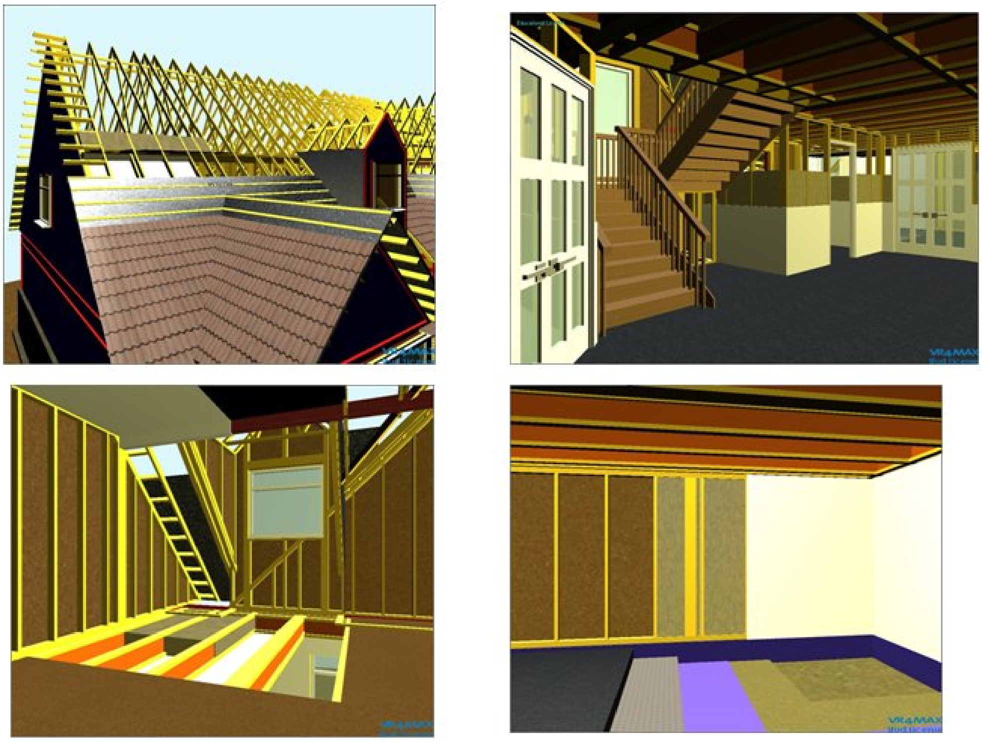


Figure 4. Fully interactive VR model of timber frame house showing construction details. (Student: Peter Jones)

Case Study 3: 3D Modelling for Building Services Analysis

Figure 5 illustrates work from a final year design project and is the culmination of the course of B.Eng. (Building Services Engineering). The project provided an opportunity for development of a major design, involving consideration of building environmental performance and building services systems design. The project was based upon simulated brief and architectural sketch scheme design ideas. The project provided the opportunity to apply the knowledge gained throughout the four year course and allowed for individual development of personal interests within a range of building services engineering topics.

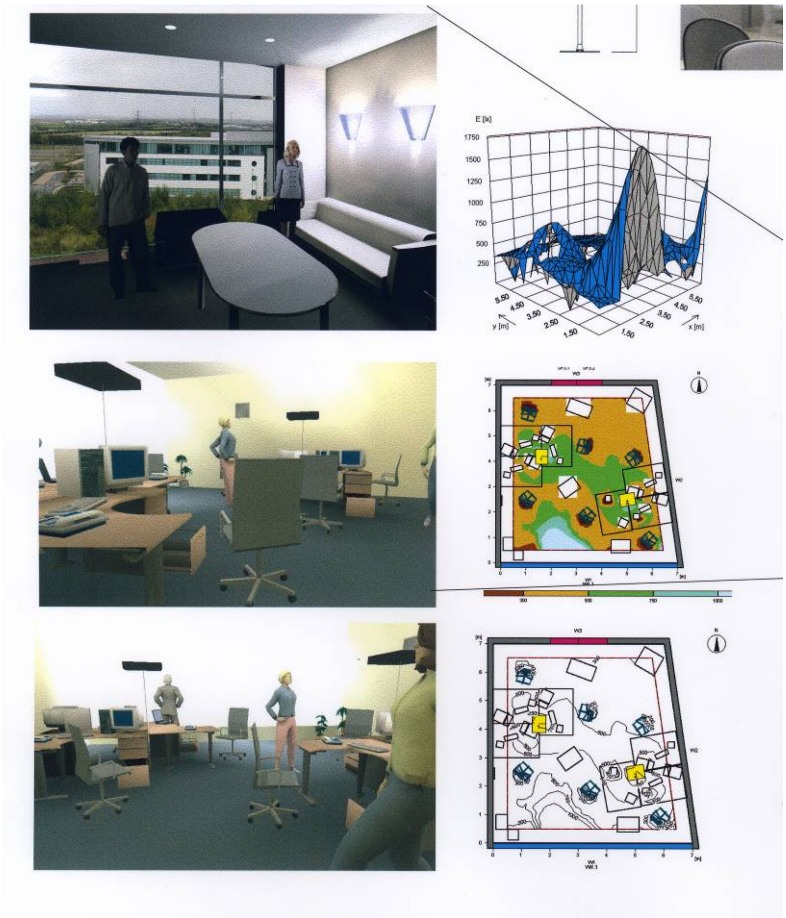
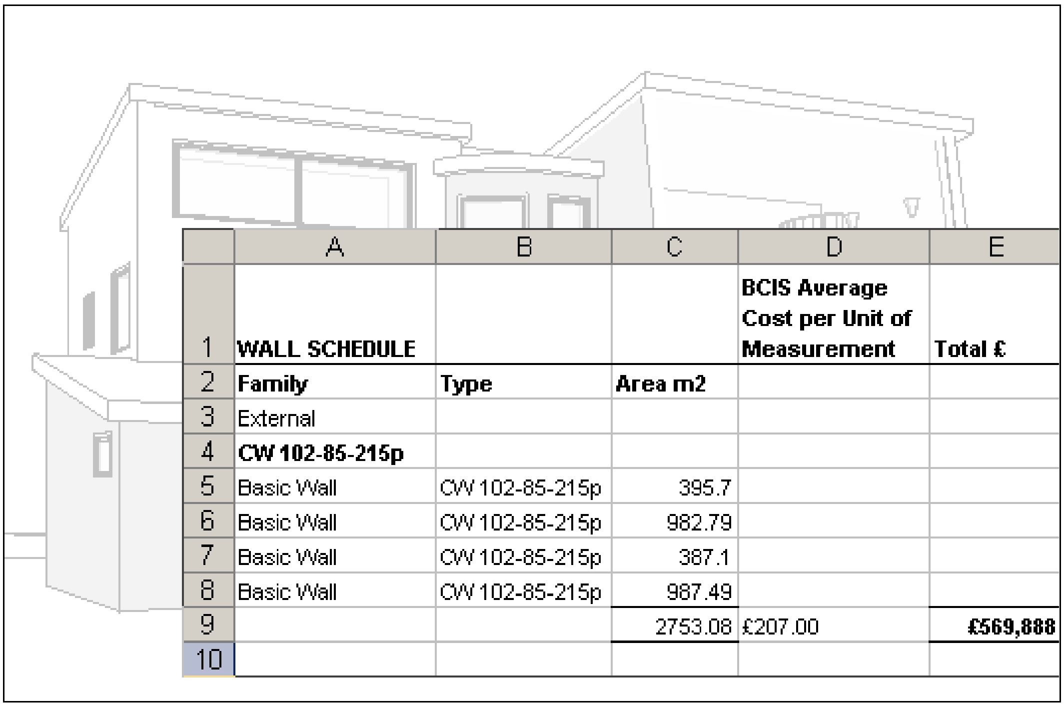


Figure 5. Lighting studies detailing the factors contributing to good lighting design for a successfully serviced media centre (Student: Edward Miley).

This study developed the requirements of a media centre through the initial stages of design, to establish effective building performance. In this case the student aimed for the building to achieve an Excellent BREEAM rating and he adopted a holistic approach and an understanding of ‘what the building was about’ before considering the selection of building services systems. Renewable opportunities were identified and high efficiency low/ zero carbon systems were matched to the buildings characteristics making for a sustainable centre incorporating energy cogeneration where practicable. He considered the relationship between natural and artificial lighting and produced detailed visual and numerical simulations to support his design ideas. Energy analysis simulations involved data transfer between AutoCAD, Revit and IES software.

Case Study 4: 3D Modelling for Quantity Surveying

Figure 6 illustrates how students of Quantity Surveying are learning to understand traditional cost control procedures through the design and construction of building projects. Students are encouraged to make extensive use of appropriate information and communication technologies (ICT) to search for, synthesise and abstract building cost data and to effectively manage the cost information on a construction project. 3D object oriented software is used to integrate design and cost information.



	A	B	C	D	E
1	**WALL SCHEDULE**			**BCIS Average Cost per Unit of Measurement**	**Total £**
2	**Family**	**Type**	**Area m2**		
3	External				
4	**CW 102-85-215p**				
5	Basic Wall	CW 102-85-215p	395.7		
6	Basic Wall	CW 102-85-215p	982.79		
7	Basic Wall	CW 102-85-215p	387.1		
8	Basic Wall	CW 102-85-215p	987.49		
9			2753.08	£207.00	**£569,888**
10					

Figure 6. External wall schedule converted into an estimate (Student: Mark Janney).

Revit is used with Year 2 surveying students as a tool for providing quantitative information which can be fed into the cost model for a building project. Students use the scheduling tool to generate quantities for significant elements of a project and import this information into a spreadsheet. Students are then tasked with sourcing matching cost information from an industry database in order to produce estimates for the building elements. The outcome involves an appreciation that the building model contains information which can be used for purposes beyond the drawn representation of the building, in this case the derivation of quantities for estimating. The process requires the students to examine the specification of the building element and therefore what the schedule quantities actually represent in order to be able to apply appropriate costs from another source.

Potential Contribution of IT to further Multi-Discipline Integration

The case studies outlined above are encouraging as they illustrate the interest and uptake of computer modelling applications in a multi-disciplinary school. Building Information Modelling, using Autodesk Revit, has been incorporated into modules which introduce design, visualisation, and costing and energy analysis. Hence, a new model is beginning to emerge (Figure 7) in which IT can play an integration role. However, IT itself doesn’t enable this communication if it is attached to separate modules and is not treated as a whole. This model can also lead to problems in some subject areas if students, having gained an appreciation of the multi-purpose capabilities of the software, apply it to other subjects prior to any underlying theory being covered. The classic ways of teaching some subjects need to be examined in order to manage and exploit the capabilities of the emerging IT technologies of interest to industry.

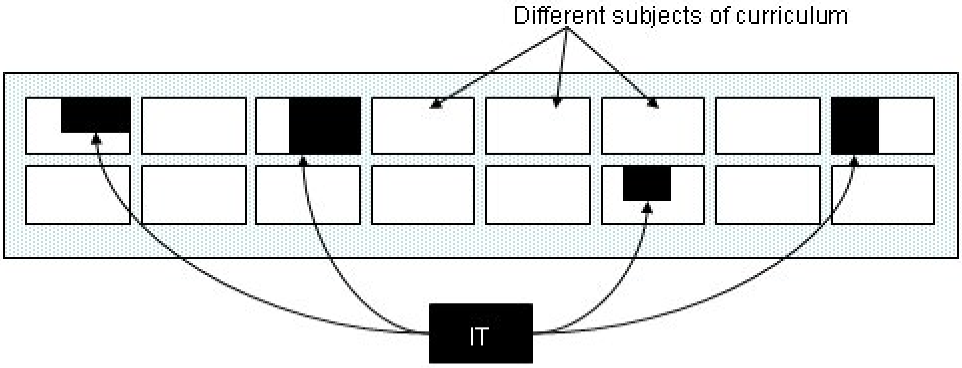


Figure 7. IT as an axis for academic curriculum integration

As long as IT applications are attached to separate modules and not treated as a whole, this situation will continue. However, technologies such as 3D CAD and VR are offering a chance for a more collaborative way of working and for students to work on the type of integrated projects they will meet in industry. The lessons to be learned from adopting a more integrated approach may lend themselves also to the progression from 3D to nD technologies, which have application throughout the complete building process, from design, management, construction and maintenance.

Figure 8 shows a model which brings all subjects into contact and enables exchange of information. Such a model will only be possible if we start to think of IT applications in a different way. Virtual Reality is one such technology which is beginning to demonstrate this, and should provide lessons for the introduction of nD modelling into the academic curriculum.

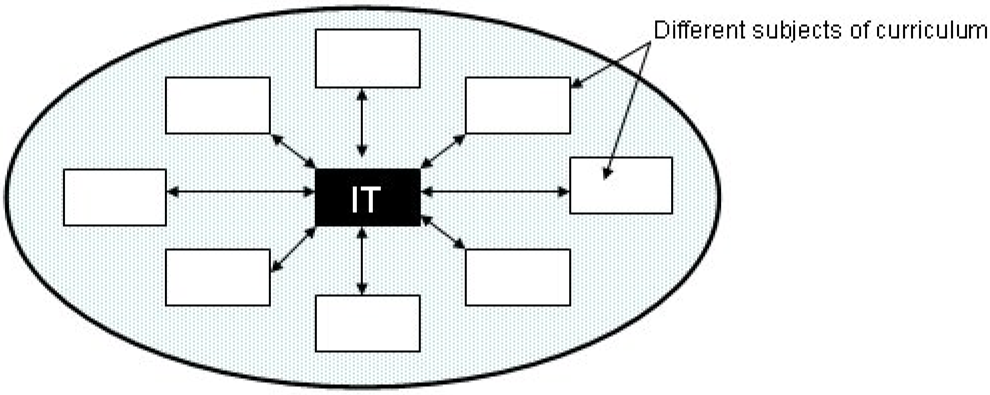


Figure 8. IT facilitating academic integration

Virtual Reality for collaborative working

VR adds the dimensions of *immersion* and *interactivity* to three-dimensional computer generated models. It enables the exploration of designs and the consideration of alternative options not offered by any other form of traditional representation. However the technology is still perceived by many as being inaccessible and cost prohibitive, but this is beginning to change and current lessons being learned in the implementation of

VR for higher education students could be applied for the subsequent implementation of nD enabled construction.

VR Systems

Virtual Reality can be of a type known as '*full sensory immersion*' where the user wears headsets and maybe gloves to gain a total immersive feeling of 'being' in a simulated environment. Applications of immersive VR have been seen in the fields of aeronautics, medicine and military applications – developed often at high cost by those whose need for a prototype was justified. To enable more participants to experience a simulated environment, a type of '*semi-immersive VR*' describes small cinema-like studios where audiences can share the feeling of being in a scene, although the navigation is usually in the hands of an experienced operator. CAVE installations can also be described as '*semi-immersive*' as the participants can be surrounded on three sides by screens onto which are projected images of a scene (Shiratuddin et al, 2004). A third type of VR is becoming known as '*desktop VR*' and the increasing power of PCs and graphics cards is making the technology accessible to those with computers typical of those found in many offices.

The performance of the computer hardware selected for VR has to be such that simulated scenes can be navigated in real-time and that users' exploration is not hampered by hardware limitations. Hardware needs to be compatible with software already in use and software planned to be used, and configurable to display the scene on a large screen system.

Considerable advances have been made in CAD software and architectural design programs such as AutoCAD, ArchiCAD, Revit, MicroStation and SketchUP. Commercially available VR software is capable of producing visual interpretations in real time which can enable the exploration of ideas and scenarios. There are have been a number of PC-based VR systems, including Superscape, VRML and World Tool Kit, tried for their suitability for use in the AEC sector. Some products are also being developed which offer VR as an 'add on' to CAD packages already widely used by the industry. As in the early days of CAD, software selection and implementation is far from straightforward as users are faced with many choices. A key criterion for selection is usually 'ease of use' which can be facilitated by choosing familiar computing environments and tried and tested commercial applications wherever possible (Otto et al, 2003).

Users of VR Systems

Successful implementation of VR begins by considering *who* will be the users of the facility and *how* it will be used. Various design decisions have to be made when considering a VR facility. The financial and human resource investment in implementing VR has to be balanced against the returns on any investment in computer hardware, software and space requirements for the VR facility.

The requirements of the users will also determine the location of a VR facility. Whilst a single mounted headset display may be the most appropriate type of VR simulation for flight simulation, in the AEC industry it is likely that VR will be used for collaborative purposes and the space and location should be designed with this in mind. The integration of hardware and software within the VR facility still remains in the hands of the VR specialists, but advances in computer PC hardware and software are resulting in more affordable systems which can be used by non-computer specialists.

Integration of Virtual Reality into the Academic Curriculum

Increasingly it is becoming acknowledged that visualisation can assist all AEC professionals, from the presentation of an initial concept to the effective planning, management and maintenance of a project (Bouchlaghem, 2005).

However, the relatively new profession of the architectural technologist has a specific need to be able to simulate and interact with a model in order to resolve both design and technical issues and to ensure optimum building performance and efficiency. Students of architectural technology have an immediate requirement to apply VR to enhance buildability and performance in their design projects. A stand-alone module entitled VR for the Built Environment was designed to offer progression from the introduction of CAD (Year 1), Building Information Modelling (Year 2), with VR strategically placed to be introduced to final year students. This module was designed to introduce students to the theoretical aspects of VR, including the planning, management, documentation and archiving of VR projects, as well as hands-on use of the software.

An approach was adopted to implement the integration of the knowledge and skills acquired in this VR module with the undergraduate architectural technology students' final year design project (Figure 9). This integrated approach was adopted to minimise the time pressures and risks on students, increase their motivation and encourage to them to apply the software to their discipline in a focused way.

The first group of twenty undergraduate architectural technology students in the School of the Built Environment to use VR did so from October 2004 to April 2005. Their degree is a 4 year modular programme structured around several core areas. IT provision had been introduced strategically alongside other modules, culminating in the integration of knowledge and skills within a design project.

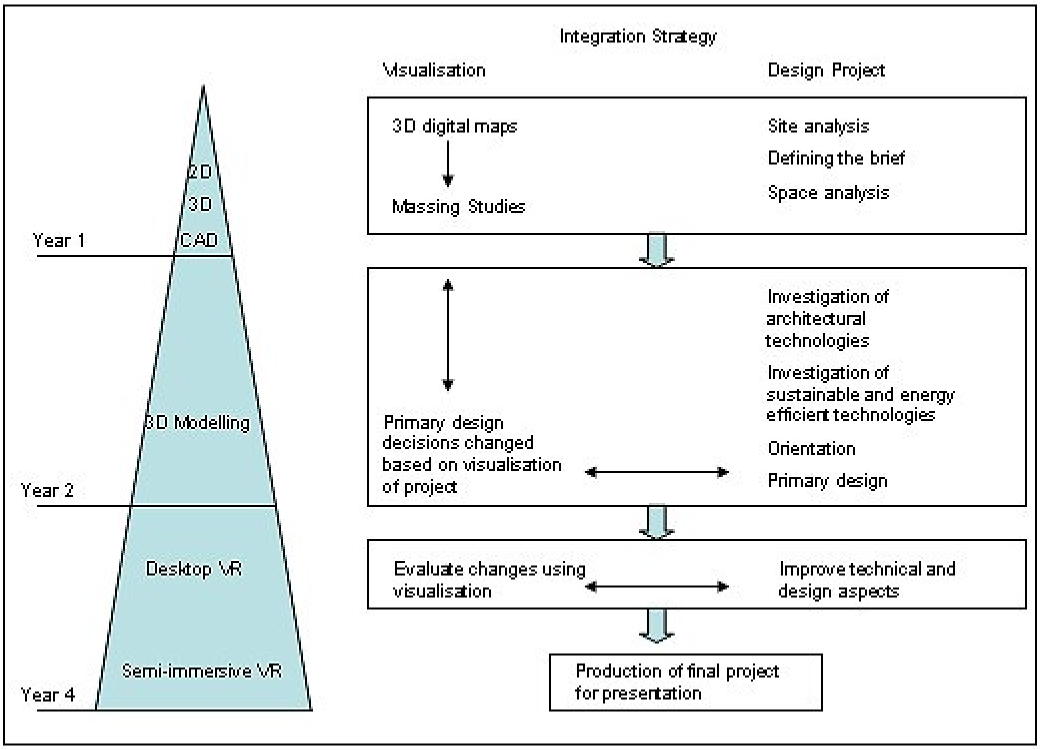


Figure 9. Integration Strategy of Visualisation into Architectural Technology Curriculum

Desktop VR facilities were introduced to provide access for up to thirty students. VR software (VR4Max) was chosen that could interface with the commercially available CAD and Visualisation software (AutoCAD and 3ds Max) already used in the School, enabling the direct transfer of data from traditional CAD systems into a VR application.

Collaborative Virtual Environment

In addition to desktop VR software installed in computer labs, the School has also implemented a semi-immersive Virtual Environment, located in a well-situated, central position to allow convenient access for students and staff. The facility can be used by groups of up to thirty participants and allows students to view their designs in stereoscopic format, from multiple viewpoints, and to navigate through space in real time. A cordless mouse allows user interaction with the system and a wireless control panel enables projectors, mono/ stereo display, lights and sound to be controlled from one convenient source. The familiar Windows desktop environment resulted in an immediate confidence by users to operate the system and encouraged other academics in the School to consider that the technology was not as ‘out of reach’ as they had perceived. The implementation of the semi-immersive Virtual Environment included the additional installation of six workstations to be used by students and staff specifically for 3D modelling and visualisation. This was seen as an important inclusion in order to maximise the use of the facility from the outset, to promote possibilities of collaboration, and to demonstrate potential applications of VR to projects.

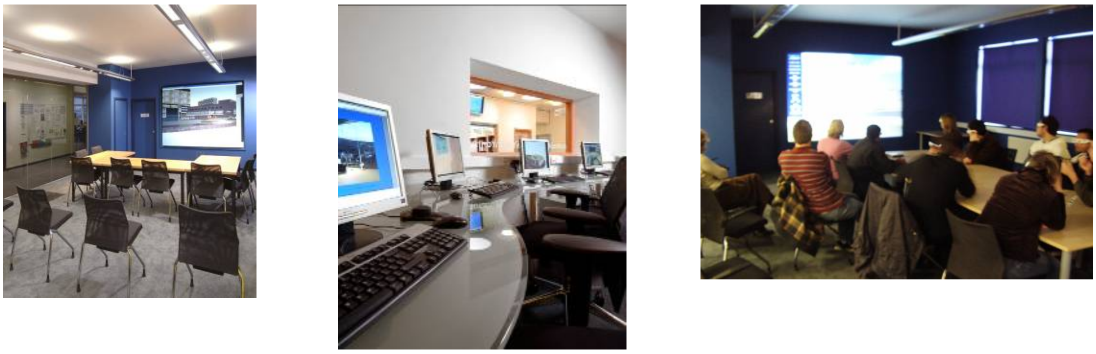


Figure 10. Collaborative Virtual Environment

The architectural technology students who had linked VR to their design project used the Virtual Environment for their final presentation and students presented their VR models alongside paper plans, sections, elevations and 2D renderings, supporting the view that VR, if used appropriately, supplements and extends other forms of traditional representation (Giddings, 2001). The process, end results and feedback from the students has provided valuable lessons which can be used in determining a correct integration methodology between two subject areas (Horne, 2006). The VR module and Design Project module were assessed separately to minimise the risk to students at this stage of investigation. Tutors noted that some students spent a longer time learning how to use the software, which affected their focus on design and choice of architectural technologies. Future integration for architectural technology will encourage the students to focus more on visualising the interface between various constructions and finishing materials. Also the development of further subject specific VR tutorial material and workshops will speed up the process of skill acquisition and enhance the appropriate application of the technology. Student feedback encouraged continuation of this integration with more emphasis on using visualisation for communicating the interface between materials and related operational and maintenance issues.

3D to nD

The approach outlined in this chapter has been focused on selecting and implementing appropriate technologies alongside the strategic integration of IT into the academic curriculum of built environment students. In the case of 3D CAD and VR it has shown that:

- 3D technologies must be selected first and foremost to be appropriate for the needs of the users.
- 3D technology is becoming less technically demanding and cost prohibitive.
- Fairly sophisticated 3D models can now be created by non-computer specialists using commercially available software.
- Increased student engagement in using 3D will enhance design and construction knowledge and extend traditional communication techniques.
- The careful selection of 3D CAD and VR systems may effect greater collaboration between AEC disciplines as visualisation develops to provide substantial integrative capability.

Further Integration

The Virtual Environment was used initially only by students of architectural technology, but is already finding a wider role, with 390 students from across the School having currently been introduced to its capabilities. Academic staff, initially apprehensive about the supposed complexity of VR, are showing acceptance of a technology which employs the familiar Windows operating system, uses wireless, unthreatening peripherals, and is conveniently located in an accessible location. Staff concerns centre on the constant need for training, necessary to keep abreast of what advancing technologies can offer. Nonetheless, after a series of staff awareness events, 3D applications are being proposed for development which could aid teaching and learning programmes throughout the School. It is anticipated that the facility will enable the exploration of possible benefits of 3D across a wide range of projects and disciplines.

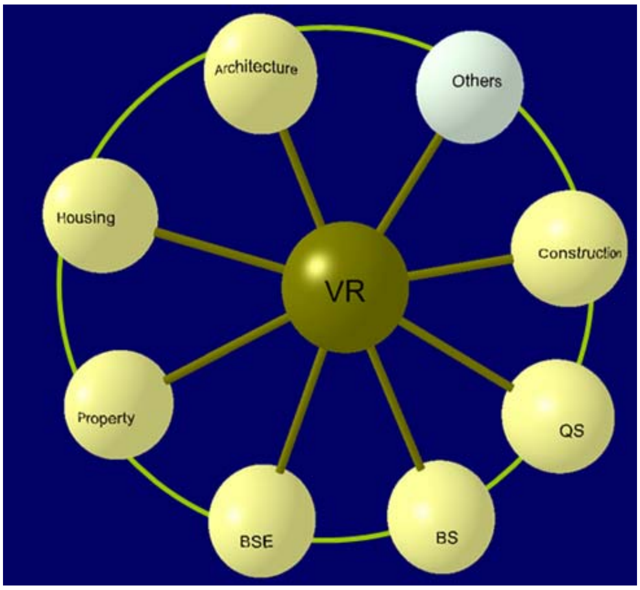


Figure 11. Integrative role of Virtual Reality for the Built Environment

As students and staff gain more confidence in the use of 3D we should see more widespread and earlier application.

VR Earlier in the Design Process

This chapter has illustrated how VR is beginning to be integrated in the design process of built environment students, yet it is often used after traditional visualisation techniques have taken place. However, the growing interest in 3D modelling technologies is resulting in emerging strategies for earlier adoption, subsequent evaluation, and potential for integration. The advent of parametric building information modelling software which considers massing elements and building elements (walls, columns, doors, windows etc) rather than geometric lines, points, faces and surfaces (as in traditional CAD software) heralds a new way of working. Evidence is emerging that adoption of building information modelling software is resulting in productivity gains of 40-100% during the first year (Khemlani, 2004). Students and staff who are being introduced to such software, such as Autodesk Revit, are beginning to appreciate its capabilities and potential to be used throughout a project. Whilst the three-dimensional models currently created with such software may still be too detailed to be used as VR models, some researchers believe that because the data is object-oriented it is easier to simplify or replace certain elements when used in a VR application (Roupé and Johansson, 2004).

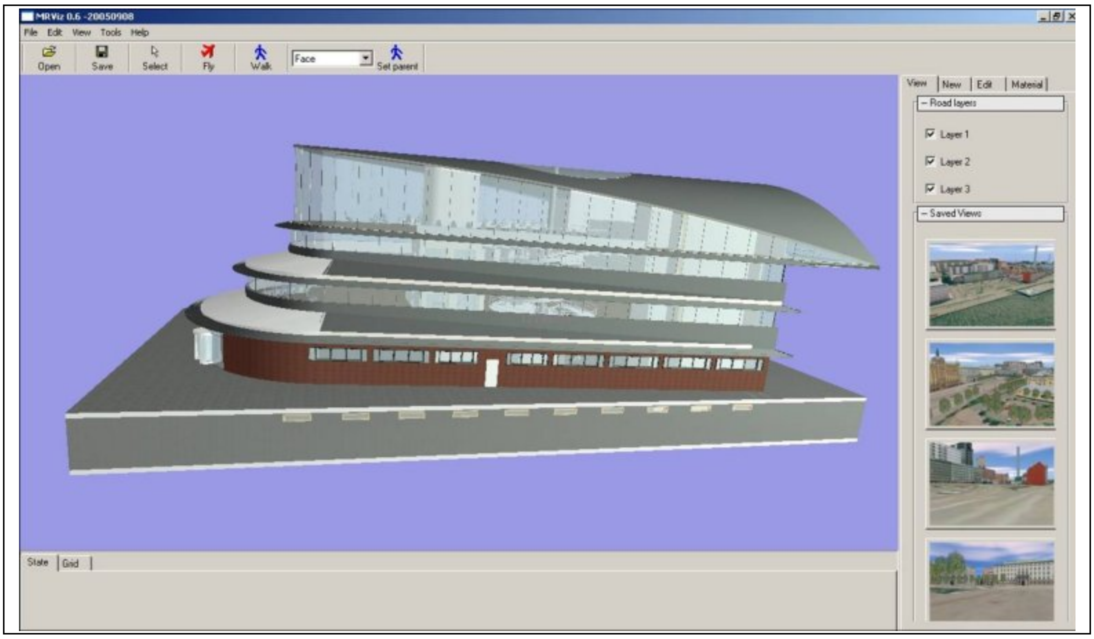


Figure 12. Student work transferred directly from Revit to VR application MrViz

This could extend the *nature of interaction* within VR models from that of navigation and ability to decide *what* to look at, to that of intuitive modification of objects (facades, trees, roads etc) at run-time whilst viewing the model. This extension would lend support for the belief that VR could be successfully applied to the earlier stages of design (Leigh et al, 1996) and offer the user greater control over the virtual environment, as is the case with CALVIN – an immersive approach to applying Virtual Reality in architectural design. As building information modelling is further adopted into the design process, and a new generation of students emerge into practice with 3D modelling skills, the demand for a seamless integration between building information modelling and VR will increase. The established divisions between software will become less distinct as technologies develop and blend into one another (Whyte, 2002).

Future Challenges

This chapter has outlined the classic modular approach in introducing new technologies into an academic curriculum. It has identified that it will be necessary to think of IT in a different way if we are to maximise the benefits that nD modelling can bring. For 2D-3D-4D-nD technologies to have a wider uptake will require a 'centralised' approach to their management and implementation throughout academic programmes and curricula. The introduction of nD modelling technology will require a change in the classic ways of teaching if it is to support the requirements of different disciplines, and facilitate and encourage a multi-discipline culture.

A systematic introduction of nD technologies into the academic curriculum of students across all disciplines of the built environment would enable the assessment of the benefits and feasibility of the technology. The School of the Built Environment is well-placed to integrate a multi-disciplinary project which involves participation from a range of built environment professions, each contributing their specialist knowledge and skills. This could help establish a foundation for a more detailed analysis of the implementation of nD modelling, including organisational and human issues, in higher education. The benefits and feasibility of nD modelling technology could be assessed via such a pilot study which would have the potential to prepare students for the future, and for an industry in pursuit of more widespread collaborative environments. Indeed, the more widespread uptake of nD modelling in industry will depend on how we teach it.

Acknowledgments

Undergraduate students Oliver Jones, Peter Jones, Edward Myers and Mark Janney whose projects appear in this paper, and their tutors Paul Jones, Steve Baty, John Thornton, Neveen Hamza and Derek Lavelle for supporting them in their application of new technologies, and permission to reproduce their work.

Senior Research Assistant Emine Thompson for furthering the application of VR in the School.

Funding for the Virtual Environment has been provided Professor David Fleming, Dean of the School of the Built Environment, Northumbria University.

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