BLENDING THE 'VIRTUAL' AND THE 'REAL' — USING FREEWARE 3D SIMULATION TO ENHANCE REALISM IN AUDIO ENGINEERING

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Abstract

Freeware graphics tools were used to create a 3D simulation of a building and deliver it online to audio engineering students via a Virtual Learning Environment. A pilot group of students were required to design a sound reinforcement system for the virtual building, while another group of students were given a similar task based only on 2D architectural plans. Questionnaires and interviews were used to assess the learning experience of the two groups. Results indicated that the use of the simulation increased realism of the learning experience, increased motivation and enabled more effective communication amongst the group compared to those using only the 2D plans.

Background

Teaching audio engineering produces a number of challenges to tutors. Like all engineering subjects, it is inherently practical, and a key requirement is for students to be exposed to realistic scenarios so that they can apply theoretical understanding to solve real-world problems. While it is often possible to base technical tasks in a laboratory environment, audio systems design and architectural acoustics courses examine the acoustic design of large buildings — both real and planned — which are often impossible to get access to for students.

Case studies in this area are traditionally based on using two-dimensional architectural plans to visualise the building and then basing calculations and design on these. However, audio systems in reality are frequently designed after the building has been completed and so the engineer will usually be able to examine and make measurements in and around the building. If the building is still at the design stage, measurements can at least be made around the proposed site of the building. This allows the engineer to visualise the space, comparing the materials, structure, location and noise levels to his or her prior experience of other constructions, allowing a more detailed visualisation than is possible from the plans. The application of prior experience of different spaces therefore plays a major part in defining solutions to audio engineering problems. Site visits also allow the use of on-site measurements, which are invariably more accurate than theoretical acoustic models.

The use of 3D Modelling and acoustical rendering software is in now common use in the audio engineering industry (Funkhouser et al., 2004). However, software capable of doing acoustical simulation is extremely expensive, costing several thousand pounds per license. In a university environment where there may only be a couple of site licenses of this type of software it is not practical to use with large cohorts of undergraduates, particularly if they need to work off campus. In addition, this type of software obviates the requirements for students to learn fundamental principles, as it removes the need for the learner to apply theory to the problem, as it removes several decision-making processes from the students and gives them to the computer. This can lead to students becoming reliant on 'correct' answers given by the software and eliminating the option of creative responses to this type of engineering problem.

A proposed solution is to use a simulated environment which can provide a simplified 'real' environment for the student to explore, but which still requires the student to make their own decisions regarding application of theory and synthesis of a solution to the design problem.

Simulated environments have been demonstrated to provide opportunities for students to both interact with learning materials and enhance realism of the learning experience (Dickey, 2005). Three-dimensional interactive environments such as Second Life and 3D graphics rendering programs provide potential alternatives to expensive architectural modelling programs for enabling increased interaction of students in this area.

The key educational attribute of a simulation in this context is its ability to model a real system in which variables are clearly specified, which feigns real situations and provides feedback to students, promoting the development of mental models and improved knowledge of reality (Milrad, 2002). Whilst technical accuracy and fidelity to reality are important, the simulation also allows for simplification, through an incomplete representation of a system which preserves its essential characteristics (Hung et al., 2005). This controlled reality allows learners to concentrate on the educational objectives of the designers (Sauve et al., 2007), and reduce the cognitive load on the learner (Schnotz & Rasch, 2005).

In their early work on the use of computers in education, Kemmis, Atkin and Wright (1977) describe simulations as "revelatory," whereby a student is guided through the process of learning by discovery. In simulations the software is acting as a mediator between the student and a hidden model, gradually revealing more information as they progress through it. This contrasts with instructional delivery, often associated with undergraduate students' most common interaction with computer-enabled learning, the virtual learning environment, where subject matter is presented by the system and the student's progress through it is controlled.

It is important to stress that there is a difference between simulations and games. Games have attracted widespread attention for their educational potential (see, for example, Gee, 2004; Kirriemuir & McFarlane, 2006), but they tend to be aimed primarily at primary and secondary school level learning rather than the undergraduate level. Little work reflects the diverse age range of undergraduate students and hence the variety of experiences they bring to their learning. Adult students especially want their learning to be linked to the real world (Schank, 1997) and to be based on their previous experience (Hartley, 2000), and to be delivered at a pace that they can control. The situated, authentic and student-controlled nature of simulations fits well with these requirements.

Unlike the use of Virtual Worlds in many situations, in which the interaction between students and student/tutor is key (Corbit, 2002), the main requirement for an audio engineering simulation is to allow the student to interact with the building itself, and in particular to assess both the construction materials and the situation/positioning of the building in relationship to the external environment. This means that the tools used must allow both 3-dimensional rendering and be able to create a virtual 'environment' for the building to be placed in, as location has a considerable impact on building acoustics.

This paper examines a pilot study in which a 3-dimensional graphical simulation of a building was integrated into an audio engineering assessment tool, delivered online via a virtual learning environment.

The key research question was to examine whether the use of computer simulation of 3D environments and the combination of the 'real' and 'virtual' environment affects the learning experience and the methods of interacting with the tasks of students working on an audio engineering assignment. In particular, does the experience enhance learning, and if so in what manner, or does it distract from the task?

Method

A number of available software tools were assessed for cost, capability, ease of use, 'realism' of environment and potential for integration into the university VLE While all of these packages are capable of creating 3 dimensional graphics, their primary purposes lie in different areas:

ODEON is a professional acoustics rendering package which enables the user to import 3D architectural plans, render them and perform acoustic calculations and modelling of a building. While highly able, it is a very complex programme, not suited to learning the fundamentals of acoustics. It has no means of integrating into a 'real world' environment, and is several thousand Euros for a license.

Fundamentally, it is capable of performing required acoustic calculations *on behalf* of the user, meaning that it would be likely to be a poor learning tool for a student learning basic theory. It could also not be integrated into a VLE due to complexity and licensing restrictions

Plan 3D is a cheap, web-delivered tool designed for home design and interior design. It is capable of 3D simulations of buildings, including visual representations of their materials. Links to the program or created files could easily be integrated with a VLE. However its price of £35 GBP per year per license would put students off using it, and it was not capable of integrating into a ‘real world’ environment.

Xara3D is an inexpensive and simple to use 3D graphics program which is capable of designing 3D objects and applying surface renders of materials. It is however unsuited to complex 3D graphics such as buildings. It could not integrate into a ‘real’ environment, and the cost to the students would still make it unsuitable for use for many students.

Second Life is an online ‘virtual world’ that has been commonly used for educational purposes. It is capable of being integrated into the university VLE and can have complex 3D buildings and renders. There is no cost to the user, to navigate the world and it is simple to operate. The university already has a Second Life presence so initially its use appeared to have considerable potential. However it lacked the ability to place the buildings in a ‘real’ environment, which reduced its effectiveness in blending real measurements and calculations of the virtual space. It also has a high cost to the developer for purchase of ‘land’ on which to ‘build’.

Autodesk is a Computer Aided Design (CAD) package, used widely by the design and engineering industries. It offers a free version for student use and can easily be integrated with the VLE. However, for students unused to using it, it is complex and time consuming to learn, and cannot place designs in a ‘real’ location.

The highest scoring tool was Google Sketchup, a freeware 3D rendering program developed by Google. This has similar graphics capabilities to Plan3D or Second Life, but also has the capability of integrating models into Google Earth, allowing extremely high levels of realism of situational placement. Programme features of all software evaluated are summarised in Table 1.

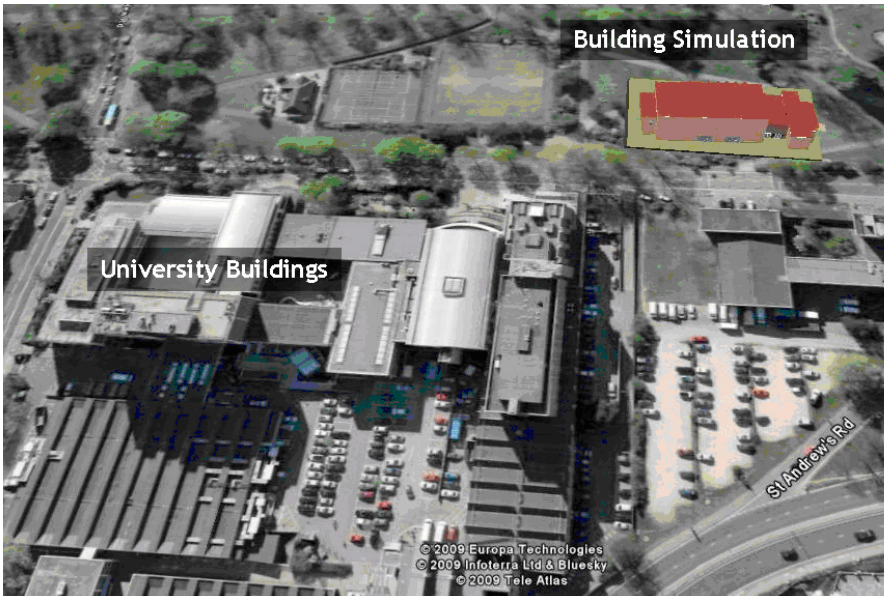
Table 1: Assessment of Available Software

Package	*3D capability*	*Surface render*	*Ease of use**	*Real world integration*	*Integration into VLE*	*Pricing*	*Cost per license*
ODEON	Y	Y	Complex	N	N	Payware	7000 Euro
Plan3D	Y	Y	Easy	N	Y	Payware	£35 pa
Xara3D	Y	Y	Easy	N	N	Payware	$29USD
Second Life	Y	Y	Medium	N	Y	Payware	Free to user. ~$40USD pm for land.
Autodesk	Y	Y	Complex	N	Y	Freeware (education)	Free
Google Sketchup	Y	Y	Easy	Y (via Google Earth)	Y	Freeware	Free

**Ease of use was assessed by the time taken for a 'novice' user to define and render a simple 3Dimensional structure.*

A case study was developed, in which a small pilot group (n = 7) of undergraduate students were required to design the sound reinforcement system and architectural acoustics of an auditorium in a conference centre. In order to integrate an architectural simulation into the learning experience, the building structure was simulated in 3D using Google Sketchup, including rendering of materials and placement of interior features such as furniture. The Sketchup file was then imported into Google Earth and virtually 'built' on a plot of land near the university (Figure 1). This simulation was made available online through the university's Moodle-based VLE, allowing students to download it and use it remotely on non-university computers. The application of Google Earth allowed the student to navigate around both the exterior and interior of the building (Figures 1 and 2), view in 3D key details such as construction materials, the number and type of seating and microphone positions, and get a general 'feel' for the building. The virtual placement of the building in Google Earth in a 'real' position close to the University allowed the students to visit the actual site on which the auditorium was 'built' enabling the student to blend the design calculations based on theoretical modelling with practical measurements and observations made on site.

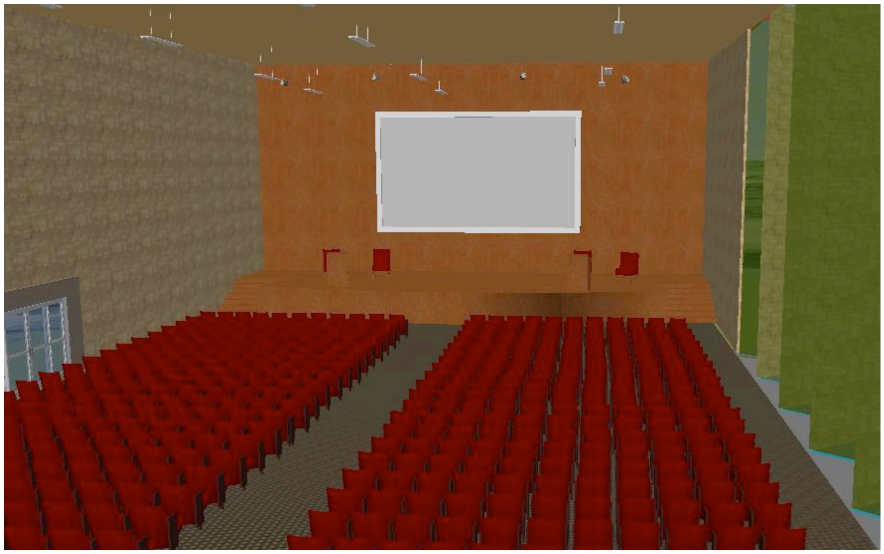
Figure 1: Location of the Simulated Building



(© Google Earth 2009)

The assignment task was designed around one that had been used many times before building upon a number of theoretical and practical exercises the students had done throughout the course. It had, traditionally, relied on a paper-based model with 2D architectural drawings and tables of physical values. So a control group of students (n = 8) were given a similar task to the pilot group, but using the traditional method, without the simulation of the building. The building design used for the control group was different in order to prevent this group making use of the simulation. The aim of the exercise in both cases was for students to be able to solve both the straightforward acoustic calculations required, and to examine the more complex interactions between different elements of the acoustic space to provide design recommendations for an audio installation.

Figure 2: Interior of the Simulation (Main Hall)



Data Collection

Traditionally, educational research has relied heavily of the proof of theory as a model. However, Salmon (2002, p. 198) advocates the rejection of the role of overarching theory in the research of online educational tools, preferring to focus on their actual use in order to develop models of understanding.

As this project was examining unknown attitudes, motivations, and approaches of students to learning a particular subject in a particular context, data collection was based on the use of independent questionnaires and semi-structured interviews. Questions focused on the way in which students had visualised the acoustic space, their approach to the assessment requirements, their interaction as a group and their methods of getting further information about the task. Their prior experience with online assessment and learning was also assessed in order to consider whether this had an impact on their approach to the task.

This study explores the processes of a group of students working on a piece of assessed material for a unit in Audio Systems Design. The sample numbers were defined by the subjects taking the unit, restricting the sample size. Whilst the sample is broadly representative of the larger student population, it is chosen on the basis of availability and can therefore not be considered to be truly random. The sample size is also not large enough for statistical interpretation of the student responses. However, as it would be inappropriate for the conclusions of an intrinsic case study to generalise about the whole population, this “convenience sample” (Cohen et al., 2007, p. 113) has only to represent itself and is therefore legitimate.

Analysis

Prior Experience and Motivation

There were no particular differences in experience indicated between the two studied groups. All of the students from both groups indicated that they were confident at working and learning online, with a high level of internet usage across a typical week (typically in excess of 20 hours). They all indicated that they had a good working knowledge of the VLE, and that they were confident with the studied subject matter. All students indicated that they were well motivated, partly intrinsically through a high level of interest in the subject and partly extrinsically through a desire to get good grades.

Visualisation of Building

An important affordance of any simulation is its ability to represent a complex system visually. Chris Dede promotes the use of “visualization” as a tool for enhancing learning: “People have very powerful capabilities to recognize patterns among images: much of our brain is ‘wetware’ dedicated to this purpose” (1996, p. 4). He asserts that learners gain increased insight into a system when tabular data of numerical values are represented by graphical objects with apparent shape, size, texture and colour. It has also been shown that graphical feedback and explanation improves comprehension and retention of information (Rebetez & Bétrancourt, 2007).

This was reflected by the comments of the simulation users, who said the 3D image made the assignment “about as realistic as it potentially could be” by “using Google Earth and Sketchup to view the interior and exterior.” Interestingly, ‘realism’ was rated approximately the same by both study groups, regardless of method of delivery (though there is some suggestion in their comments that they may have interpreted realism to mean relevance). However, the group that used the paper-based task almost all suggested a site visit would have been useful to create a visual image of the space, unlike the simulation group for whom this suggestion was rare.

Without the simulation, the students tended to simplify the space into geometric shapes based upon the floorplan. They indicated that this made it difficult to imagine the more complex elements, such as the pitch of the roof and the various building materials. They also indicated that they were only using mathematical modelling to provide the ‘answers’ to the assignment task and that it was difficult to relate their results to reality. This resulted in an “assignment based on the numbers” which they felt was unsatisfactory.

Interaction with Task

Most of the students that used the simulation found the experience ‘enjoyable’, saying, for example, that it *“added realism to what is used in lessons rather than just theory”* and that this was particularly important to them. There were some verbal comments that the simulation was occasionally difficult to navigate effectively, and that it was possible to move through solid objects.

A number of students that undertook the parallel traditional, paper-based task suggested that they would have liked to have done the simulation as it was more “interactive”, even though they had not actually seen it. Upon questioning, they revealed that this meant they would like to be in control of what they viewed and when they viewed it, and that they thought the simulation should provide them with that opportunity. Most of today’s students come from a generation that has grown up surrounded by computer technology and they are familiar with the world viewed through electronically-generated images (Prensky, 2001). They therefore have a predisposition to the use of computer-based technology as a mediating tool and this may have motivated this suggestion. This view was not universal, and whilst it is clear that simulations often build on the curiosity, fantasy and motivation developed in young adults by computer-generated graphics and inexpensive video games (Kirkwood & Price, 2005), they will not appeal to everyone.

Interaction with Others in the Group

Both groups of students indicated that they discussed the tasks with other their colleagues, but the content of these discussions were different. The group using the traditional method tended to concentrate on ‘surface’ discussions of the task, such as useful resources, amount of detail required and what formats to use. The group using the simulation drilled down into more detail, discussing subjects like specific equations, absorption coefficients, gain, power and intensity. It appeared that the shared experience of the visual image of the acoustic space afforded by the simulation allowed them to more easily contribute to discussion about the content of the task. In this way, they jointly constructed more knowledge about the system than each would have done through the interpretation of their individual experience alone. So, the simulation could be seen not only as a method of scaffolding an individual’s mental modelling, but also as a socially constructive discussion support tool.

Processes of Gaining Further Information

There was no substantial difference in the two groups’ perceptions of the amount of information they had available, with around half of each group indicating that they believed they had been provided with all they needed. Of those who suggested they required more, the paper-based group were more likely to require information about the materials employed in the building whereas the simulation group were more likely to request details like clarification of scale.

Discussion

The delivery of the task via the computer did not, in itself, enhance the learning process. It would have been be possible to create simple computer-designed floorplan models of the acoustic space, together with height and material construction information, for the students to analyse as a practice application of taught theory. However, Jonassen et al. (2000) compared this cognitivist approach of traditional drill-and-practice technology with that of constructivist simulation technology and found that the latter provided measurable learning advantages.

A specific constructivist instructional design model that applies well to the case studied here is that defined by Jerome Bruner (1967) of discovery learning, whereby the learner draws on past experience, and explores a problem with questioning and experimentation to discover new relationships and facts. The simulation enables this form of learning by allowing the students the freedom to determine for themselves what to analyse, based on the knowledge and skills they have developed thus far as guided by their tutor (Hammer, 1997). Also, it has been shown that discovery learning may increase content relevance and student engagement (Rieber et al., 2004) So, the affordances of the simulation include hypothesis generation (*I think this space will conform to a particular model*), experimentation (*this is how I will measure that*), prediction (*these are the results I expect*) and data analysis (*what the results mean*) (after van Joolingen, 1999). The development of each of these four meta-cognitive skills is key to the objectives of the simulation, as well as being important in “solving” the problem that constitutes the overall assessment requirement of the task.

Conclusion

The use of the simulation impacted on the learning experience of the students in three key ways:

- The increased realism of a 3D model reduced the perceived requirement to visit the actual building — this is important because the control group students believed that the lack of a site visit created a substantial hole in their knowledge.

- The students enjoyed the experience of the simulation, despite some technical issues with navigation, suggesting an increase in intrinsic motivation.

- Most importantly, the shared visualisation of the space through the simulation enabled more effective communication between the students about the task itself, encouraging discussion and hence developing shared understanding.

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