2010

Assessing the Application of 3D Collaborative Interfaces within an Immersive Virtual University

Gavin McArdle
University College Dublin

Bianca Schoen-Phelan
Dublin Institute of Technology, bianca.phelan@dit.ie

Michela Bortolotto
University College Dublin

Assessing the Application of 3D Collaborative Interfaces within an Immersive Virtual University

Gavin McArdle
University College Dublin, Ireland
Bianca Schön
University College Dublin, Ireland
Michela Bertolotto
University College Dublin, Ireland.

Abstract

The need to stimulate and engage students is of paramount importance within any learning scenario. Despite this, recent developments in online learning have failed to take this requirement into account. As a result e-learning courses which utilise traditional online learning management systems have a higher dropout rate than their classroom based counterparts. The attrition rate is attributed to boredom with the interfaces used to deliver learning material and also to the lack of opportunities to interact socially with others. Furthermore, being in a virtual environment imposes a whole new set of challenges onto users due to the distinct lack of stimuli provided, compared to the real world. Technological advances now permit the development of multi-user, networked, virtual reality environments which can address these issues. Such environments provide an immersive desktop 3D interface which is used to deliver learning material. Real-time communication and collaboration tools permit interaction between students and tutors. This chapter describes one such environment called CLEV-R (Collaborative Learning Environments with Virtual Reality) which fosters collaboration and social interaction via specialised tools. Although there are systems which offer similar functionality to CLEV-R, these have not been adequately evaluated. This chapter describes two studies which were conducted using the CLEV-R interface. The first study assesses the usability of this paradigm for e-learning while the second determines which factors influence performance in the Virtual Reality environment in order to ensure that some students are not unfairly advantaged by this means of e-learning. The studies have shown that several factors, such as age and experience in Virtual Reality games influence a user's success in Virtual Reality environments. Furthermore, the study shows that students enjoy and benefit from the opportunity to interact with each other.

1. INTRODUCTION

Recent years have seen an increase in the use of computers as a form of e-learning. The primary focus in this area has been on providing tools to deliver course material using web pages, while also providing techniques to manage both the material and users within such systems. These systems are often referred to as Learning Management Systems (LMSs) and predominantly support asynchronous interaction between their users. While the penetration of such approaches is vast and their popularity continues to grow, research indicates that courses which rely solely on these mainstream e-learning applications have a higher dropout rate than their face-to-face counterparts (Martinez, 2003). Studies indicate boredom, ennui and a lack of motivation are contributing factors to the high attrition rates within online courses (Serwatka, 2005). Research in this area is ongoing with techniques to resolve the problems of the lack stimulation and interaction being explored (Mowlds, Roche & Mangina, 2005; Sun & Cheng, 2007). One major concern with conventional e-learning techniques is the absence of mechanisms for instant communication. This leads to a lack of timely interaction between learner and instructor, hinders social interaction among learners and is one of the major drawbacks of standard online learning techniques. Ultimately, it has been shown that this absence of interaction and social connection with peers, and the tutor, can lead to feelings of isolation and loneliness for students (Kamel et al., 2005). Similarly the traditional approach relies on text-based web-pages which involve students reading large passages of text which they may find boring and unappealing (Anaraki, 2004). Figure 1 highlights the main issue with conventional LMSs.

Collaborating with peers is an important element of learning in the real world (Kitchen & McDougall, 1998; Vass, 2002). It teaches students about cooperation and teamwork. The asynchronous communication techniques provided by mainstream e-learning applications are not entirely suitable for organising group projects and consequently such tasks are generally absent from e-learning courses. Social interaction and the sense of a social presence among students are also important (Laister & Kober, 2002). Students often build friendships with their classmates in the real world. This interaction with others plays a key role in the personal development of students and their formation of social skills. The asynchronous communication methods offered within traditional e-learning applications do not permit a natural flow of conversation which hinders social interaction among students. Consequently they may feel they do not have a social presence within the learning environment or experience a sense of a community, both of which can lead students to withdraw from their course of study prematurely (Serwatka, 2005).

Figure 1. Issues with existing e-learning techniques

Arguably, there are technologies available which can be combined and deployed successfully in the e-learning domain in order to address the issues discussed in this chapter. Increasingly the development of immersive 3D environments is seen as a possible approach to resolve these issues (Jones & Bronack, 2008; Wheeler 2009). For example, improvements in computing, such as increased internet connection speeds, permit more advanced technologies, including 3-Dimensional (3D) graphics and multimedia, to be utilised online. Researchers have already explored the use of immersive desktop 3D environments in a number of fields such as e-commerce (Chittaro & Ranon, 2002; Cordier, Seo & Magnenat-Thalmann, 2003) and data management (Cockburn & McKenzie, 2002) where they were shown to be successful. Some research on immersive 3D environments for use within e-learning has been also carried out (Bouras, Philopoulos & Tsiatsos, 2001; San Chee & Hooi, 2002; Bouras, Giannaka & Tsiatsos, 2003). Some research has been conducted in order to provide for example navigational aid in such environments in order to offer a better user experience (Darken & Peterson, 2000). However, a more in depth study of this paradigm is required to determine if it is usable and whether it is a means of e-learning which appeals to students. Furthermore, research in this area focuses on facilitating learning activities. The benefits of such environments for social purposes still needs to be explored. The success of 3D environments in other domains motivates the examination of this paradigm to establish if it offers a suitable solution to the drawbacks of conventional LMSs. When combined with real-time communication methods, these technologies offer a powerful form of interaction and help overcome issues of solitude experienced by some e-learners (McInnerney & Roberts 2004). As highlighted in Figure 1, many of the shortcomings are rooted in the lack of instant communication tools and lack of stimuli, and so combining such features with a multi-user Virtual Reality (VR) environment offers a valid solution.

In order to determine the possibilities of these media within e-learning, this chapter describes the development of an e-learning platform called CLEV-R (Collaborative Learning environments with E-Learning). CLEV-R combines a collaborative desktop virtual reality learning environment with several real-time communication channels in order to facilitate learning and social interaction between students. The resulting system is then assessed on two levels. Firstly, the usability of the platform is gauged through a series of user trials; this is accompanied by a further user study that assesses factors that influence user performance in VR. This is an important facet of the evaluation as it helps to determine which factors could result in certain groups of students obtaining an unfair advantage when learning through VR and also highlights techniques to alleviate this problem. The results indicate that such systems are usable; however care must be taken to understand the user and offer suitable spatial support so that certain students are not disadvantaged by the VR paradigm.

2. RELATED WORK

Using multi-user 3D environments, CLEV-R engages and stimulates students on several levels. Novel communication tools augment the VR interface to offer facilities for real-time interaction between students, their peers and tutors. The goal of the system is to augment the tools provided by traditional LMSs in order to resolve the issues discussed in the previous section.

Several research studies also explore this area. Two such examples are EVE (Bouras, Giannaka & Tsiatsos, 2003) and INVITE (Bouras, Philopoulos & Tsiatsos, 2001). While these systems have some unique features and are targeted at diverse users, they both utilise 3D graphics to create a virtual onscreen environment in which students are immersed. Each user of these systems is represented on screen by an animated character. All other users, currently connected to the system can see this avatar. Learning content, including lecture notes and videos are displayed simultaneously in the 3D space of all users that are interacting with the system. Students can interact with each other using some synchronous communication techniques including text and voice chat, which permits collaboration between them.

Other systems such as C-Visions (Chee & Hooi, 2002) and Virtual European Schools (VES) (Bouras et al., 1999) focus on providing an environment for specific subjects. C-Visions uses VR to support science education. Interactive animations, experiments and hands-on tasks teach students about mass, velocity and acceleration. On the other hand, the VES project created a 3D environment with a number of themed rooms. Uniquely, book publishers provide the content for the themed rooms. Slideshows, animations and links to external sources of information, relevant to the specific theme or subject, are utilised.

When the systems above were evaluated in small user trials, the results indicated that they were popular with users. In particular any real-time communication methods were seen as a major advantage of the systems. The 3D paradigm itself was also rated highly by the test subjects who appreciated the interactivity which it offers. (Bouras & Tsiatsos 2006; Chee, 2001). No large scale evaluation was conducted to obtain a greater understanding of the usability of the VR environment for e-learning.

Second Life (Harkin, 2006) and Active Worlds (Hudson-Smith, 2002) are prime examples of online VR communities. In these systems, computer users have on screen personas and inhabit a virtual 3D environment. At present, researchers are examining techniques to utilise these systems within education. Kemp & Livingstone (2006) propose using Second Life as an interactive interface to access learning material currently maintained in a traditional text-based LMS. Doherty & Rothfarb (2006) have developed a science museum using Second Life. The interactive environment permits students to interact with historical objects and participate in online meetings and talks. Henderson et al. (2008) discuss Second China, which is another environment developed in Second Life. Second China educates students about Chinese culture and history. Users of the system can access information and participate in guided learning sessions while also collaborating with others. Dickey (2003) uses Active Worlds as a distance education tool within a university setting, while Riedl et al. (2001) describe an environment developed in Active Worlds, for teacher-training programmes. An evaluation carried out by Riedl et al. (2001) highlighted the awareness of others, which the on screen personas create, as a major benefit of such systems. The interaction with others, which was made possible through the shared virtual space, was also seen as an advantage of such systems.

The platforms discussed here address the needs of students by providing an interactive medium for accessing learning content. However, as shown in Table 1, they tackle the issues with existing LMSs to varying extents. One aspect which is lacking in many of these systems is the provision of dedicated tools for socialising online which has been shown to be important in face-to-face learning (Laister & Kober, 2002). In particular, the file sharing functionality, which is one of the key elements of social networking websites, is often absent from these systems.

Table 1. Comparison of features of current Immersive E-Learning Systems and CLEV-R

	VES	INVITE	EVE	Active Worlds	Second Life	CLEV-R
Multi-user	X	X	X	X	X	X
Avatars	X	X	X	X	X	X
Text Communication	X	X	X	X	X	X
Voice Communication		X	X			X
Web-cam Feeds						X
Tutor File Uploading		X	X	X	X	X
Student File Uploading		X	X			X
Defined Social Areas				X	X	X
Tutor-Led Activities	X	X	X	X	X	X
Student-Led Activities		X				X

While social facilities are provided in Second Life and Active Worlds, they are predominantly social environments which have been adapted for e-learning. Therefore they are not dedicated e-learning systems and instead use ad-hoc methods for delivering learning content. The quality of the learning tools thus depends on the creative abilities the course designer. In the system described in this chapter, CLEV-R, the need for social tools forms a major element of the design which is achieved through the addition of specialised tools for social interaction. While these facilities allow natural communication between students within the 3D environment, further dedicated functionality also permits students to share and discuss photos and videos. Many have the current systems have been evaluated using small scale or ad-hoc user trials. On the contrary, the system described in this chapter was evaluated using an in depth user trial with industry standardised usability questionnaires. Furthermore, in order to assess the factors which influence students' performance in such environments, a study to ascertain different performance levels among learners was also conducted. This is vital to ensure that no group of students obtains an unfair advantage caused by the medium in which learning material is presented.

3. CLEV-R SYSTEM DESCRIPTION

CLEV-R concentrates on providing collaborative tools, so students can work, learn, and socialise together. Mimicking a physical university setting, it consists of a central common area, a lecture room, meeting rooms, and social rooms. Multimedia techniques are used to display the learning content while text and audio allow users of CLEV-R to communicate with each other (Monahan, McArdle, & Bertolotto, 2008). The following paragraphs outline the most salient aspects of CLEV-R.

3.1 User Representation

In order to resolve one of the principle problems with existing LMSs which involves the lack of social presence and the feeling of isolation, CLEV-R endeavours to create a sense of community among learners and thus remove the sense of loneliness that is often experienced. This is achieved through multi-user support which permits multiple users to access the same virtual environment simultaneously. Within this framework, it is necessary for users to be aware of the presence of others. Therefore, within CLEV-R, each user is represented by a personal avatar. This 3D character is the user's on-screen persona for the duration of a course. By allowing users to customise their avatar, each avatar unique and so users of the system can recognise others and hence feel a social presence in the learning environment.

3.2 Communication Tools

Collaboration is a key aspect of the design of CLEV-R, which means that communication technologies are imperative. As discussed above, the lack of real-time communication is a major drawback of traditional e-learning systems. In all learning scenarios, communication with peers and instructors is important which is well documented in the literature (Redfern et al., 2002; Laister & Kober, 2002). In particular, it has been shown that students learn from each other in an informal way. Such unstructured communication also helps remove feelings of isolation which may be experienced in single user learning environments. As such, a major aspect of CLEV-R is the provision of communication methods. These facilities are provided in a Graphical User Interface (GUI), as shown in Figure 2. Text and audio chat communication are supported. Users can send both public and private messages via text-chat and can broadcast audio streams into specific areas of the VR environment. Additionally, web-cams can be use to broadcast directly into the 3D environment which permits real-time, face-to-face conversations with others. The avatars in our system are equipped with gesture animations, which are a further form of communication. For example, avatars can raise their hand if they wish to ask a question and can also nod or shake their head to show their level of understanding or agreement.

3.3 Interactive Tools

In traditional web-based learning environments, content is mainly presented through various forms of text, primarily using the HTML format. This delivery method is neither motivating nor engaging for the student (Anaraki, 2004). To resolve this, CLEV-R provides multiple multimedia methods for presenting course content within a desktop 3D virtual reality learning environment. The system supports features such as PowerPoint slides, movies, audio, animations, and images. Rather than downloading these media files to the students' own PC, they can be experienced directly within the virtual environment in real-time simultaneously with other students. Many different services and facilities are available within the various virtual rooms of CLEV-R to support these file types. Each of the rooms is now discussed below.

Figure 2. CLEV-R Graphical User Interface

3.4 Lecture Room

The *Lecture Room* is the virtual space where tutor-led synchronous learning occurs; it operates in a similar fashion to traditional classroom-based education. The room provides several features to enable a tutor to present learning content to several students simultaneously. An example of an online lecture can be seen in Figure 3. Lecture slides, such as PowerPoint files, can be displayed on a presentation board, which also supports image files. A media board is also provided, where the lecturer can upload both audio and video files. Where appropriate, the lecturer also has the option of streaming live Web-cam feeds into the *Lecture Room*. This can be used for demonstrating more practical aspects of a course or as a video conferencing tool for guest speakers.

The tutor controls this presentation board and can advance through the slides at their own pace. Once the tutor changes the current slide, it is changed in the worlds of all connected students. In this way, students are always aware what learning content is currently displayed. The streaming audio facility can also be used to provide live commentary to accompany the presentation and answer any questions the students may have.

Figure 3. CLEV-R 3D Interface showing a Lecture Taking Place

3.5 Meeting Rooms

Collaboration is of primary concern within the design of CLEV-R and so dedicated rooms to support student-to-student interaction are included. The *Meeting Rooms* provide specialised facilities for groups of students to meet and work together. The *Meeting Rooms* provide a similar set of tools found in the *Lecture Room*. For example, students can use audio and text messages to communicate their ideas. A presentation board, similar to that found in the *Lecture Room*, permits students to upload their own material for others to see. Each student can share slideshows, animations, and media clips. Live video can also be streamed into this room via a student's Webcam.

3.6 Social Rooms

As social interaction is a key component of CLEV-R, dedicated areas within the virtual university have been provided for this function. In these areas, students can mingle, interact and converse informally. While students can use these areas to discuss the course they are attending, they can also use them for social purposes. In a similar way to the *Meeting Rooms*, small numbers of students can gather together to share their experiences and stories as well as photos, pictures, and movies. A media board facilitates the sharing of files. In addition to the *Social Room*s, a centrally located lobby serves as an informal setting, where students can chat with others. Here users can talk about the course material or display their project work on special static presentation boards provided; others can then peruse these posters at their own pace.

3.7 Library

In addition to the synchronous learning which takes place in the *Lecture Room*, CLEV-R also provides asynchronous access to learning material through a library within the 3D environment. The *Library*, shown in Figure 4, contains a bookcase and a number of desks. Lecture notes, which have been uploaded by the tutor, automatically appear on the bookcase. Students can then display this material on a desk in the *Library* or download it to their own computer. Additionally, the bookcase in the *Library* also contains a number of links to external information sources such as online dictionaries and encyclopaedias.

Figure 4. CLEV-R 3D Interface showing the Library

4. EVALUATION

When adopting new technologies, it is important to carry out an evaluation to assess its benefits and to determine the effects this new technology will have on users. The evaluation of CLEV-R and its 3D virtual reality environment was carried out in two phases. Firstly in order to gauge users' opinions of the system and to test its functionality, a user trial was carried out. Secondly, recognising that this is a new paradigm for most, a study into the factors that influence performance in VR was also carried out. Detailed descriptions of these two studies are provided in the following sections.

4.1 Usability Study Setup

The first study, presented in this chapter, followed a previous user study which was carried out when the prototype had reached a mature stage. Details of this study and its results can be found in McArdle & Bertolotto (2010). The purpose of the second trial was to gauge user opinions of the system and determine its usability. Usability testing involves studying the interface and its performance under real-world conditions and obtaining feedback from both the system and its users (Nielsen, 1993). With this in mind, a series of tasks was devised. The tasks established common scenarios which occur in learning situations. Participants in the user trial had to interact with CLEV-R, and the tools it provides, to complete the tasks. A total of 20 test-subjects took part in the user trial. The participants were representative of the target users of the system (university students), the profile of which can be seen in Table 2. All test-subjects stated that they had a good level of computer literacy while the majority had experience of using traditional e-learning systems. All test-subjects took on the role of students during the user trial, while a person familiar with the functionality acted as the lecturer.

Table 2: Profiles of the Evaluation Participants

	Number
Total Users	20
Males	15
Females	5
Average Age	26.27
Previous Experience of E-Learning	12

Four tasks, indicative of typical scenarios within an e-learning system, were devised. Details of these tasks are detailed below.

Task 1 - Social Interaction: The purpose of this task was to serve as a means of introducing the participants to the CLEV-R interfaces and the modes of interaction which are available. The task consisted of an ice-breaker game, in which the test subjects needed to use the text and audio-chat facilities to converse with one another. The game, 'Who am I?', involved one participant taking on the identity of a famous person, the other participants then had to ask questions in order to identify the famous character. In this task, participants also needed to collaborate in order to choose a topic for a group project which they would present through the interfaces during the third task of the evaluation study.

Task 2 - Learning: The second task consisted of the participants attending a synchronous lecture within CLEV-R. The lecture material concerned geography and the tutor provided facts, videos and music about a particular country. The participants were encouraged to ask questions and interact where appropriate. The tutor used voice chat and web-cam feeds during the class in order to demonstrate the facilities available.

Task 3 - Collaboration: In order to assess the functionality of the *Meeting Room*s, the participants were asked to work together to produce a group project. Users were required to upload a Microsoft PowerPoint file to the presentation board in one of the *Meeting Rooms* and use the audio communication facilities to talk about their part of the project.

Task 4 - Social Interaction: The final task of the evaluation study was a free session. The purpose of this task was to permit participants to socialise and interact with each other. In particular, the test subjects were encouraged to share different types of media with one another. This task gave the participants free reign with the system and permitted them to uncover any usability issues which might arise.

4.1.1 Evaluation Techniques

In order to obtain feedback from the test subjects, several standard usability questionnaires were administered during and after the user trial. These questionnaires were augmented with several questions which were specific to CLEV-R and its functionality. After each of the 4 tasks outlined above, the After Scenario Questionnaire (ASQ) (Lewis, 1991) was given to the test subjects. This questionnaire consists of 3 statements, shown in Table 3, which assess user satisfaction regarding the ease of completing the task, the time taken to complete the task and the support information available when completing the task. The satisfaction is measured on a 7-point Likert scale anchored at 1 by Strongly Agree and at 7 by Strongly Disagree. The results from these 3 questions can be condensed to give an overall rating of user satisfaction with the interface for completing a specific task. The ASQ was augmented with additional questions regarding the effectiveness of the features provided by the interfaces for each specific task.

Table 3. The Three Questions of the After Scenario Questionnaire

The After Scenario Questionnaire (Lewis, 1991)
Overall, I am satisfied with the ease of completing the tasks in this scenario
Overall, I am satisfied with the amount of time it took to complete the tasks in this scenario
Overall, I am satisfied with the support information (online help, messages, documentation) when completing the task

4.1.2 Results and Discussion

There were 4 tasks in this usability study. A brief 6-item questionnaire was presented to participants after completing each task in the usability study. The questionnaires contained 3 items from the ASQ and 3 items, which were devised based on the current activity of the user. These 3 items were designed to give a clear understanding of the user's opinions of CLEV-R and its effectiveness.

Task 1 - Social Interaction Tools

Task 1 involved participants interacting with each other, using the tools provided, to carry out the icebreaker game, 'Who am I?'. Firstly, the results relating to the 3 items on the questionnaire dealing with the effectiveness of the system to complete the task are presented and discussed. Figure 5 shows a graph detailing the questions and the findings. Lower ratings indicate a better the result. The majority of the subjects found the communication were tools effective for completing this task. This task was a social one and participants were asked to rate the effectiveness of the facilities for social interaction as well as rating the acceptability of the interaction as a means for socialising. All test-subjects felt the facilities provided during the task were sufficient to allow social interaction to take place. The average result returned for the statement regarding the acceptability of this as a form of socialising was 2.1, with favourable answers returned by the majority (90%) of test-subjects. The results suggest this aspect of CLEV-R is an acceptable means of social interaction and the tools which support and facilitate it are more than sufficient.

Figure 5. Results for User Trial Task 1

The ASQ is an instrument used to assess overall satisfaction with completing a task or scenario. By condensing the results obtained from the questionnaire, it can be seen that on the 7-point Likert scale the average value returned for this task is 2.23. This is a positive result and indicates a high level of satisfaction among the test-subjects. This is further supported by the standard deviation value of 0.622 for this result. Looking at Figure 6, the results can be seen in more detail. In general, the responses are skewed towards the positive end of the axis. Satisfaction with the ease of completing the task was high. 90% of participants expressed agreement with the statement. When the graph is examined, it can be seen that 2 test-subjects declined to rate the statement about their satisfaction with the support information provided with the system. One possible explanation for this is that these participants did not see any support information. For example, help support is only provided when the user seeks it. The remaining 18 participants that did answer this question gave an average rating of 2.35. Although this result is not negative, it is perhaps one area that could be improved upon. It can be concluded that users are satisfied with the set of tools provided by CLEV-R to facilitate this form of social interaction and agree that the scenario they took part in is an acceptable means of socialising online.

Figure 6. Results for User Trial Task 1

Task 2 - Learning Tools

The second task for this user study instructed participants to use the learning tools provided in CLEV-R to attend an online lecture. Although this was a learning task, feedback relating to the content of the learning material was not of interest, but rather feedback regarding the students' experience of interacting with CLEV-R was important. As in the previous task, a combination of the ASQ and 3 additional questions were administered after the task was completed. The results relating to the effectiveness of CLEV-R for learning are shown in the graph in Figure 7. 95% of the participants agreed that they could easily follow the lecture and stated it was an acceptable means for attending an online lecture. A negative response was seen from one test-subject in relation to communication tools and being able to follow the lecture. After examining individual questionnaires it was discovered this respondent had technical issues with their computer during this task.

Figure 7. Results for User Trial Task 2

The results pertaining to the ASQ elements of the questionnaire are shown on the graph in Figure 8. Combining the results from the ASQ shows the overall trend is one of satisfaction with an average rating of 2.02. However, the results, while skewed to the positive edge of the axes, are distributed across 4 of the scales. 90% of the participants agreed they were satisfied with the ease of completing the task. This suggests the tools provided in the *Lecture Room* of CLEV-R are easy to use. The majority of test-subjects did not see the amount of time taken to complete the task as an issue, as 95% agreed they were satisfied with the time it took. Examining the results for the third question on the questionnaire, it can be seen that a number of participants (in this case 4) failed to answer this question. The reasons for this are most likely that the subjects did not need to utilise the help files or they were unaware of their presence and so did not experience the supporting material. Of those that did respond, 87.5% were positive towards the support information provided when completing the tasks, while the remainder were indifferent. Overall for this task it can be said that the satisfaction level towards CLEV-R in completing this task is high with an average rating of 2.02 (standard deviation: 0.82). Likewise, the tools provided by CLEV-R for completing this task were seen as easy to use.

Figure 8. Results for User Trial Task 2

Task 3 - Collaboration Tools

The third task was a collaboration one in which the participants had to work together to share their knowledge by uploading relevant information to the presentation board in a designated *Meeting Room*. As with the previous 2 tasks the 6-item questionnaire was administered after the task had been completed. The 3 questions, which were added as a supplement to the standard ASQ, asked the respondents specifically about the tools for collaboration, the results of these questions are shown on the graph in Figure 9. Communication was seen as effective for this collaboration task for 90% of the participants. The average response relating to the effectiveness of the communication tools was 2.1. 95% (19) of the test-subjects agreed that the other facilities, such as those for uploading the Microsoft PowerPoint files, were suitable for this collaboration task. Similar results were returned for rating the task as an acceptable means of collaboration. The graph shows a correlation between the responses for effectiveness of communication and the rating of this task as an acceptable means of online collaboration. This suggests the quality of the communication tools directly impacts the users' perception of the acceptability of this as a form of interaction for collaboration and this supports the theory that audio (voice) communication is very important for collaboration. The negative responses seen in the graph were attributed to a single test-subject and further analysis of their questionnaire found that they experienced technical problems with the prototype during this task.

Figure 9. Results for User Trial Task 3

The results for the ASQ elements of this questionnaire can be seen in Figure 10. The satisfaction with ease of completing the task was rated highly by 90% of participants with an average response value of 2.05 on the 7-point scale. This indicates the participants found this task particularly easy to complete. As seen in the previous 2 tasks, a proportion, in this case 40%, of test-subjects failed to rate their satisfaction with the support information for this task. The remainder, that did answer this question, overall agreed that they were satisfied with the support information provided. After condensing the results of the ASQ, an overall satisfaction level of 2.03 (standard deviation: 0.776) is obtained. This is a favourable result and, when combined with the feedback relating to the questions regarding the effectiveness of the collaboration tools, indicates that CLEV-R and the tools it provides are useful and practical to support collaboration among students.

Figure 10. Results for User Trial Task 3

Task 4 - Social Interaction Tools.
The final scenario was a social one. The task involved the test-subjects using the various tools in the 3D environment to socialise with each other. The aim of the task was to demonstrate the tools provided and how they can be used to build friendships online. The task involved sharing photos, videos and music. The 6-item questionnaire was administered immediately after the task was completed. The results, displayed in Figure 11, show a positive reaction to this task. All of test-subjects agreed that the communication tools were effective for the task. This task depended heavily on the communication facilities and the positive feedback, with an average score of 1.75, is a good endorsement that they are useful and valuable tools. The feedback regarding the other tools provided, such as the facilities for uploading and sharing photos and videos, is also positive. 90% of respondents agreed that the facilities are sufficient for this type of socialising to take place. Further encouraging results were received for the statement regarding the acceptability of this type of scenario as a means for socialising online. The need for social interaction between students is very important and these results indicate CLEV-R succeeded in delivering an acceptable means for socialising online with 95% of test-subjects agreeing.

Figure 11. Results for User Trial Task 4

The results relating to the ASQ aspects of task 4 are shown in the graph in Figure 12. When the results are condensed, an overall satisfaction score of 2.15 is recorded. This indicates, that overall, the participants were satisfied with this social task. The ease of completing the task was rated positively by 90% of the test-subjects. Again, this indicates the tools required for this task have been designed in an intuitive way and the participants found them easy to use. While, the amount of time taken to complete the task was seen as satisfactory overall, 1 respondent did not agree. This result is surprising because this task had no set structure and the test subjects were free to do what they wanted, including finish the task when they felt it was appropriate. On the contrary, the other test-subjects engaged in this task and remained in the 3D environment for a longer period than anticipated. As in the previous ASQs a number of participants failed to respond to the statement regarding their satisfaction with the support information provided. The results suggest satisfaction among test-subjects towards this social task and indicate that the social tools, which have been incorporated into CLEV-R, support social interaction between students.

Figure 12. Results for User Trial Task 4

Results for each of the 4 tasks have been presented in detail. A summary of the average satisfaction level of participants with CLEV-R following completion of each of the tasks is presented in Table 4. These results indicate a high level of satisfaction experienced by the participants during each task and with CLEV-R in general. This is supported by the relatively low standard deviation scores which indicate the responses returned by all the test-subjects were similar.

Table 4. ASQ Results for Each Task

Task #	Average	Standard Dev.
1	2.23	0.62
2	2.02	0.82
3	2.09	0.77
4	2.16	0.91

4.2 User Study

This section presents an additional user study which was conducted in order to assess influencing factors on performance in VR environments and to highlight that some students may have an unfair advantage due to the medium which is used to deliver learning content.

It is well known that e-learning courses are challenged by a higher dropout rate than their real world counterparts (Martinez, 2003). Boredom, ennui and lack of motivation (Serwatka, 2005) are suggested as reasons for this effect. This chapter argues that VR offers a means to resolve this issue. Consequently, associated effects of conducting learning in VR should be considered at the design stage of such environments. Relatively little research has thus far has investigated which factors influence performance in VR environments. Performance issues are particularly important in an e-learning environment where it is unfair to disadvantage students and as a result it is important to understand these factors and take them into account. Some research has identified gender as an influencing factor in VR, as it has been well reported that genders process spatial information differently. Dünser et al. (2006), for instance, investigated spatial ability in 3D navigational tasks for augmented reality and found that men perform significantly better than women. They attributed a general higher amount of experienced VR gamers within the male sample for the significant performance difference. Coluccia & Louse (2004), on the other hand, surveyed 14 studies examining gender differences in simulated environments. They concluded that gender differences are due to the characteristics of the task, rather than the task being in a virtual environment.

Although gender has been identified as one of the performance influencing factors in VR, research has yet to answer how this difference can be mitigated or at least how the effect can be reduced which is essential in an e-learning situation. Other factors, such as a possible connection between age or experience with VR gaming and performance are often assumed. However, performance influencing factors have yet to be properly investigated. This chapter presents results of a study that has been conducted to assess these factors. Understanding what really influences users in VR is crucial for improving participation and continued success in e-learning courses. The following factors have been investigated in this study:

- Gender
- Age
- Previous experience with VR gaming
- Sense of direction

4.2.1 Experimental Setup

The aim of this study is to investigate which of the previously listed factors affect performance during VR tasks. For this purpose the VR e-learning environment was employed in this study in order to conduct a trivial search task. Subjects were provided with a clue that was given to the users prior to commencing the task. It was expected that users would retrieve an object that was described in the clue (for example, a book in the library). Performance was evaluated with the use of the AMPERE algorithm (Schön, O’Hare, Duffy, Martin & Bradley, 2005), which delivers a performance value (pv) ranging from 0 (failed) to 1.0 (excellent) in normalised cases (otherwise the pv can go beyond 1.0).

4.2.2 Evaluation Results and Discussion

This study was conducted with 20 subjects, 9 men and 11 women. The following statistical values describe this evaluation:

Table 5. Statistical Values

Variance	Mean	Median	Stand. Deviation	Skew	Stand. Error
0.21	0.63	0.55	0.46	0.77	0.1

As illustrated in Table 5, this study's population did not follow a normal distribution. Consequently, non-parametric statistical methods are employed in the following paragraphs (Coolican, 2004, p.292).

Gender

Gender differences within spatial tasks have been well documented and have thus been anticipated to be reproducible within this study. Men achieved an average pv of 0.8, whereas women achieved an average pv of 0.42. Men's performance was therefore twice as good as women's performance. The Mann-Whitney U test (Coolican, 2004) confirmed that this is a significant difference with U=20 and the critical value at 23. Naturally, it can be followed that gender and performance are correlated within this study. Figure 13 illustrates the correlation diagram for gender and performance, where 1=female, 2=male and performance values are ranked in categories of 0.25 steps. The graph shows a linear pattern with zero slope that appears strong. This indicates correlation and the Spearman ρ test confirms this result with the correlation coefficient at ρ=0.57 and the critical value at 0.423.

Figure 13. Scatter Plot Gender Comparison - PV

This evaluation confirms that gender is a factor that influences performance in VR. Interestingly though, Coluccia and Louse (2004) evaluated 14 independent studies examining gender differences in VR. They concluded that gender differences occur as a result of the nature of the task rather than the task being conducted in VR. This a first indication that the gender gap could be significantly decreased and techniques, for example appropriate spatial help, might be instrumental in doing so thereby removing the advantage to male e-learners in VR environments would have over female e-learners.

Age

Age is another factor that was expected to influence a user's performance in VR tasks. The general expectation is that younger subjects perform better in computerised environments and have also gained more experience using computers. This study grouped subjects into the following six age categories: ≤20, 21-25, 26-30, 31-35, 36-40 and >40. As the experiment was conducted within a university setting, it is not surprising that the age group of 21-25 year olds are represented strongest with 46%. 26-30 year olds formed the smallest group tested with a representation of just fewer than 3%. Figure 14 presents the age distribution within this study.

Figure 14. Age Distribution

The figure shows the actual amount of people who participated in this study. We examined the results of this experiment towards a correlation between age and performance value (pv). Figure 15 presents the performance achieved according to age groups. This chart is not sufficiently representative though, as the age group of 31-35 year olds are not represented in this sample.

Figure 15. Distribution Age to Performance

A scatter plot in Figure 16 illustrates the correlation between age and performance and shows zero slope and a linear pattern with several outliers. In order to test for a correlation between age and pv a Spearman ρ test is conducted, which delivered a correlation coefficient of $\rho=0.49$ and the critical value at 0.423. A correlation between age and pv could therefore be identified. Indeed, the scatter plot illustrates that younger candidates potentially perform better. It is generally anticipated that younger participants would perform better in VR tasks, as their exposure to computers and VR gaming has trained them to process digital information more rapidly. Care should be taken however not to generalise this effect by anticipating that older users underperform within a VR e-learning environment because, as illustrated in Figure 16 this is not generally the case.

Figure 16. Scatter Plot Age and Performance

Gaming Experience

A recent study indicated that experience in VR gaming is a crucial factor in VR tasks (Burigat & Chittaro, 2007). Furthermore, experience is often perceived to be a main factor for achieving good performances regardless of the task. Therefore, it was desirable to include a variety of experience levels within this study. Naturally, it would be expected that users with good VR gaming experience would perform better in any VR task. It is consequently of interest to test for this effect within this experiment.

Subjects were asked to rate their experience of computer games on a scale from poor to excellent. Out of a sample of 20 candidates half rated their level of VR gaming experience as average. However, a quarter of subjects rated their knowledge as poor. The distribution of expertise with VR games throughout the iterations is presented in Figure 17, which illustrates the amount of people who participated in each experiment.

Figure 17. Experience with VR Gaming

Interestingly, self-ratings were distributed equally between men and women. Figure 18 illustrates the scatter plot for the gaming experience correlation. In order to compare gaming experience and performance values categories were introduced. Performance categories were incremented by 0.25 pv points, while experience as matched on a scale from excellent = 1 to poor = 4. Interestingly, the graph does not indicate any significant correlation. However, the Spearman ρ test indicates that there is a slight correlation with $\rho=0.478$ and the critical value at 0.423. Realistically however, this study could not identify a correlation between performance and experience, as the graph does not indicate a significant correlation and the statistical analysis barely indicates significance.

One explanation for this result may lie with the problems of self-evaluation. Many factors may influence an individual's self-rating. Lack of comparability or a different evaluation scale might be reasons. For future evaluations it would be beneficial to include a questionnaire that stabiles user experience in terms of usage frequency.

Figure 18. Correlation between VR Gaming Experience and Performance

Sense of Direction

A further expectation relates to sense of direction and the expected performance within VR tasks, which are predominantly spatial in nature. It would be natural to assume that subjects who rate their sense of direction as good or excellent would outperform subjects who rate their sense of direction as average or poor, as this particular evaluation was established as a search task.

Figure 19 displays the distribution of perceived sense of direction. Numbers denote the actual amount of people within this study. This study showed a relatively level distribution of ratings. The minority of subjects considered their sense of direction poor. Interestingly, twice as many men than women rate their sense of direction as excellent or good.

Figure 19. Distribution of Sense of Direction

Figure 20 presents a scatter plot to illustrate if there is a correlation between the variables sense of direction and performance. As in the previous paragraph, performance values were categorised in intervals of 0.25 points. Sense of direction was categorised from 1=excellent to 4=poor. No pattern can be identified in this graph. The Spearman ρ test confirms that the two factors sense of direction and performance do not correlate, with $\rho=0.2$ and the critical value at 0.423. Similar to the previous test, further evaluations should include a separate test regarding the sense of direction. Female users appear more modest in their self-evaluation, which might have distorted results in this study.

Figure 20. Correlation between Sense of Direction and Performance

The experiment described in this section has highlighted the main issues to consider when designing a VR environment. These factors are particularly important in the e-learning domain where it is important that no students obtain an unfair advantage, due to the environment, over their peers. In the next section the results of this usability study and the previous user trial are discussed and used to provide guidelines for the design of e-learning environments which utilise VR.

5 CONCLUSION AND FUTURE WORK

Although the need to motivate and stimulate students is well known, such techniques have not been widely adopted and evaluated in the e-learning domain. This chapter has described and evaluated collaborative techniques which engage students with learning environments and promote a better learning experience for students. The approach relies on the use of a 3D VR environment which simulates a university setting. The platform is multi-user and students can use real-time communication tools to interact with each other. Learning material is delivered synchronously via live lectures. A user trial was conducted in order to gauge the opinions of users regarding this novel mode of e-learning. The results are positive and the test subjects involved in the trial could easily see the merits of the approach and felt it was a suitable technique for carrying out a series of tasks, common in an e-learning situation.

When using new modes of teaching, it is important that no student obtains an unfair advantage merely by the medium which is used to deliver material. To examine this, a user study was carried out to assess which factors influence performance in a VR situation. The user study outlined to which extent factors such as age, gender and gaming experience influence users' performances during tasks in VR scenarios. Many of these factors are naturally assumed to influence performance. However, no prior significant studies into these effects have been conducted to date. Age, Gender, gaming experience proved to be significant factors to influence performance in VR. The perceived, sense of direction on the other hand, was not identified as a performance influencing factor. While factors such as age and gender are relatively simple to assess, fuzzy classifications such as the level of gaming experience and sense of direction are less trivial in their assessment. Within this study a self-evaluation questionnaire was employed. However, for future studies it would be beneficial to include a pre-test in order to evaluate these factors independently. The advantage of a pre-test as opposed to a self-evaluation is that users are assessed on a consistent and objective scale. Furthermore, some research has already been conducted in order to develop novel techniques that aim to minimise the effects of these factors (Schön & O'Hare, 2008) and indicates that more intuitive navigational support techniques, such as those offering subliminal stimuli, can be instrumental in creating a better user experience in VR.

While the focus of the research presented here has been on providing collaborative real-time support, the merits of asynchronous e-learning should not be overlooked. One of its benefits is the lack of time constraints which it places on students. While CLEV-R provides asynchronous access to lecture material via the *Library*, the synchronous lecture is where the majority of learning takes place. By offering both forms of e-learning, it is up to the student to decide which is most beneficial to them. Similarly, CLEV-R offers few opportunities for off-line, asynchronous communication such as message boards, emailing and forums. These can be easily incorporated into the design and form the focus of future studies to determine how they compare to the real-time communication which is currently offered in CLEV-R and ultimately improve the learning experience for students.

ACKNOWLEDGEMENTS

Research presented in this chapter was funded by a strategic Research Cluster grant (07/SRC/I1168) by Science Foundation Ireland under the National Development Plan. The authors gratefully acknowledge this support.

Key Terms and Definitions

3D Environment: A virtual representation of a location in which users can interact with each other

Avatar: The onscreen persona which represents the user as they interact with the environment and other users

CLEV-R: Collaborative Learning Environments with Virtual Reality; this is the online learning system described in this chapter which uses virtual reality to provide an interactive environment in which users can collaborate.

Collaborate: To cooperate and work together on the same topic, can be done synchronously or asynchronously.

Immersive: An engaging experience in which the use feels they are part of the environment which they are experiencing.

Online Learning: Using the internet as a means of obtaining an education

Social Interaction: Using synchronous tools, such as voice chat and photo sharing to communicate with peers and fellow users of the system

Usability: Study: An evaluation method used to determine if the system being tested offers the functionality required by users

User: The individual who is interacting with the system. In the case of the system described here, that is generally a student or a teacher.

Virtual Reality: An onscreen representation of a real or imaginative environment in which the use can interact.

REFERENCES

Anaraki, F. (2004). Developing an Effective and Efficient eLearning Platform. *International Journal of the Computer, the Internet and Management 12*(2), 57–63.

Bouras, C. & Tsiatsos, T. (2006). Educational Virtual Environments: Design Rationale and Architecture. *Multimedia Tools and Applications 29*(2), 153–173.

Bouras, C., Fotakis, D., Kapoulas, V., Koubek, A., Mayer, H. & Rehatschek, H. (1999). Virtual European School-VES. In Proceedings *of the IEEE International Conference on Multimedia Computing and Systems* (pp.1055-1057), Florence, Italy, June 7 - 11,. IEEE.

Bouras, C., Giannaka, E. & Tsiatsos, T. (2003). Virtual Collaboration Spaces: The EVE Community. In *Proceedings of the 2003 Symposium on Applications and the Internet* (pp. 48-55), Orlando, Florida, USA, January 27 - 31, IEEE.

Bouras, C., Philopoulos, A. & Tsiatsos, T. (2001). E-Learning through Distributed Virtual Environments. *Journal of Network and Computer Applications 24*(3), 175–199.

Burigat, S. & Chittaro, L. (2007). Navigation in 3D Virtual Environments: Effects of User Experience and Location-Pointing Navigation Aids. *International Journal of Human-Computer Studies 65*(11), 945-958.

Chittaro, L. & Ranon, R. (2002). New Directions for the Design of Virtual Reality Interfaces to E-Commerce Sites. In *Proceedings of the 5th International Conference on Advanced Visual Interfaces* (pp.308-315), Trento, Italy, May 22 - 24, ACM Press.

Cockburn, A. & McKenzie, B. (2002). Evaluating the Effectiveness of Spatial Memory in 2D and 3D Physical and Virtual Environments. In *CHI '02: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp.203-210), Minneapolis, Minnesota, USA, April 20 - 25, ACM Press.

Coluccia, E. & Louse, G. (2004). A UML-Based Software Engineering Methodology for Agent Factory. In *Proceedings of the 16th International Conference on Software Engineering and Knowledge Engineering*, Alberta, Canada.

Coolican, H. (2004). *Research Methods and Statistics in Psychology*. Hodder Arnold.

Cordier, F., Seo, H. & Magnenat-Thalmann, N. (2003). Made-To-Measure Technologies for an Online Clothing Store. *IEEE, Computer Graphics and Applications 23*(1), 38–48.

Darken, R. & Peterson, B. (2000). *Handbook of Virtual Environment Technology*, Stanney, K., Chapter 28: Spatial Orientation, Wayfinding and Representation.

Dickey,M. (2003). 3D Virtual Worlds: An Emerging Technology for Traditional and Distance Learning. In *Proceedings of the Ohio Learning Network; The Convergence of Learning and Technology-Windows on the Future*, Easton, Ohio, USA, March 3 - 4.

Doherty, P. & Rothfarb, R. (2006). Building an Interactive Science Museum in Second Life. In *Proceedings of the Second Life Education Workshop at the Second Life Community Convention* (pp. 19-24), San Francisco, California, USA, August 18 – 20.

Dünser, A., Steinbügel, K., Kaufmann, H. & Glück, J. (2006). Virtual and Augmented Reality as Spatial Ability Training Tools. In *Proceedings of the 7th ACM SIGCHI, Design Centred HCI*, (Vol. 158, pp. 125-132). ACM Press.

Harkin, J. (2006). Get a (Second) Life. *Financial Times*, Published: November 17 2006 .

Henderson, J., Fishwick, P., Fresh, E. & Futterknecht, F. (2008). An Immersive Learning Simulation Environment for Chinese Culture. In *Proceedings of Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC)*, Orlando, Florida, USA, December 1 - 4.

Hudson-Smith, A. (2002). 30 Days in Active Worlds: Community, Design and Terrorism in a Virtual World. *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments* (pp. 77-89), Springer-Verlag, New York, New York, USA.

Jones, J.G. & Bronack, S.C. (2008). Rethinking Cognition, Representations, and Processes in 3D Online Social Learning Environments. *Digital Literacy: Tools and Methodologies for Information Society*,(pp. 176–217).Hershey, PA: IGI Global.

Kamel-Boulos, M. N., Taylor, A. D. & Breton, A. (2005). A Synchronous Communication Experiment within an Online Distance Learning Program: A Case Study. *Telemedicine Journal and e-Health, 11*(5), 283-293.

Kemp, J. & Livingstone, D. (2006). Putting a Second Life Metaverse Skin on Learning Management Systems. In *Proceedings of the Second Life Education Workshop at the Second Life Community Convention* (pp.13-18), San Francisco, California, USA, August 18 – 20.

Kitchen, D. & McDougall, D. (1998). Collaborative Learning on the Internet. *Telemedicine Educational Technology Systems, 27*(3), 245-258.

Laister, J. & Kober, S. (2002). Social Aspects of Collaborative Learning in Virtual Learning Environments. In *Proceedings of the Networked Learning Conference*, Sheffield, UK, March 26 - 28.

Lewis, J. (1991). Psychometric Evaluation of an After-Scenario Questionnaire for Computer Usability Studies: the ASQ. *ACM SIGCHI Bulletin 23*(1), 78–81.

Martinez, M. (2003). High Attrition Rates in E-Learning: Challenges, Predictors, and Solutions. *The E-Learning Developers' Journal, 14*(1).

McArdle & Bertolotto (2010). *Assessing the Application of 3D Collaborative Technologies within an E-Learning Environment, Interactive Learning Environments*. Boca Raton, FL:Taylor & Francis. (In Press).

McInnerney, J. & Roberts, T. (2004). Online Learning: Social Interaction and the Creation of a Sense of Community. *Educational Technology & Society 7*(3), 73–81.

Monahan, T., McArdle, G. & Bertolotto, M. (2008). Virtual Reality for Collaborative E-Learning. *Journal of Computers and Education 50*(4), 1339 –1353. Elsevier Science.

Mowlds, F., Roche, B. & Mangina, E. (2005). ABITS: Learning More about Students through Intelligent Educational Software. *Campus-Wide Information Systems 22*(3), 131–139.

Nielsen, J. (1993). *Usability Engineering*. San Francisco: Morgan Kaufmann Publishers Inc. Redfern, S. & Naughton, N. (2002). Collaborative Virtual Environments to Support Communication and Community in Internet-Based Distance Education. *Journal of Information Technology Education 1*(3), 201–211.

Riedl, R., Barrett, T., Rowe, J., Smith, R. & Vinson, W. (2001). Sequence Independent Structure in Distance Learning. In *Proceedings of the Conference on Computers and Learning*, Coventry, UK, April 2 - 4.

San Chee, Y. & Hooi, C. (2002). C-VISions: Socialized Learning through Collaborative, Virtual, Interactive Simulations. In *Proceedings of Computer Supported Collaborative Learning (CSCL)* (pp.687-696), Boulder, Colorado, USA, January 7 - 11.

San Chee, Y. (2001). Networked Virtual Environments for Collaborative Learning. *in Proceedings of ICCE/SchoolNet: the 9th International Conference on Computers in Education* (p. 311), Seoul, South Korea, November 11 - 14.

Schön, B., O'Hare, G.M.P. (2008). Navigational Support Methodologies for 3D Virtual Worlds. In *Proceedings of the 21st Annual Conference on Computer Animation and Social Agents (CASA 2008)*, Seoul, Korea, September 1 - 3.

Schön, B., O'Hare, G.M.P., Duffy, B., Martin, A. & Bradley, J. (2005). The AMPERE algorithm – Area-Based Masking with the PERformance Equation. *In Proceedings of FLAIRS 2005, AAAI*, Clearwater Beach, Florida, USA, May 15 - 17

Serwatka, J.A. (2005). Improving Retention in Distance Learning Classes. *International Journal of Instructional Technology and Distance Learning, 2*(1), 59–64.

Sun, P. & Cheng, H. (2007). The Design of Instructional Multimedia in ELearning: A Media Richness Theory-based Approach. *Computers & Education 49*(3), 662–676.

Vass, E. (2002). Friendship and Collaborative Creative Writing in the Primary Classroom. *Journal of Computer Assisted Learning, 18*(1). New York: Blackwell Science.

Wheeler, M. (2009). Developing the Media Zoo in Second Life. *British Journal of Educational Technology, 40*(3). New York: Blackwell Publishing.