Journal for Education in the Built Environment, Vol. 3, Issue 1, July 2008 pp. 5-24 (20)

ISSN: 1747-4205 (Online)

The Role of Virtual Reality in Built Environment Education

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Abstract

This study builds upon previous research on the integration of Virtual Reality (VR) within the built environment curriculum and aims to investigate the role of VR and three-dimensional (3D) computer modelling on learning and teaching in a school of the built environment. In order to achieve this aim, a number of academic experiences were analysed to explore the applicability and viability of 3D computer modelling and VR into built environment subject areas. Although two-dimensional (2D) representations have been greatly accepted by built environment professions and education, 3D computer representations and VR applications, offering interactivity and immersiveness, are not yet widely accepted. The study attempts to understand the values and challenges of integrating visualisation technologies into built environment teaching and investigates tutors' perceptions, opinions and concerns with respect to these technologies. The study reports on the integration process and considers how 3D computer modelling and VR technologies can combine with, and extend, the existing range of learning and teaching methods appropriate to different disciplines and programme areas.

Keywords: 3D Computer Modelling, Virtual Reality, Visualisation, Built Environment

Introduction

Technology is having more influence on education today than it has ever done. Students are entering higher education increasingly computer-literate, with high expectations that they will be introduced to appropriate technologies for their subject disciplines. Academic schools are challenged by these new technologies and require appropriate strategies for their effective integration and adoption. Such strategies should foster greater awareness and understanding of innovation, encouraging others to learn more and embed changes within the academic curriculum (Knight, 2006).

The use of computers in the built environment sector had a vast breakthrough in the mid-1960s with Ivan Sutherland's thesis (1963), "Sketchpad: A Man-machine Graphical Communications System" which introduced a highly precise computerised drawing system. This graphical tool made possible today's computer aided drafting (CAD) systems. Since that time, the impact of computers, both in education and in the professions, has become increasingly apparent and has resulted in much research and application. In particular, there emerged a specific need to identify the role computers could play in built environment education (Bridges, 1986). Bridges identified three basic elements involved in computing:

- the technology of computing;
- the application of computing in architecture and other built environment subjects; and
- the use of computing as a teaching resource.

The latter element raises some important issues for education, such as how, when, and what type of computing to introduce into the curriculum for built environment education. The initial inclusion of computer-related subjects as stand-alone modules in the structure of academic programmes can offer a way for students and staff to become more familiar and confident with computer applications. This can then result in further appropriate integration into other subject areas (Horne and Hamza, 2006).

Since many tasks in our everyday life depend on our ability to recognise the three-dimensionality of the environment around us (Dalgarno *et al.,* 2002), from conceptual design to the final product itself, it is important to be able to appreciate the built environment in this manner as well. Although the use of 2D CAD has been integrated into built environment curriculum for many years, 3D modelling and especially VR have not found extensive and frequent use in built environment education. Yet, it is argued that 3D virtual environments can provide a rich, interactive, engaging educational context, supporting experimental learning (Mantovani, 2003). A key potential role of virtual reality will be its use to teach a subject (Pantelidis, 1997).

It has been observed that the lack of mainstream acceptance of VR systems may have been because of a lack of availability of richly featured, discipline-specific, VR-enabled applications for use by non-programmers. Also the challenging programming environment for non-programmers, and a typically high cost of purchasing and maintaining VR facilities were perceived as barriers for the acceptance of VR (Otto *et al.,* 2002). Yet, more recently, the rapid advances in computer graphics technology are challenging the supposition that VR is unaffordable and inaccessible. It is now possible to implement *semi-immersive* VR facilities, small cinema-like studios where audiences can share the feeling of being in a scene, to meet a range of end-user requirements. The issues of successful implementation of new technologies are not simply financial or technical, but include the location of facilities, needs and types of users, and institutional business strategy which all play a part (Horne and Hamza, 2006). Additionally, any integration and application of visualisation technologies have to consider the pedagogical expectations of higher education (Hamza and Horne, 2006).

VR in Built Environment Education

The history of VR can be traced back to the early 1950s, although most key developments occurred in America during the 1980s (Stone, 1994). The possibilities for VR, previously considered unaffordable and inaccessible, requiring specialist facilities, were defined several years ago for architectural education (Alvarado and Maver, 1999). Since that time research into the use of Virtual Reality for design education (Achten *et al.,* 2004; Bourdakis and Charitos, 2002; Petric and Maver, 2003) and construction education (Haque, 2005; Shelbourn *et al.,* 2001) has been ongoing. More recently, research has focused specifically on the integration of commercially available VR technologies within a broader built environment curriculum (Horne and Hamza, 2006) and raised issues relating to effective integration and application.

Ellis *et al.* (2006) believe that information technology has the potential to enhance the quality of educational experience for all students and ongoing work on the development of a virtual construction site project, *Virtualsite,* is demonstrating favourable reactions from those students introduced to new technologies. Virtualsite adopted a multi-media approach, combining digital images, video, sound and interactive panoramic scenes to create on-line virtual construction site tours for students. A recent discussion of teaching and learning approaches in built environment education has emphasised the role of visualisations and graphic representations to enhance students' learning experiences (Frank, 2005).

Aims and Objectives

This paper aims to further explore the issues of integrating 3D computer visualisation and VR technologies in built environment education. The project builds on previous research which has focused on selecting and implementing appropriate VR strategies and technologies, as well as exploring the pedagogical benefits of integration into the curriculum.

The paper has the following objectives:

- to consider why 3D computer modelling and VR technologies are justified for built environment education;
- to describe how 3D computer modelling and VR may be integrated into built environment teaching and learning;

- to identify the challenges, perceived benefits of and barriers to the use of 3D computer modelling and VR in built environment education.

Methodology

This study presents data that was gathered from September 2005 from a research project designed to further VR integration in the School of the Built Environment, Northumbria University. A strategic, systematic approach was adopted to raise awareness of VR technologies in the School. A series of staff development events were held in the School's semi-immersive Virtual Environment and staff were informed about different types of VR and potential applications for the built environment. Academic staff were encouraged to propose further ideas and suggestions for the integration of 3D modelling and VR into their teaching and learning, and all suggestions were recorded into a database where their proposals could be systematically stored and readily accessed.

Forty-four projects were developed for staff across the School, and twelve of these were selected for analysis in this study. The method of selection focussed on examples of academic practice where 3D modelling and VR were being used to extend traditional forms of representation and enhance the students' learning experience. Projects were developed using commercially available 3D-modelling and VR software. Qualitative research methods were seen as the most suitable way of collecting, analysing and reporting data for this study in order to understand the attitudes, perceptions, opinions and concerns of academic staff with regard to use of 3D and VR technologies in their teaching. A total of 11 semi-structured interviews were conducted with key participants involved in the integration of 3D technologies into the built environment curriculum. Each interview lasted one hour and was audio-taped to facilitate data analysis. The interviews were then transcribed and analysed. The interview questions were designed to gather data systematically, although it should also be acknowledged that the researchers' experiences, thoughts and beliefs inevitably played a part in the final analysis. The following concepts were accepted as the basis of the interview process:

> Although there are a lot of superficial similarities between a conversation and an interview, interviews are actually something more than just a conversation. Interviews involve a set of assumptions and understanding about the situation which are not normally associated with a casual conversation. When someone agrees to take part in a research interview:
>
> - There is consent to take part – an agreement to be interviewed generally means that there is informed consent;
> - The interviewee's word can be treated as 'on the record' and 'for the record';
> - The agenda for the discussion is set by the researcher.
>
> (Denscombe, 1998, p.109).

Throughout the period of this study professional relationships were developed and maintained with VR suppliers, VR modellers and VR researchers who offered insight and case study projects for educational purposes. These supplemented the models which were developed internally and which are outlined in this paper.

The Justification for Visualisation Technologies

Visualisation in any architecture, engineering and construction (AEC) subjects is not an end in itself. As Bouchlaghem *et al.* (2005, p. 287) explain "the process of design and visualisation should be iterative, with changes made as a result of insights gained through visualisation propagated into the next version of the design" and as they continue to explain, (2005, p. 287) this "collaborative building design requires a shared understanding to be reached between all parties involved". Furthermore as Messner and Horman, (2003, p. 146) point out "observing and experimenting with the building construction process" is very important but "it is difficult to provide this opportunity to the students in an educational setting". With 3D, 4D and VR visualisations "students can experiment with different 'what-if' scenarios and actively discover unique solutions to construction planning challenges" (Messner and Horman 2003, p. 146). As Mantovani (2003, p. 213) indicates "the point is no more to establish whether VR is useful or not for education; the focus is instead on understanding how to design and use VR to support the learning process".

The authors believe that 3D modelling and VR technology can be useful in built environment education in order to:

- prototype buildings, sites and cities;
- demonstrate features and processes involved in built environment subjects more specifically;
- allow users to observe and interact with the buildings, designs, concepts in their entirety or as partial close-up views. It also allows easy changeover between these different views;
- provide motivation and make learning experiences more interesting;
- allow users to experience a sense of immersiveness in the buildings, designs and concepts;
- offer an alternative when site visits etc are costly and hard to arrange because of health and safety issues.

Virtual Reality can be used when teaching using the real thing is dangerous, impossible, inconvenient, too time-consuming or too costly (Pantelidis, 1997). In order to establish a shared understanding of the built environment between diverse professions, different representations of the real world, such as sketches, scale models, drawings, photomontages etc. are being introduced into academic programmes, and built environment students are made familiar with these techniques. However, it is also imperative that students should have some knowledge of new, emerging technologies appropriate to their subject discipline in order to extend their understanding of the built environment.

How can VR be Integrated into the Curriculum?

The School of the Built Environment, Northumbria University, provides undergraduate and postgraduate degrees in architecture, architectural technology, construction, building services engineering, building surveying, estate management, housing, project management, and quantity surveying. Two-dimensional CAD was introduced into the academic curriculum in 1990 and this has become well integrated and applied throughout the School. In 2003 the School implemented a strategy to embed 3D computer modelling and VR technologies into the academic curriculum of its multi-discipline degree programmes. Building Information Modelling (BIM) and VR technologies were selected, and modules were designed to introduce both the theoretical and hands-on use of these technologies to students (Horne and Thompson, 2006). VR was selected to extend the traditional forms of representation by offering *interactivity* and *immersiveness* in the simulations of buildings, sites, cities and landscapes. The School's semi-immersive VR facility, called the "Virtual Environment", was commissioned during 2005. After careful consideration of location and the needs of users, the facility was centrally situated in the heart of the School, to allow easy access and to promote this technology to students, staff and visitors. The Virtual Environment consists of a projection room and a presentation room (Figure 1).

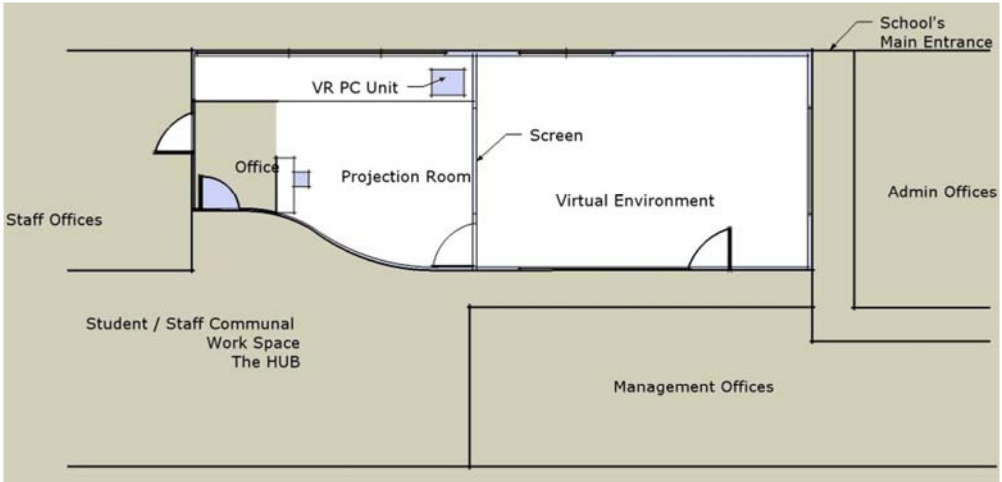

Figure 1 Sketch of the location and the arrangement of the Virtual Environment in the School of the Built Environment

The VR facility was designed to be used by groups of up to thirty participants and to allow staff and students to view designs in stereoscopic format, from multiple viewpoints, and navigate through space in real time. The aim from the outset was to foster VR applications across all disciplines within the School and to encourage collaboration with local practices and other researchers. 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.

Raising awareness

The integration process involved raising awareness amongst academic staff of VR as another teaching tool across the built environment subject fields. The School selected desktop VR and semi-immersive VR technologies as appropriate types of VR to be used by students and academics. The approach of developing links with software companies and built environment professional practices offered real-world case studies and applications of VR which illustrated how the technology could be applied. Figure 2 shows how VR relates to all the subject areas within the School. The technology has the ability to assist the teaching process, enabling students to view and interact with the concepts they are working on in 3D immersive environments, and there are applications for all built environment subject areas.

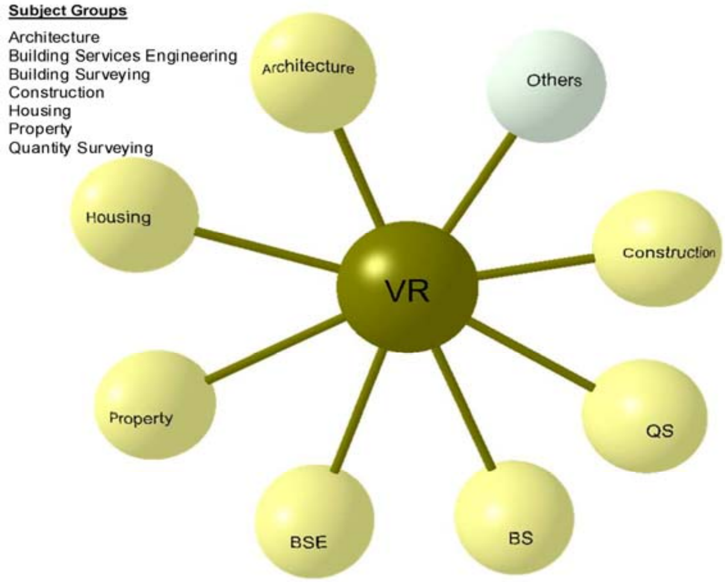

Figure 2 VR and built environment subject areas

Ausburn and Ausburn (2004) suggest some simple steps to introduce VR to tutors:

- acquaint tutors with the basic characteristics of VR;
- discuss benefits, strengths, limitations and problems with VR in teaching and learning;
- provide an overview of the types of VR systems;
- have tutors use the VR systems in their own industries and share the outcomes with each other;
- discuss how they might apply VR in their own programmes;
- include VR in curriculum development;
- encourage them to explore VR technologies and how to use them effectively; and
- assist them in hands-on developments.

This approach was adopted in the integration process described in this study. In order to raise awareness of the capabilities of the technology, an exemplar project was developed by creating a VR model of the University campus, followed by a systematic programme of staff development events. These events informed academic staff across the School about the potential of the technology, the types of VR available, and the possibilities that it could offer to enhance teaching and learning activities and students' learning experiences.

Establishing needs

The process of systematically contacting staff and collecting ideas was formally started in September 2005. Informal discussions with staff led to individual meetings with interested academics. Ideas were systemically recorded and stored in a Microsoft Access relational database where data could be easily accessed and quantified (Figure 3).

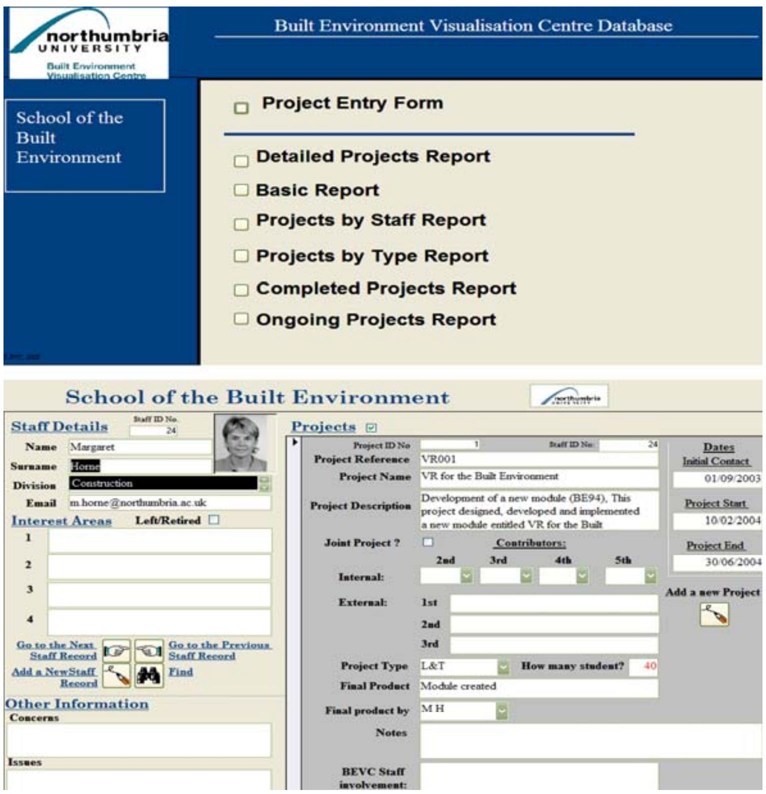

Figure 3 Opening page and project entry form of the database

Ideas for projects were entered onto the Project Entry form on this database and different reports were created from the gathered data. Projects were classified under five categories: Learning and Teaching (L&T), Continued Professional Development (CPD), Research, Management/Strategy, and Staff Development. Each project was allocated a project number and name, along with a start and an end date. A small project description was also noted onto the system.

A total of 44 projects to enhance teaching and learning were suggested and, within a period of six months, half were completed with the end results integrated into the curricula of various subject areas across the School. This study now describes a selection of the projects to illustrate the range of applications for different built environment subjects and how they are being used to support student learning of concepts that have often been difficult to understand via traditional methods.

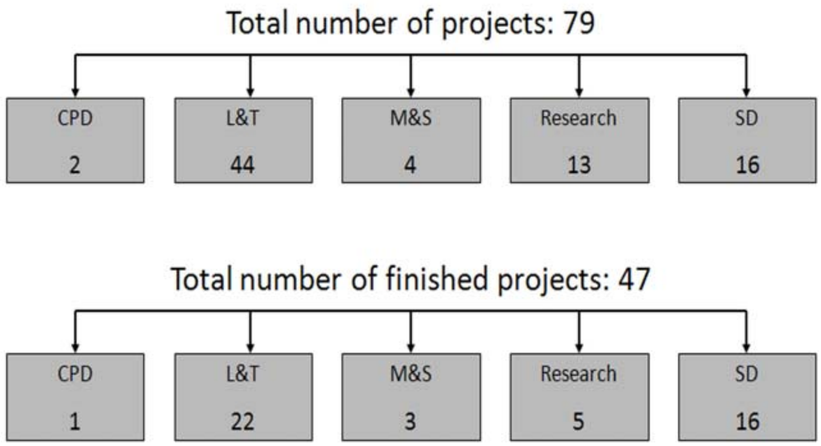

Figure 4 Total and completed VR and 3D visualisation projects across the School

Areas of the curriculum which have been supported by 3D modelling or VR are shown in Figure 5. Those areas further discussed in this paper are denoted with an asterix.

Property Marketing (Residential) (Commercial)*	Year 2
Commercial Property Marketing	Year 2
Measurement, Surveying and Drawing Skills*	Year 1
Site Surveying*	Year 2
The Evolution of the Built Environment	Year 1
Project Information Systems	Postgraduate
Construction Economics	Year 2
Town and Country Planning *	Year 2
Design Technology and Procedure	Year 2
Professional Practice (AT)	Year 2
Architectural Technology Design Project *	Final Year
Building Surveying Project	Final Year
Professional Practice Project	Year 2
The Building Envelope and Environmental Service	Year 2
Measurement and Co-ordinated Project Information *	Year 1

Figure 5 Academic programmes supported by 3D modelling or VR

Case studies

Measurement, Surveying and Drawing Skills

This project is based on the translation of 2D representations into a 3D form. Originally, students were given 2D plans of a model (Figure 6-A), and asked to describe the 3D shape by explaining the object outline and hidden lines etc. Students found it very hard to visualise the 3D shape and therefore a 3D model of the object and section drawings of the object were created in order to help to students in this interpretation process.

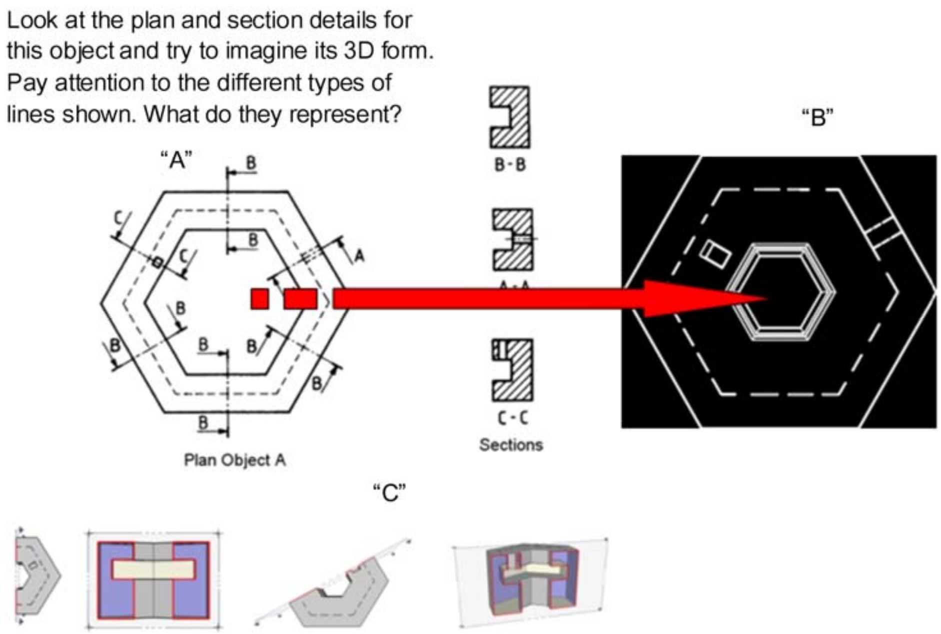

Figure 6 Example project, showing the original drawing, "A", and the 3D model of the object "B" and "C"

Site Surveying

This model was used as an example of vertical control points that can be used to establish design points during construction. It demonstrated the use of sight rails in conjunction with a traveller to control the excavation levels in a trench for a drainage run. The model helps to explain the calculations required to determine suitable traveller lengths. It also visually depicts the use of the traveller in conjunction with the sight rails in determining whether the excavation is at the correct level. The model is more effective at demonstrating how the information is being used than any 2D drawing or description.

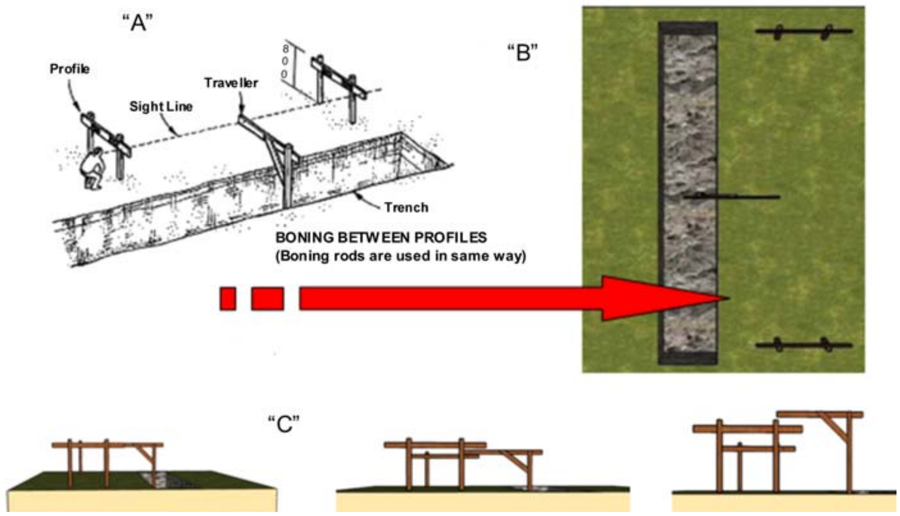

Figure 7 Example project, showing a visual demonstration as to how "B", a plan view, can give wrong information because it is impossible to guess different heights as shown in "C"

Measurement and Co-ordinated Project Information

This model was used as an example of showing sub-structures and translating 2D plan information into a 3D form. Students received a drawing in two dimensions and were asked to visualise it in 3D. Some students found this very difficult. Students need to be able to appreciate a 2D plan and gain an understanding of what is actually happening when looking at sub-structures and earthwork supports.

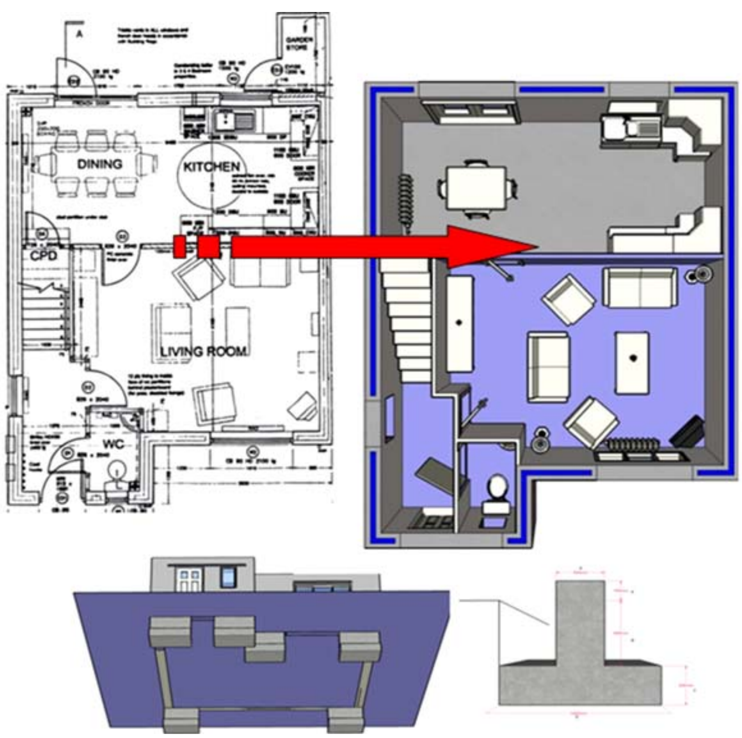

Figure 8 Example project for Measurement and Co-ordinated Project Information module

Property Marketing (Residential) and Property Marketing (Commercial)

In this project the advantages of using 3D and VR technology in the property marketing sector were investigated and examples were compiled for presentation purposes. These were shown to students to inform them of how both residential and commercial property marketing practices were applying 3D technologies. Two approaches were identified. The first approach was the creation of a 3D computer model of a proposed scheme, in order to show potential purchasers what a future property would look like. The second approach, used to visualise existing properties, was the creation of Quicktime VR models produced by digitally stitching together several digital photographs.

Figure 9 Example project for Property Marketing (Residential) and Property Marketing (Commercial) modules

Architectural Technology Design Project

Final year students of Architectural Technology have a specific need to resolve both technical and design issues in order to ensure optimum building performance and efficiency. This project applied their knowledge of VR, both theory and practice, to interact with their designs in a way that had not been possible previously. Students programmed behaviours into their models which enabled the exploration of external and internal cladding options, movement of doors, vehicles, elevators, etc and simulation of air flow. Such behaviours provided the perception of immersiveness when navigating around the models using stereoscopic projection in the Virtual Environment. Figure 10 shows the end results of fully immersive, interactive VR models of sustainable designs.

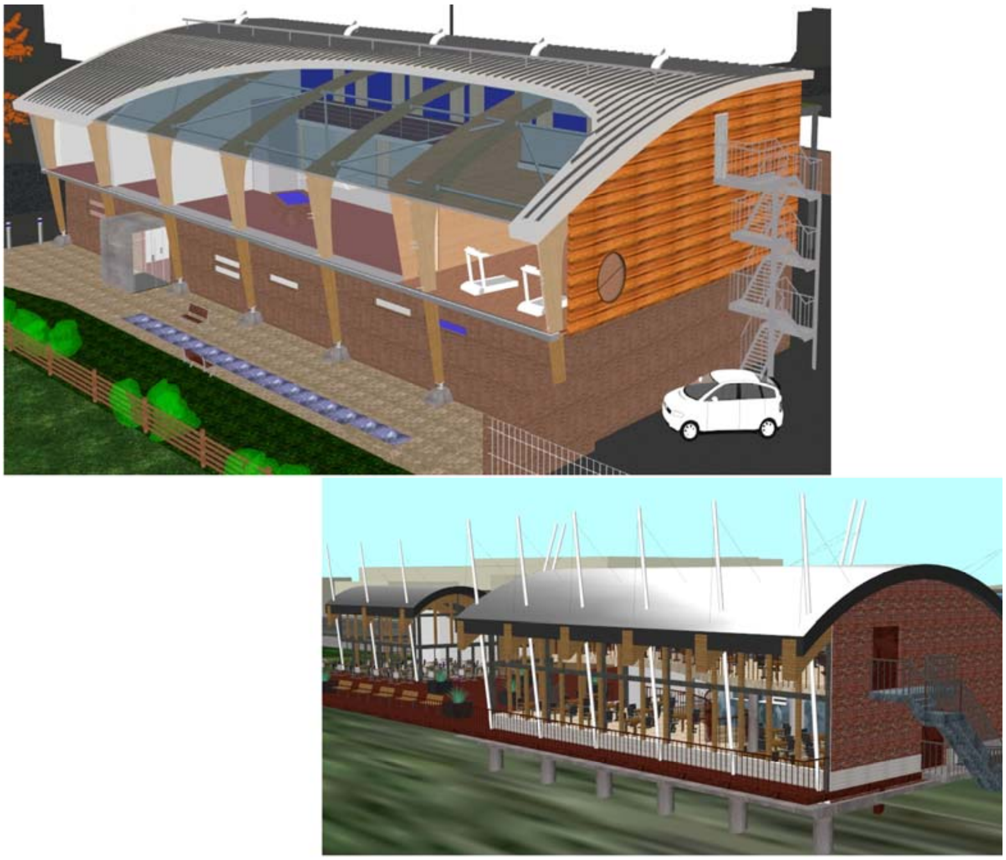

Figure 10 Student VR projects from Architectural Technology Design Project module

Town and Country Planning Project

Two interactive VR models were provided by a professional practice of landscape architects to illustrate how VR technologies have been applied for planning consultation purposes and environmental impact assessment studies. The academic tutor learnt how to interact with and navigate these models in the Virtual Environment and used them to explain important issues and concepts to students.

Figure 11 VR model from professional practice used in Town and Country Planning module

Challenges

Although there are clear advantages in using 3D visualisation and VR technology in built environment subjects, there are also several challenges in the integration process.

Until recently one of the major disincentives of implementing VR technology in higher education was the cost of display equipment and computers. However, with recent technological developments, it is now possible to base VR systems on familiar and affordable Windows operating systems. This encourages non-technical staff to become involved and to consider potential applications.

Software selection and up-date is also a challenge for any integration of visualisation technology. It is necessary to select the most appropriate software at the right time, and to keep it up-to-date with the ever advancing technology. Extensive research should be done before introducing any software, and good technical support is an essential part of this process.

Another major challenge is introducing change to a wider group where existing working practices may need to be modified. A structured and consistent approach can demonstrate the advantages of any new technologies. It is necessary to educate tutors in this technology; this is increasingly difficult when time is limited because of existing commitments.

Analysis and Discussion

There is some evidence that VR can contribute to increased interest and motivation in students, and to support knowledge transfer effectively, since the learning process can be settled within an experiential framework (Mantovani, 2003). The introductory knowledge transfer regarding VR and 3D modelling took place in five categories in this study:

- presentations, demonstrations;
- creation of specific models/presentations for tutors to use;
- lecture and seminar series;
- existing VR models provided by built environment professional practices for use by module tutors.
- VR and 3D modelling integration at a structured level.

Although there were different levels of integration throughout the modules, it should be pointed out that during the interview process there was a general positive reaction towards VR and 3D modelling application in the built environment subjects taught.

Themes emerging from interviews

The following themes were identified by analysis of the transcribed interview recordings. During the content analysis of these transcripts, similar beliefs, perceptions and concerns were collated under the following headings:

- VR and 3D visualisation in the built environment curriculum;
- tutors' initial perception towards 3D and VR technologies;
- tutors' requirements after the initial integration with 3D and VR technologies; and
- tutors' concerns.

These themes linked with the information gathered throughout the literature review.

VR and 3D visualisation in the built environment curriculum

The tutors who were involved in this study can be categorised in two main groups. The first group had already introduced a significant level of 2D and or 3D computer visualisation into their teaching curriculum. The second group consists of tutors who wished to develop better understanding of their subject areas by adapting new technologies into their teaching environments. These groups were not intentionally selected in this manner but fell naturally into these two main groups. Although the tutors came from different backgrounds and subject fields and their visualisation software capabilities differed widely, the interest they showed towards the VR and 3D visualisation area were similar. There were two main focuses in using this technology in their teaching. The first one was that, by using available technology, they discovered that they could explain complex issues in a much easier way. They believed that as a communication tool, VR and 3D visualisation would improve students' understanding of built environment elements. The second focus was that they wanted the students to be exposed to this technology. So, by at least introducing the technology and helping students become aware of its capabilities, they believed that students would make use of it during their professional careers.

Tutors' initial perceptions towards 3D and VR technologies

Although some tutors had initial uncertainty and apprehension towards the technology and the VR facility itself, this changed rapidly when they were taken through the introduction and implementation stages with informal discussions and presentations. The next logical step was for some of the tutors to begin to integrate the technology in their teaching activities. Some thought that VR would allow them to enrich the student experience and would result in students becoming more involved in the subject fields they were studying. Tutors also thought that, overall, the technology and the facility was an attractive and valuable resource to use in their teaching activities.

Tutors' requirements after the initial integration with 3D and VR technologies

More integration was, by and large, the general requirement of the tutors. The need for more integration ranges from a need for more detailed and developed models to use in their teaching, to establishing hands-on sessions for more students to use the 3D modelling and VR software. They also wish to be able to demonstrate to students applications of VR currently used in practice. Although digital media usage varies broadly in the different subject areas, and the use of AutoCAD, or any other 2 or 3D visualisation software, is not a requirement for every subject, a basic introduction to 3D and VR visualisation was requested. Tutors suggested involvement at this stage could only be achieved by enhancing existing modules they run with 3D and VR visualisation lectures and tutorials. Whilst hands-on sessions for students were a general request, the need for different, flexible levels of involvement was apparent. It can be said that, according to the different subject groups, there is a need for a varying degree of intensity for the lectures and tutorials. Some academic tutors expressed a wish to learn how to use the 3D modelling software themselves, so that they could use and create basic models. They also expressed a wish to be able to use the Virtual Environment themselves.

Tutors' concerns

The main concern was the time and timetabling arrangements that would be necessary to effect further integration. Time to develop ideas and integrate these into already crowded curriculum was one of the main issues. Another main concern for some of the tutors was the high number of students requiring some level of hands-on sessions to apply the technology in a practical way, and the way the School could manage and accommodate this.

Conclusion and Recommendations

This study sought to investigate the effects of VR and 3D computer modelling on learning and teaching in a school of the built environment. The benefits of using a systematic approach in recording ideas for possible applications were evident and aided the development of projects utilising the technology. A number of academic experiences were analysed to explore the usefulness and viability of 3D modelling applied to various subject areas. The reviewed case studies related to ways that the technology could aid communication to, and from, students. The benefits of using visualisation technologies were seen as having enabled academic built environment tutors to support students' learning. Finding effective ways to use technology to enhance learning is a challenge that educators, academics, policymakers and the technology industry must work together to solve (Gates, 2002). The approach of developing links with software companies and built environment professional practices can offer real-world case studies and applications which, if effectively integrated, can increase both staff awareness as well as students' motivation and learning. The benefits of using VR and 3D modelling technologies are varied, but were seen as having the potential to improve and extend the learning process, increase student motivation and awareness, and add to the diversity of teaching methods.

The difficulties and barriers encountered to date were not so much concerned with technical issues but more with organisational issues. The selected technical specification for the Virtual Environment and supportive 3D modelling software has proved to be reliable and stable, and compatible with that used in industry, and this has facilitated model exchange. The study found that the greatest problem at present is lack of available time for academic tutors and the support staff involved in the integration process. In time, with higher demand for integration in several subject fields, there will be a need for more personnel who can help with this process.

Time limitations of this study have resulted in an evaluation of the integration of 3D modelling and VR so far confined to interviewing those academic tutors who showed positive interest and support after attending staff awareness events. To determine the extent of opinion across the School would have necessitated the gathering of feedback from tutors with less positive reactions, and this was beyond the scope of this study. However, this would enable a clearer picture to emerge about other issues and concerns regarding the value of the technology to improve students' learning. Nonetheless the study has demonstrated that a well planned, systematic approach supported by a carefully designed strategy, is very important to ensure new technology is embedded and integrated strategically into the curriculum effectively.

Future Work

Future work will include a more formal evaluation of the effectiveness of the integration, and further evaluation of the benefits to students' learning. It will also report on further use of advancing technologies and the challenges of integrating these into the academic curriculum of a school of the built environment. Further development of the project ideas which were compiled into the database is ongoing and will result in additional case study material. The establishment of a repository of 3D and VR models for built environment learning and teaching, which could be shared between other schools of the built environment, is a major project which would need to be undertaken separately.

Acknowledgements

Academic staff interviewees: Andy Dunhill, Kevin Elliot, Claire Fallow, Peter Fisher, Minnie Fraser, Neveen Hamza, Derek Lavelle, Elaine Paterson, Simon Robson, Susan Weinder, and Craig Wilson for giving their views openly and for their time. Student projects: James

Charlton and Martin Podevyn for excellent application of VR to design projects. Professional practices Insite Environments, now part of SLR Consulting, and Space, formerly known as Waring and Netts, for granting permissions to use models from practice for educational purposes. School of the Built Environment for funding the Virtual Environment.

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