VIRTUAL REALITY AND 3D MODELLING 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 Virtual Reality 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 Virtual Reality (VR) into built environment subject areas. Although two-dimensional representations have been greatly accepted by built environment professions and education, three-dimensional computer representations and VR applications, offering interactivity and immersiveness, are not yet widely accepted. The project builds on previous studies which focused on selecting and implementing appropriate VR strategies and technologies (Horne and Hamza, 2006) and offers an approach on how three-dimensional computer modelling and virtual reality may be integrated into built environment teaching. It identifies the challenges and perceived benefits of doing so by academic staff and reports on the systematic approach which was adopted by Northumbria University, School of the Built Environment, to raise awareness of VR technologies across the spectrum of built environment disciplines. A selection of case studies is presented which illustrate how VR and 3D modelling have been integrated to extend traditional forms of representation and enhance the students' learning experience. The attitudes perceptions, opinions and concerns of academic staff in regards to use of 3D and VR technologies in their teaching are discussed.

KEYWORDS: Virtual Reality, 3D computer modelling, built environment, curriculum.

1. INTRODUCTION

Students are entering higher education increasingly computer-literate. Built environment students have expectations that they will be introduced to appropriate technologies for their various subject disciplines, perceiving that this, alongside theoretical knowledge, will enhance their employment opportunities. Academic schools are challenged by new technologies and require appropriate strategies for its 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 need to identify the role that computers can play in built environment education, and the technology of computing, its application to built environment subjects, and use as a teaching resource has long been recognized (Bridges, 1986). The latter element raises some important issues, such as how, when, and what type of computing to introduce into built environment academic programmes. Recent discussions of teaching and learning approaches in built environment education have emphasised the role of visualisations and graphical representations to enhance students' learning experiences (Frank, 2005). This paper identifies the challenges and perceived benefits of adopting such approaches by academic staff in the School of the Built Environment, Northumbria University.

2. THE NEED FOR THREE-DIMENSIONAL REPRESENTATION

Messner et al (2003) 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 et al, 2003). As Mantovani (2003) 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 used 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 (Horne and Thompson, 2007).

3. METHODOLOGY

This paper presents data that was gathered 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 three-dimensional modelling and VR into their teaching and learning, and all suggestions were recorded into a relational database. 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 focused on examples of academic practice where three-dimensional 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 in regards 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.

4. INTEGRATION PROCESS

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 three-dimensional computer modelling and Virtual Reality (VR) technologies into the academic curriculum of its multi-discipline degree programmes. Building Information Modelling (BIM) and Virtual Reality 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 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.

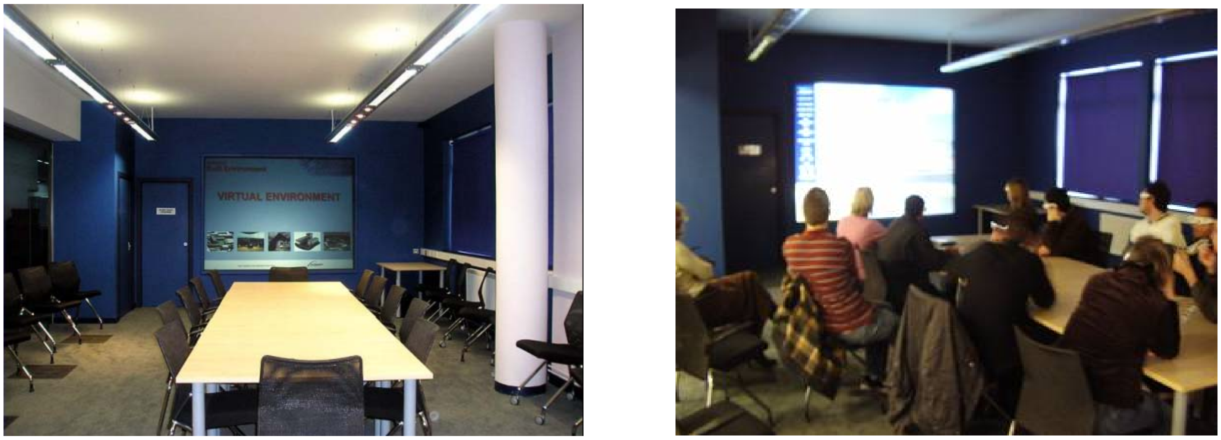

FIG. 1: Collaborative virtual environment.

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.

4.1 Awareness raising

The integration process involved raising awareness 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 virtual reality to be used by students and academics. Figure 2 shows how VR relates to all subject areas within the school.

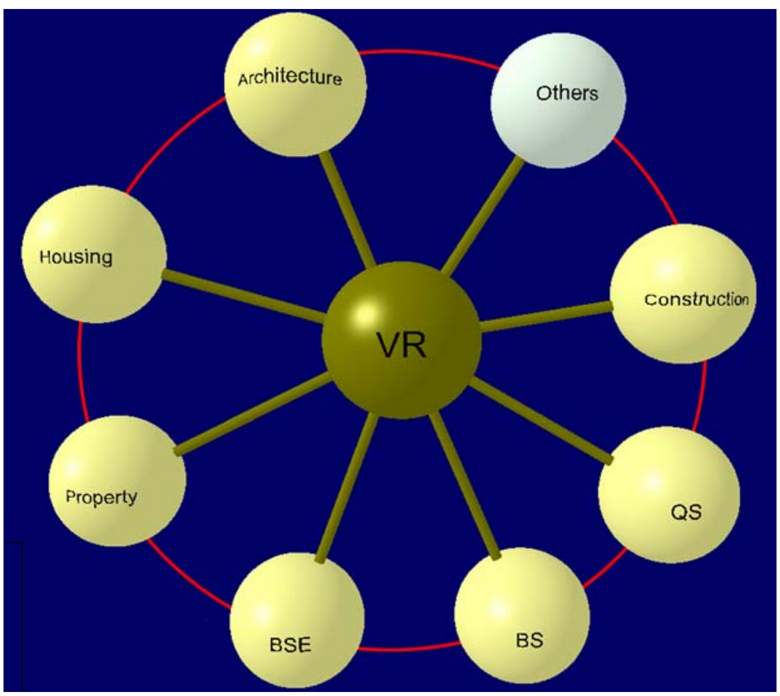

FIG. 2: VR and built environment subject areas.

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 informed academic staff across the school about the potential of the technology, the types of VR available, and the possibilities it could offer to enhance teaching and learning activities and students' learning experiences.

4.2 Recording ideas

The process of systematically contacting staff and collecting ideas began with informal discussions with staff which then 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).

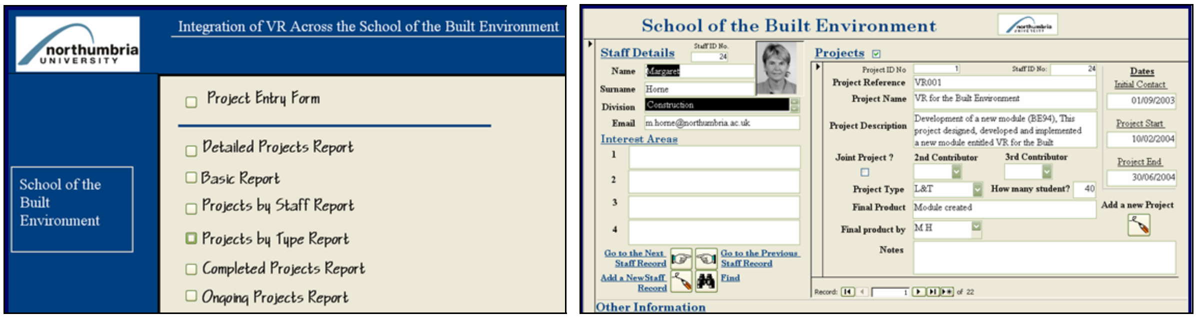

FIG. 3: Opening page and project entry form of relational database.

Ideas for projects were entered onto the Project Entry form on this database and different reports could be 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. Every 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 paper 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. Areas of the curriculum currently supported by 3D modelling or VR in teaching and learning include:

- Property Marketing (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)
- Health and Safety (Final Year)
- Interior Design (Year 1)

5. CASE STUDIES

5.1 Measurement, surveying and drawing skills

This project is based on the translation of two-dimensional representations into a three-dimensional form. Students were given 2D plans of a model (Figure 4), and asked to describe the 3D shape. Students found it very difficult 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. The 3D model was created using SketchUp and incorporated into PowerPoint for presentation purposes.

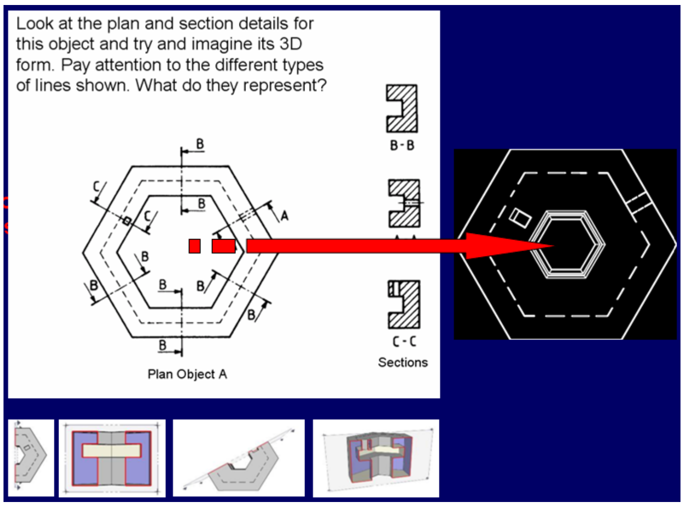

FIG. 4:The translation of two-dimensional representations into a three-dimensional form.

5.2 Site surveying

This three-dimensional 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. The 3D model was created using SketchUp and incorporated into PowerPoint for presentation purposes.

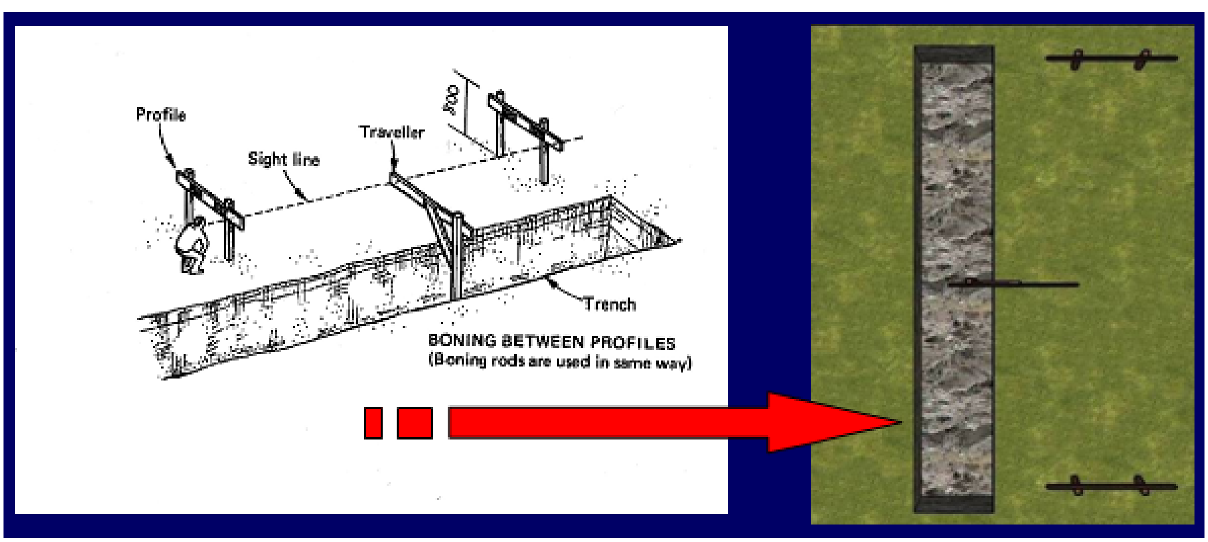

FIG. 5:Visualisation of traveller and sight rails.

5.3 Measurement and coordinated project information

This model was used as an example of showing sub-structures and translating 2D plan information into a three-dimensional 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. The 3D model was created using Autodesk Revit then incorporated into PowerPoint for presentation purposes.

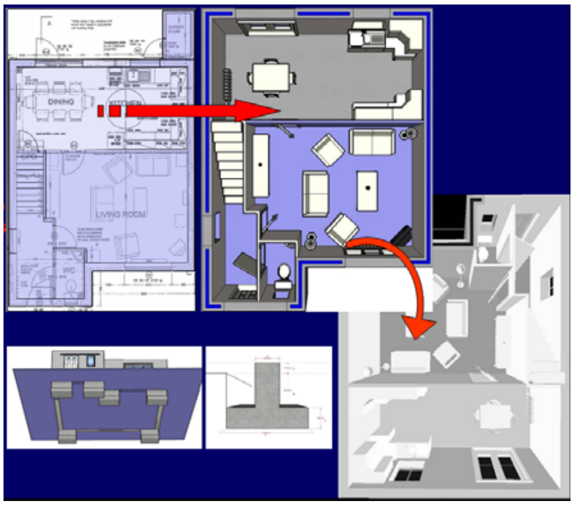

FIG. 6: Measurement and co-ordinated project information.

5.4 Architectural technology design project

Final year students of Architectural Technology have to ensure optimum building performance and efficiency and have a specific need to resolve both technical and design issues. Students applied their knowledge of Virtual Reality, both theory and practice, to interact with their designs in a way that had not been possible previously. They 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 7 shows the end results of a fully immersive, interactive VR model of a sustainable design. The 3D models were created using 3ds Max and VR4Max.

FIG. 7: Interactive VR model of architectural technology design project (student Karl Brown).

5.5 Health and safety project

Final year construction students were assigned a project in which they had to communicate the issues pertaining to potential hazards on a construction site. Whilst the application of VR was not a prerequisite in this module, some students felt its application was appropriate, and they were able to model a fully interactive simulation which effectively communicated the issues they had identified. The 3D models were created using Revit, 3ds Max and VR4Max.

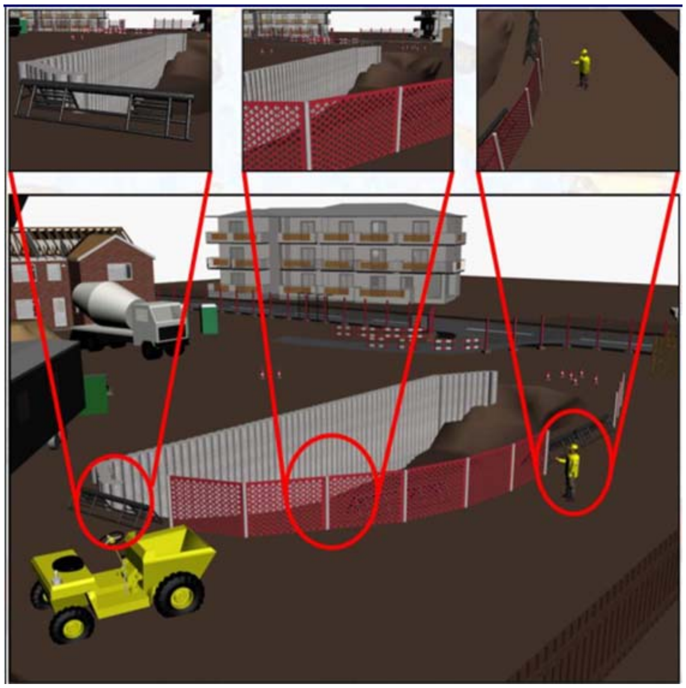

FIG. 8: VR model simulating hazards on a construction site (student David Lee).

6. FEEDBACK

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 in regards to use of 3D and VR technologies in their teaching. The introductory knowledge transfer in this study, regarding VR and 3D modeling, took place in:

- Presentations, demonstrations of existing VR models
- Development of specific models for tutors to use
- Lecture and seminar series

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 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 modelling in the built environment curriculum
- Initial perception of 3D and VR technologies by tutors
- Tutors' requirements after the initial integration with 3D and VR technologies
- Tutors' concerns

6.1 VR and 3D modelling 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 consisted 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.

6.2 Initial perceptions of VR and 3D modeling technologies by tutors

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 into 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. The use of a familiar Windows based operating system resulted in staff feeling some confidence from the outset.

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

More integration was the general requirement of the tutors. This ranged for more detailed and developed models to use in teaching, to the establishment of hands-on workshops for more students to use the 3D modelling and VR software. Staff also required an ability to demonstrate to students' appropriate applications of VR currently used in practice. Although digital media usage varies broadly in the different built environment subject areas and the use of AutoCAD, or any other two-or three-dimensional visualisation software, is not requirement for every subject, a basic introduction to 3D modelling and VR was requested. Tutors suggested involvement at this stage could only be achieved by enhancing their existing modules 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 three-dimensional 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.

6.4 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.

7. CONCLUSIONS AND RECOMMENDATIONS

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). This study sought to investigate the effects of Virtual Reality and three-dimensional 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 utilizing the technology. A number of academic experiences were analysed to explore the usefulness and viability of three-dimensional 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. The benefits of using Virtual Reality 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 three-dimensional modelling software has proved to be reliable and stable, and compatible with that used in industry, thus facilitating 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.

7.1 Limitations of study

Time limitations of this study have resulted in an evaluation of the integration of three-dimensional modelling and virtual reality 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 into the curriculum effectively.

8. FUTURE WORK

Future work will report on further applications of advancing technologies and the challenges of integrating these into the academic curriculum of a school of the built environment. Further development of the projects ideas which were compiled into the database is ongoing and will result in additional case study material. The establishment of a repository of three-dimensional 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.

9. ACKNOWLEDGEMENTS

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