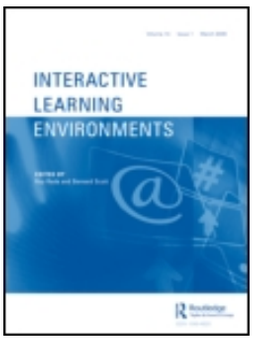

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Assessing the application of three-dimensional collaborative technologies within an e-learning environment

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Today, the Internet plays a major role in distributing learning material within third level education. Multiple online facilities provide access to educational resources. While early systems relied on webpages, which acted as repositories for learning material, nowadays sophisticated online applications manage and deliver learning resources. Courses that use solely traditional e-learning methods have high attrition rates, which are often attributed to boredom and lack of interaction with others. Indeed static text-based interfaces, where communication with others is often asynchronous, fail to stimulate students. In this article, we present a system which uses stimulating three-dimensional environments to present learning material to students, combined with multi-user and real-time technologies to permit interaction and collaboration between them. The article focuses on presenting results from a user study which indicate that these technologies can be used effectively to resolve several of the issues with existing e-learning systems. The results show that students enjoy interacting in the environment and appreciate the benefits the paradigm brings to e-learning.

Keywords: collaborative learning environments; social awareness; virtual learning communities; virtual reality; web-based education; multimedia

Introduction

The popularity and proliferation of the Internet has brought about a shift in how computers are used for teaching and learning. Sophisticated technologies are being utilised to manage learning content and offer this material to students, both as an accompaniment to conventional classroom teaching and also as a means of providing distance education to those who cannot partake in a traditional location-based teaching scenario. These e-learning (electronic-learning) platforms provide support for tutors and lecturers to present learning material to students via webpages. They are often referred to as Learning Management Systems (LMSs) or Course Management Systems (CMSs) as they offer tools which enable tutors to manage learning material and students in an effective and efficient way (Paulsen, 2003). For example, they can monitor the actions, participation levels and progress of students through a particular course and provide reports of this information to instructors. LMSs predominantly support asynchronous learning as interaction

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between teachers and students is primarily via the actual learning material. For tutors, these systems provide a convenient way to operate and manage courses using the Internet and for students, the lack of time constraints, which they impose, is an attractive proposition.

Although some of these individual learning environments offer sophisticated techniques to intelligently adapt learning material to individual student needs (Weber & Brusilovsky, 2001), studies indicate that courses which rely solely on mainstream e-learning applications tend to have a higher dropout rate than their face-to-face counterparts (Owston, 2000). Boredom, ennui and a lack of motivation are cited as contributing factors to the high-attrition rates within online courses (Serwatka, 2005). The delivery of learning content through LMSs relies heavily on webpages, where text is used to present the material. The use of this text-based interface involves the student reading large passages of text which they may find boring and not very stimulating (Anaraki, 2004). Such conventional e-learning techniques do not offer mechanisms for instant communication. This leads to a lack of timely interaction between learner and instructor and is one of the major drawbacks of the standard LMSs. Ultimately, it has been shown that this absence of interaction with others and the tutor can lead to feelings of isolation and loneliness for students (Kamel Boulos, Taylor, & Breton, 2005).

Collaborating with peers is an important element of learning in the real world (Kitchen & McDougall, 1998). It allows students to develop skills for dealing with people and teaches them about cooperation and teamwork. The asynchronous communication techniques provided by mainstream e-learning applications are not entirely suitable for organising group projects and so such tasks are often absent from e-learning courses. While interaction is important for collaboration, so too is social interaction between students (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 not feel that they 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).

The focus of our research is to address these shortcomings within mainstream e-learning applications. In order to achieve this, we have developed a system called collaborative learning environments with virtual reality (CLEV-R). Using a variety of technologies, notably multi-user virtual reality (VR) environments combined with real-time communication methods, CLEV-R specifically targets the problems highlighted above in order to provide an interactive interface for university students to access online learning content. In order to assess the benefits of using CLEV-R as a learning tool, a usability study was carried out. Details of this study, along with a discussion of the major findings, form the main focus of this article.

The next section discusses existing and current research which is related to our own work and places CLEV-R within this context. The article then proceeds to describe CLEV-R and detail the functionality which it offers learners. The Evaluation section forms the main focus of the article and describes the user study which was conducted, while also providing a discussion and analysis of the results. The article concludes by summarising the main findings of the research presented

here and also provides details of possible further developments of CLEV-R and the general research within this field.

Background and related work

CLEV-R is an e-learning system which addresses the issues, discussed above, in relation to mainstream e-learning platforms. Through the use of multi-user three-dimensional (3D) environments, CLEV-R engages and stimulates students. Communication tools augment a VR interface and provide opportunities for real-time interaction between students and their peers as well as supporting communication with tutors.

A number of research studies also explore this area. Educational Virtual Environments (EVE) (Bouras, Giannaka, & Tsiatsos, 2003) and Intelligent Distributed Virtual Training Environment (INVITE) (Bouras, Triantafillou, & Tsiatsos, 2001) are two such examples. While these systems have some unique features and are targeted at different types of learner, they both use 3D graphics to create a virtual onscreen environment. Within these systems each user is represented in the virtual world by an avatar and all other connected users can see this character. Learning content, such as lecture notes and videos are displayed simultaneously in the 3D space of all users. Students can interact with each other using some synchronous communication techniques including text and voice chat, allowing collaboration to take place.

Other systems such as C-Visions (Chee & Hooi, 2002) and Virtual European Schools (VES) (Bouras et al., 1999) focus on teaching specific subjects. C-Visions is a VR environment that supports science education by providing interactive animations and experiments. Hands-on tasks teach students about mass, velocity and acceleration in an interesting and novel way. The VES project created a 3D environment with a number of themed areas. Book publishers provide slideshows, animations and links to external sources of information relevant to the specific theme or subject. The evaluation results of some small user trials, conducted with the systems discussed above showed that they proved popular with users, who found them intuitive. The real-time communication methods were cited as a major advantage of the systems. The 3D paradigm itself was also rated highly by the test-subjects who liked the interactive features it can provide. Further details regarding the evaluations of these systems can be found in Bouras and Tsiatsos (2006) and Chee (2001).

A number of researchers are examining techniques for incorporating e-learning facilities into existing technologies. *Active Worlds* (Hudson-Smith, 2002) and *Second Life* (Harkin, 2006) are examples of online VR communities in which computer users inhabit an onscreen 3D environment via a personal avatar. Researchers are now adapting these environments for educational purposes. For example, Kemp and Livingstone (2006) discuss the possibility of using *Second Life* as an interactive interface to provide access to learning material stored in a traditional text-based LMS, while Doherty and Rothfarb (2006) have developed an educational science museum using *Second Life*, in which students can interact with 3D objects and attend online seminars. Similarly, Henderson, Fishwick, Fresh, and Futterknecht (2008) discuss *Second China*, an environment developed in *Second Life* to educate students about Chinese culture. Participants can access information and take part in guided learning scenarios while communicating and collaborating with others. Dickey (2003) describes the use of *Active Worlds* as a form of distance education within a university, while Riedl, Barrett, Rowe, Smith, and Vinson (2001) describe an

environment developed in *Active Worlds*, for training teachers. In an evaluation, Riedl et al. (2001) found that users particularly appreciated the awareness of others which the avatars create and also enjoyed the interaction with others which was possible through the shared virtual space.

Our own system, CLEV-R, has many of the traits of the systems described above. However, as discussed earlier, the need for social interaction, even in asynchronous learning environments, is of paramount importance (Rourke, Anderson, Garrison, & Archer, 1999). CLEV-R addresses this issue by providing a number of unique features, which permit students to interact with each other in a natural, fun and entertaining manner. While it could be argued that our work could utilise existing systems, particularly *Second Life*, the need for an easy to use interface, which focuses on providing tools for learning and social tasks was important. An interface which contains unnecessary and sometimes distracting functionality, such as non-humanoid avatars, was deemed inappropriate. Furthermore, when students interact within *Second Life*, there is always a risk of them encountering unsavoury individuals. In order to control access and provide dedicated learning environments, *Second Life* permits the purchase of 'islands' by institutions. However, these are expensive and developing them for learning needs is time consuming. Therefore it is more advantageous to develop a controlled environment which has the required functionality already available. In addition to the development of an e-learning system, an in-depth evaluation of CLEV-R is included within our research. Such studies, which are the focus of this article, are absent from the existing body of research in this domain.

CLEV-R

While the current trends within this area focus solely on the delivery of learning material, we are also conscious of the importance of providing a means of social interaction and collaboration tools within the learning domain. CLEV-R uniquely offers dedicated tools to support these modes of interaction in addition to facilities for various learning scenarios. In this article, the Graphical User Interface (GUI) is outlined. A full description of the implementation of CLEVR can be found in McArdle, Monahan, and Bertolotto (2007a). As CLEV-R is a web-based application, designed to operate in an online environment, the GUI is presented via a webpage. It consists of two distinct parts; a 3D VR environment which resembles a university setting and a two-dimensional (2D) interface which facilitates instant communication between users of CLEV-R. These two elements operate in conjunction with each other and their functionality is described below.

The 3D interface

The 3D interface essentially consists of an onscreen VR environment through which a user navigates using a keyboard and mouse. The environment of CLEV-R mimics a university setting and provides many of the features found in a real college or university. The virtual world is multi-user; this means the actions of a single user are seen to occur in the 3D environment of all other users. This creates the sense of a shared space. The feeling of the presence of others is further enhanced through the use of avatars, which are unique onscreen representations of each user. Students and tutors control these humanoid-characters and can instruct them to make gestures,

such as raising their hand or nodding their head, as they interact with others. This plays an important role in creating an awareness of other students. The onscreen university consists of several different rooms; each designed to facilitate a specific task. The environment includes *classrooms, meeting rooms, social areas* and a *library*. Tools, such as presentation and media boards within these rooms, enable learning, collaborating and socialising to take place.

The virtual *lecture room*, seen in Figure 1, is the hub for learning within the 3D environment. A tutor can use the tools in this room to deliver a live lecture synchronously to a group of students. A variety of media can be used by a tutor to present lecture material and provide an interactive learning experience. This can be further enhanced through the use of real-time audio and video communication. The same functionality is extended to the *meeting rooms* which can be used by groups of students to work together and collaborate. Specialised tools enable students to share and view files in the 3D environment and discuss them in real time using the communication facilities found on the 2D interface. While such facilities are suited to group learning scenarios, CLEV-R also provides a virtual *library*, which acts as an

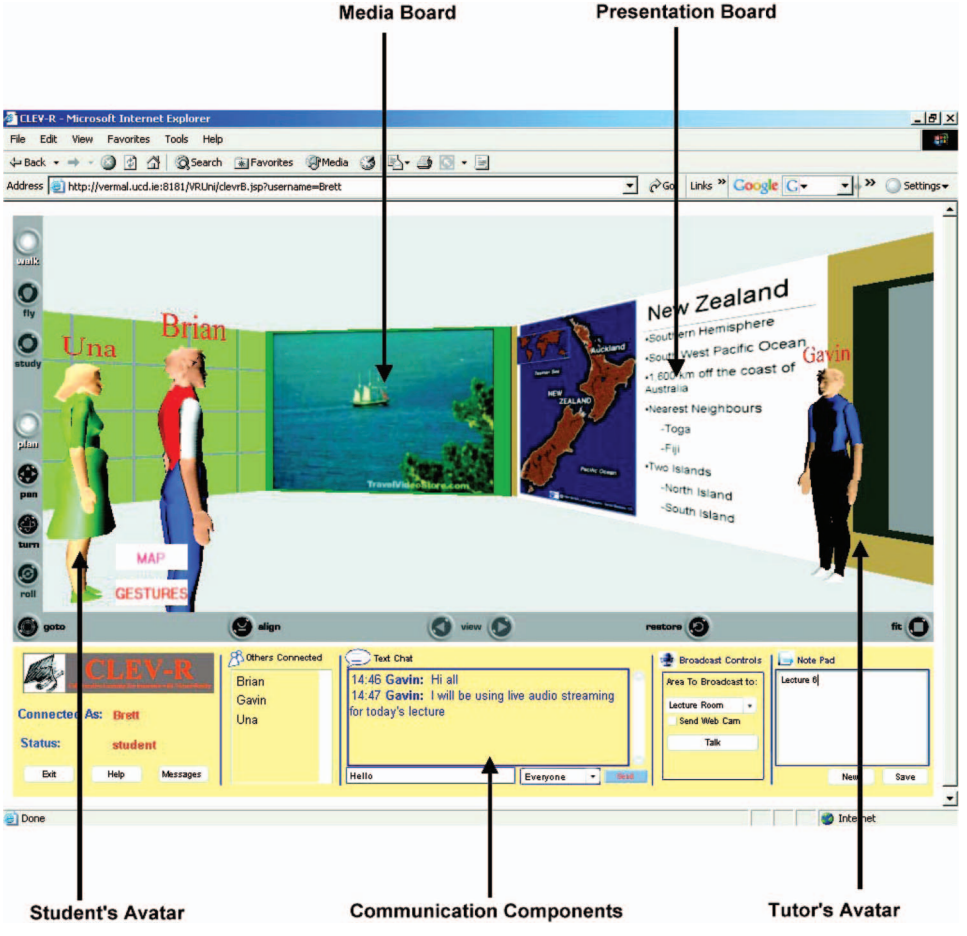

Figure 1. Students attend a lecture in the CLEV-R lecture room.

individual learning area. The *library* provides access to material which has been supplied by the course tutor. The library paradigm creates an interactive mechanism for students to obtain learning material. Learning content is placed on a bookcase, from which students can select the content they wish to study, and then view it on a desk within the *library* or download it to their computer for later review.

In addition to the tools outlined above which are used for learning, CLEV-R also promotes social interaction among students through the inclusion of a number of dedicated areas for socialising. A *common area* and *coffee area* can be used by students to interact with each other before and after class, it is equipped with communication tools to facilitate chatting and informal discussions. These social tools are extended into dedicated *social rooms*, seen in Figure 2, which like the *meeting rooms* allow students to share files with each other. For example, photos and video clips can be displayed and viewed simultaneously by a group of friends.

The 3D interface provides tools for a variety of learning and social scenarios. In addition, support tools such as interactive maps and audio assistance can be used to aid students as they interact with CLEV-R. Many of the activities offered in the 3D environment rely on real-time communication tools. These tools are offered via a 2D component which is discussed below.

The 2D interface

The primary function of the 2D GUI is to provide access to the different modes of communication available in CLEV-R. The GUI also facilitates users who wish to view

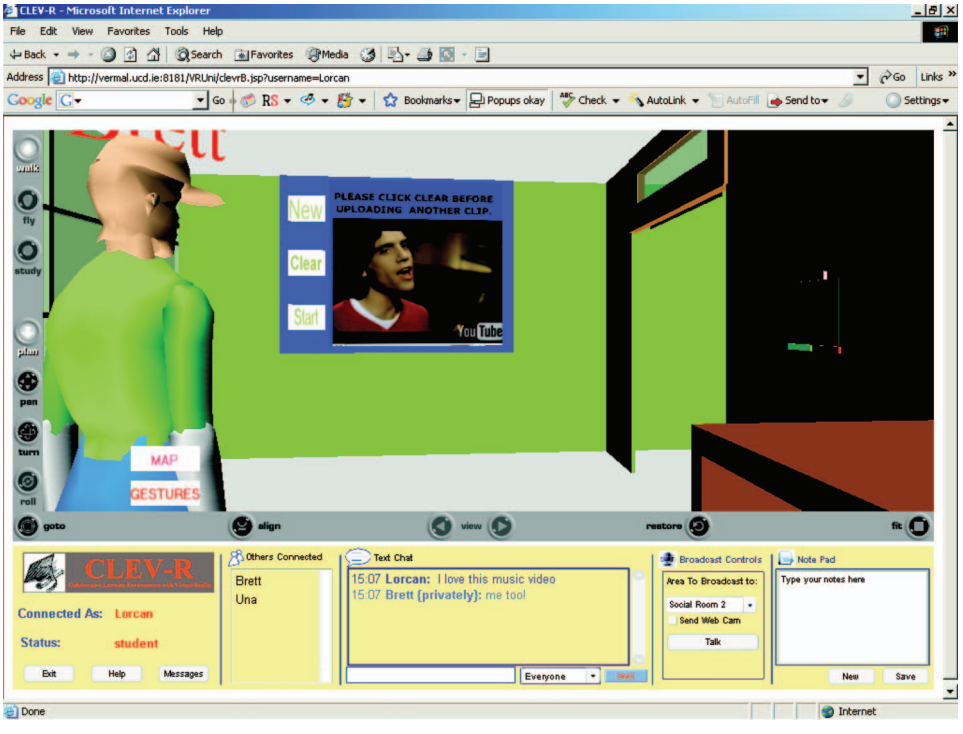

Figure 2. Students share a video in the CLEV-R lecture room.

help-files and take notes while using the system. As isolation and loneliness are major issues with existing e-learning applications, CLEV-R continually creates an awareness of others. In the 3D environment, this is achieved using avatars, while the names of other connected users displayed on the 2D interface further contribute to this. The text communication component provides an instant means of communication between all users of CLEV-R. The service operates similar to the instant messaging services provided by Yahoo! (http://messenger.yahoo.com) and Microsoft (http://messenger.msn.com). Tutors and students can type a short message in the box, shown in Figure 3, and then transmit it. Each message can be sent to all those connected to the system, known as a public message, or sent privately to selected individuals.

In addition, the 2D GUI houses controls for initiating and establishing live broadcasts from either a microphone or webcam. The provision of real-time streaming of voice and video is one of the major strengths of the CLEV-R interface and is the basis for providing synchronous learning and social opportunities to students. To establish such a communication, the user selects which room or area in the 3D environment they wish to broadcast to and then clicks and holds the 'Talk' button; the broadcast is then presented in the 3D environment of the appropriate users. During a lecture, a student may take notes using the note taking facility shown in Figure 3; once saved, these notes are then made available for viewing via the virtual *library* in the 3D environment. The 3D environment provides interactive access to learning material in order to stimulate and engage the learner. While the multi-user support, which offers students opportunities to interact, creates an awareness of others, this interaction is bolstered by a suite of communication tools which allow real-time contact between users of CLEV-R. While the discussion presented here focuses on the interface, a full description of CLEV-R and details of its implementation can be found in McArdle et al. (2007a).

Evaluation

Throughout the design and development of CLEV-R, evaluations were carried out iteratively. Cognitive and pluralistic walkthroughs (Bias, 1991; Wharton, Rieman, Lewis, & Polson, 1994) were used each time a new feature was incorporated into the system. Such walkthroughs involve a team of people assessing the ability of the system to achieve a particular task. It also ensures the steps involved in achieving this are logical. Combining these procedures with heuristics (Nielsen, 1994) to guide the design of the GUI ensured the development of a useable and appealing interface.

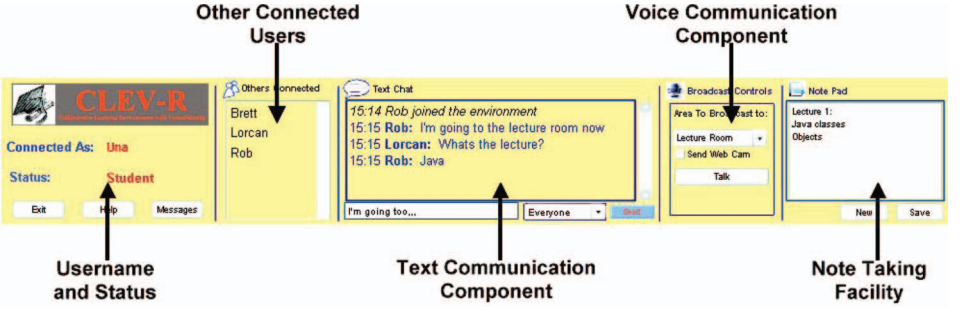

Figure 3. The 2D graphical user interface of CLEV-R.

Once development of CLEV-R had reached a mature stage, two usability studies were carried out. The first user study, details of which can be found in McArdle, Monahan, and Bertolotto (2007b), was carried out as implementation of the system neared completion. It was used primarily to determine any usability issues with the functionality of CLEV-R. Several technical issues were uncovered during this trial. These were resolved prior to the commencement of a further, larger usability test which is described in this article and was carried out when implementation of CLEV-R was complete. Usability testing (Nielsen, 1993) involves studying the interface and its performance under real-world conditions in which feedback from both the system and the users is obtained. In this section we describe the sample of users who took part in the trial, the approach which we adopted to evaluate CLEV-R and the results from a series of standard usability questionnaires, which were presented to the users after the trial.

Participants

A total of 20 volunteers were selected to take part in this user trial. This number has been shown to be sufficient for evaluating the usability of systems with the questionnaires we chose to administer (Tullis & Stetson, 2004). A user profiling questionnaire was used to gather information about each participant in the trial. The sample consisted of 16 postgraduate students from varied disciplines, one undergraduate business studies student, one teacher and three recently graduated professionals. Fifteen were males and five were females. The average age of the sample was 26.27 years old. All of the test-subjects used computers on a regular basis for a mix of activities. Nine of the male subjects had played first-person computer games in the past, whereas none of the female test-subjects had this experience. From the sample, 60% of the volunteers had used other e-learning systems previously and were reasonably satisfied with their experience. All participants took on the role of students within CLEV-R during the user trial. CLEV-R has been developed for university students and so the sample of test-subjects described above is a fair representation of the target users.

Approach

Three distinct types of scenario were identified for this evaluation, namely social, learning and collaboration and four different tasks were devised accordingly. The tasks were established around the premise of a geography course being run using CLEV-R. Each of the tasks is outlined below.

Task 1 – Social interaction

As many of the participants did not know each other prior to the evaluation study the first task consisted of an ice-breaking game. This is a standard technique employed to make people feel comfortable with new people and prepare them to interact. It is extensively used within the area of business-training and has also been more recently extended to the online domain (Clear & Daniels, 2001). We chose to use the classic game: 'Who am I? ' which involves one participant selecting a notable person from history. The other participants must ask a series of question with yes or no answers in order to discover the identity of the famous person. The task involves

social interaction and, as the students have to work together, it also involves collaboration. This task requires the use of the audio and text communication tools. In addition to the ice-breaking game, the participants were required to gather in a *meeting room* within the 3D environment. A list of countries was displayed on the presentation board in that room. The participants had to work together and select a country, about which they would complete a short project and present the findings in a later task.

Task 2 – Online learning

This task involved the participants attending a lecture in the *lecture room*. The lecture content was based on facts about a country. In order to make it as interactive as possible, the lecture material included Microsoft PowerPoint slides, movies and music files. The lecturer also used the audio communication and webcam features and encouraged participation from the test-subjects. After the lecture, the participants had to locate the *library*, find the appropriate set of notes for the lecture they had just attended and download them to their computer.

Task 3 – Collaboration

This task was concerned with presenting the findings from the project which was chosen in task 1. Each participant had to present his or her work to the others. They 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. The other members of the group were then encouraged to ask questions.

Task 4 – Social interaction

The final task was a free session within CLEV-R. This task encouraged the participants to interact and socialise with each other. In particular, they were requested to use the communication tools and share different types of media with one another. This task not only showcased the social tools within CLEV-R but also gave the participants free reign with the system to explore any usability issues which might arise and gave the opportunity to see how students might use the system in a real-world situation.

The entire sample of volunteers did not take part in the trial simultaneously, instead, the evaluation was conducted four times with five test-subjects and a lecturer taking part on each occasion and the results combined. This evaluation was conducted in conjunction with a user study of mCLEV-R (mobile CLEV-R) which is a lightweight accompaniment to CLEV-R for use on mobile devices. A subsection of the users were required to carry out the tasks on both the mobile and desktop versions of the system in order to ascertain the effectiveness of mCLEV-R. Details of mCLEV-R can be found in Monahan, McArdle, and Bertolotto (2007).

Evaluation questionnaires

The Computer System Usability Questionnaire (CSUQ) (Lewis, 1995), which is a standard usability questionnaire, was used to assess the appeal and usability of the

interface. It consists of 19 questions which determine the overall user satisfaction with a computer system. Each question is a statement and the respondent replies by selecting a value on a 7-point Likert-scale anchored at strongly agree (1) and strongly disagree (7). The questionnaire has shown to be a reliable measure of overall satisfaction with an interface with the scale having a coefficient α exceeding 0.89, indicating acceptable scale reliability. While the questionnaire can be used as an overall measure of satisfaction, it can also be subdivided into the three distinct sub-scales of *system usefulness* (to assess the participants' overall satisfaction level towards the usefulness of the system), *information quality* (to assess the participants' overall satisfaction towards the level of help and support provided with the system) and *interface quality* (to determine the participants' overall satisfaction level towards the quality of the interface and the tools it contains). It was administered after the test-subjects had completed all tasks. A further questionnaire was administered in conjunction with the CSUQ. Seventeen questions, taken from several standard questionnaires relating to participants presence in virtual environments (Biocca, Harms, & Gregg, 2001; Gerhard, Moore, & Hobbs, 2001; Schroeder et al., 2001; Slater, Usoh, & Steed, 1994; Witmer and Singer, 1998), were combined with a series of 13 questions specifically related to CLEV-R in order to gauge the sense of awareness of others and the sense of presence and social interaction experienced by the test-subjects.

Two additional questionnaires were used during this evaluation. The After Scenario Questionnaire (ASQ) (Lewis, 1991) was used after each task to obtain user feedback regarding the ease of completing each of the tasks using CLEV-R, while Microsoft Product Reaction (MPR) cards (Benedek & Miner, 2002) were used to gather qualitative feedback. MPR cards require the test-subjects to select words from a series of 118 words which they feel best describe CLEV-R. Details of these elements of the CLEV-R are not presented in this article but can be found in McArdle, Monahan, and Bertolotto (2009).

Results and discussion

The CSUQ was administered to test-subjects once all tasks had been completed in order to assess their overall satisfaction level towards CLEV-R. The questionnaire can be split internally into three distinct subsections referring to three different aspects of the system, namely *system usefulness, information quality* and *interface quality*. In addition, a single supplementary item is used to obtain the respondents' overall satisfaction with the interface and system. Initially details of the CSUQ results are provided before an analysis of the results pertaining to the social awareness and presence elements of the questionnaire are presented.

System usefulness

The first eight items on the CSUQ deal with *system usefulness*. The results are shown in Tables 1 and 2. As can be seen from the tables, the overall trend regarding the usefulness of the system is a positive one. Condensing the scores for this section of the questionnaire gives an average score of 2.18. This indicates a high level of satisfaction among the subjects regarding the usefulness of CLEV-R. The ease of use was rated highly among the participants with the majority of them perceiving CLEV-R as simple to use.

Table 1. Number of responses returned by participants regarding the CSUQ – System usefulness, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
Overall, I am satisfied with how easy it is to use this system	7	9	3	1			
It is simple to use this system	8	6	2	4			
I can effectively complete my work using this system	4	11	4	1			
I am able to complete my work quickly using this system	2	8	7	3			

Table 2. Number of responses returned by participants regarding the CSUQ – System quality, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
I am able to efficiently complete my work quickly using this system	2	7	5	5		1	
I feel comfortable using this system	7	9	2	1	1		
It was easy to learn to use this system	6	10	2	2			
I believe I became productive quickly using this system	7	8	2	1	2		

The learnability of any computer system is a very important aspect of its usability (van Weile, van der Veer, & Eliens, 1999). In this study, the majority of participants agreed that it was easy to learn how to use CLEV-R and, furthermore, believed they could become productive quickly while using the system. The 3D paradigm was a new one to many of the participants, and so assessing their level of comfort was an important factor. Despite many of the test-subjects being considered novice users with little experience operating in a 3D virtual environment, 90% of them felt comfortable while using CLEV-R.

Information quality

The CSUQ is also used as a means of assessing the participants' satisfaction with the quality of the information associated with the system. This does not refer to the content provided by the system, such as learning material, but refers to the quality of help files and feedback within the system. Seven questions are used to assess this. When combined, the results for the seven questions of this element of the questionnaire give an average score of 2.60. This is a good response indicating an overall high level of satisfaction, however, relative to the other items of the CSUQ, it is the lowest score returned. This is further emphasised by the relatively high standard deviation value of 1.11 for this result. The system scored well in relation to the information provided and how it is organised, with 85% of test-subjects agreeing the information provided is easy to understand. However, dealing with errors and mistakes is the aspect which received the most negative responses from participants.

Eighty-six per cent of those who responded were indifferent or did not agree that CLEV-R gives error messages that clearly state how to fix a problem, with one of the participants strongly disagreeing. While providing suitable support structures for users is an important aspect of developing a computer system, the focus of this CLEV-R prototype is to provide a 3D interface for e-learning. The provision of a more sophisticated structure for providing assistance would enhance CLEV-R and potentially improve the feedback relating to the *information quality* of the system.

Interface quality

The third metric which can be gleaned from the CSUQ provides a score for the *interface quality*. Table 3 shows a graph which presents the three questions used to give an average *interface quality* score of 2.02 with a standard deviation of 0.73.

This is an excellent score and indicates that participants were impressed with the interface. No negative answers were returned for any of the items in this section of the questionnaire. One hundred per cent of participants agreed that they liked using the interface and 90% found it pleasant to use. The quality of the interface is particularly important to CLEV-R as the use of 3D interfaces specifically for e-learning is a new undertaking and these results are encouraging. *Interface quality* scored the highest from the three individual metrics in the CSUQ. This is an indication that the use of cognitive walkthroughs and heuristics during the design of CLEV-R ensured the development of a high quality interface that is supported by the functionality expected within an e-learning application.

Overall score for computer system usability questionnaire

All the scores returned from the CSUQ can be condensed to give a final metric for an overall user satisfaction score. This is achieved by using the results from the above three metrics and combining them with one additional question regarding overall satisfaction. The average of the overall scores returned for the complete questionnaire is 2.21 (on the 7-point Likert-scale) with a standard deviation of 0.85. On the basis of this response, we can conclude that the participants found using CLEV-R, on this occasion, for this specific task to be an overall satisfying experience.

Social awareness and presence

The CSUQ was administered in conjunction with another questionnaire consisting of a series of questions to gauge the participants' reaction to their sense of awareness

Table 3. Number of responses returned by participants regarding the interface quality, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
The Interface of this system is pleasant	6	10	2	2			
I like using the interface of this system	7	9	4				
The system has all the functions and capabilities I expect it to have	5	9	3	3			

and presence in the 3D environment and to assess their overall opinions of CLEV-R. As in the CSUQ, the same 7-point Likert-scale was used. One of the key attributes of this type of multi-user environment is the sense of both presence and social awareness, which it can create, along with the ability to collaborate with others. We are already aware from the comments returned on the CSUQ that these features consistently appealed to the participants. These characteristics are often absent from traditional e-learning systems and so we wanted to measure to what extent they are delivered through CLEV-R. Details of the test-subjects' responses in relation to their awareness of others are shown in Table 4. Eighty-five per cent of the participants agreed that they were immediately aware of the presence of others in the 3D environment and 90% could easily recognise others, while almost all participants were aware of the actions of others. These results imply that the use of avatars within CLEV-R is sufficient to create a sense of awareness between the users and allow them to recognise each other easily within the 3D environment. Importantly, 85% of test-subjects agreed the presence of others engaged them in the learning experience, while 75% felt the presence of others actually enhanced their learning experience. This is evidence that suggests students' awareness of others is important in the e-learning domain and highlights the shortcomings of existing e-learning platforms which fail to offer this level of awareness and interaction.

In Table 5, awareness of others contributed to 75% of the participants agreeing that they had a sense of belonging during the user trial and 80% of test-subjects agreed that they felt part of a group. Despite being in physically different locations, almost all of the respondents felt as if they were in the same room as the other participants. These responses indicate that the features provided in CLEV-R are suitable for interacting with others and creating a sense of community. Furthermore, when users think back to the environment, they see it more 'as somewhere they visited rather than images they saw', indicating that the environment engaged them. CLEV-R provides a number of tools to facilitate collaboration between its users. These tools appear to have been a success. As we can see from Table 5, 95% of the test-subjects had a strong sense of collaboration with others in the 3D environment which is evidence that the facilities provided are an effective means of collaborating with others.

We were also interested in receiving feedback from the participants on their overall impressions of CLEV-R and their experience of using the 3D interface for e-learning. The most important results are presented in Table 6. In order to fully engage students and maintain their interest, it is important for the environment to be

Table 4. Number of responses returned by participants regarding their awareness of others, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
I was immediately aware of the existence of other participants on mobile devices	3	3	4	5	3		2
I was aware of the actions of other participants	4	8	7	1			
I could easily recognise other people in the 3D environment	5	8	5	1	1		
The presence of other people engaged me in my learning experience	6	8	3	3			

Table 5. Number of responses returned by participants regarding their interaction with others, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
I experienced a strong sense of collaboration with other participants in the 3D environment	3	13	4				
I had a strong sense of being in the same room as the other participants in the 3D environment	9	7	3	1			
I felt part of a group	8	9	3				
I had a strong sense of belonging	3	7	5	4	1		

Table 6. Number of responses returned by participants regarding their attitudes towards CLEV-R, where a score of 1 = Strongly agree and 7 = Strongly disagree.

	1 (strongly agree)	2	3	4	5	6	7 (strongly disagree)
Overall enjoyment level in this environment was high	11	5	4				
The virtual environment maintained my interest	7	10	3				
I felt comfortable in this environment	4	12	2	2			
The learning material was presented in a motivating way	5	5	8	1		1	

fun and entertaining. The table shows that enjoyment levels during the trial were high, with none of the participants expressing dissatisfaction. These results are echoed by the fact that all test-subjects had their interest maintained in the virtual environment with an average response score of 1.8 on the 7-point scale. Several of the test-subjects had expressed dissatisfaction with existing e-learning platforms on this front and so such positive results for CLEV-R indicate that it has more to offer the student than the current standard e-learning systems. A lack of motivation is also cited as a failing of conventional e-learning systems, however, as the results indicate, this does not appear to be a factor in CLEV-R with 90% of the test-subjects agreeing that the learning material is presented in a motivating way. The sample consisted of 12 people who had prior experience of traditional e-learning systems. From this group, 92% of them agreed that the presentation of the learning system through the 3D environment is more engaging than it being presented through a text-based webpage. This highlights that interfaces like CLEV-R have something to offer as an e-learning solution.

Conclusion

Studies indicate that courses which operate solely in an e-learning context have a higher dropout rate than their face-to-face counterparts. This is attributed to a lack of engagement with the learning environment and an absence of interaction with both tutors and fellow students. To address this issue, we have developed a system

called CLEV-R. Unlike the traditional e-learning systems, which supply a text-based interface to access learning material, CLEV-R uses immersive 3D environments to deliver learning material. Multi-user technologies create the sense of a shared space and contribute to the presence of others. In addition, real-time communication technologies allow synchronous learning, collaborating and socialising to take place. The use of 3D interfaces, such as CLEV-R, is a new paradigm within the e-learning domain and so determining their usability, usefulness and appeal is important. Twenty participants took part in a usability study which involved them performing several tasks using CLEV-R. The feedback from questionnaires administered after the study show CLEV-R appealed to the test-subjects. The ease of use of the tools provided was rated particularly high. A large proportion of the subjects had experience of using other e-learning systems. Although the majority of these were positive towards the e-learning systems they had used in the past, after using CLEV-R, 92% of them expressed a preference for accessing learning material through the 3D interface. Furthermore, it is the features and facilities which are lacking in mainstream e-learning applications that the participants most appreciated in CLEV-R. For example, the participants particularly liked the interactive and multimedia features. The questionnaire responses also show the students' interest in learning was maintained and the 3D environment engaged and motivated them.

Unlike the traditional e-learning platforms, the interface provided in CLEV-R facilitates social interaction between students using a mix of tools to create a sense of awareness of others and support students to build friendships. The results pertaining to this aspect of CLEV-R are positive. By creating an awareness of others using avatars, the participants felt part of a group and had a sense of belonging. The majority of users also saw the inclusion of tools for social interaction and discussion, which are supported by facilities for sharing files, as benefits of the system. The positive results suggest that the use of systems such as CLEV-R have much to offer e-learning. In particular, CLEV-R appears to address several issues which are prevalent in existing e-learning platforms.

When analysing the results of this study one must be conscious of the short duration in which the test-subjects were exposed to CLEV-R. It is possible that a portion of the positive feedback can be attributed to the novelty factor of the 3D interface which was a new experience for most of the test-subjects. A further study would be useful to gather information following the use of the system over a longer period of time. Extending this evaluation to include a comparative study with a simplified version of CLEV-R, without the 3D interfaces and some of the multiuser features, would be beneficial and serve as a baseline to further identify the specific characteristics of CLEV-R that make it appealing to students. The evaluation of CLEV-R, presented in this article, was conducted in a controlled environment. To combat this limitation, a real college course could be used in the longitudinal study to help determine if CLEV-R can improve retention and reverse the high dropout rates which courses operating via traditional e-learning platforms are experiencing at present. While the results relating to the sense of presence and engagement experienced by test-subjects are positive, more in-depth analyses of such factors using sophisticated physiological measures (Meehan, Insko, Whitton, Brooks, & Frederick, 2002) could further gauge how the 3D environment effects students. Despite the need for these further studies, the results presented here indicate that this paradigm certainly has something to offer within the e-learning domain. The approach demonstrates that the tools developed are effective for learning,

collaborating and socialising online and that this is an area which warrants further exploration.

Future work

There are a number of areas within CLEV-R which could be further developed to provide increased support to students in their learning and social needs. Providing e-learning functionality on a mobile device, termed mobile learning (m-learning), offers increased flexibility to students. To date, little external research has examined the possibilities of augmenting m-learning with real-time collaboration and social interaction tools. However, as discussed previously, work in this area is already underway through the development of mCLEV-R (Monahan et al., 2007). Mobile devices, such as Personal Digital Assistants (PDAs), are a convenient way for students to access learning material while on the move. Providing additional support for communication, collaboration and social interaction, which CLEV-R offers on a desktop computer, strengthens the benefits of such devices for m-learning.

There is also scope within the design of CLEV-R to include more personalisation and adaptive techniques to the interface to further enhance the learning experience. Personalisation of interfaces involves developing software that adjusts the interface based on a users' behaviour pattern and past actions (Gajos, Czerwinski, Tan & Weld, 2006; Liu, Kuen Wong, & Keung Hui, 2003). Within CLEV-R, this approach could be used to alter the physical appearance of the 2D interface or the 3D environment for a particular student based on their common activities. Similar techniques can be adopted to display learning material depending on a learner's preferences. Such adaptive techniques could also be examined and utilised to support students with disabilities. For example, those with visual impairments could access the system via a personalised interface which features larger text and graphics, while other text-to-speech techniques could be employed for reviewing learning material. In addition, the use of voice commands for navigating within the 3D environment could be explored to aid students who have difficulty in interacting with a computer using traditional input methods.

While CLEV-R addresses many of the issues with conventional e-learning systems, there is room within the approach to incorporate some of the beneficial features which mainstream e-learning applications provide. In particular, asynchronous communication places fewer restrictions on students than its synchronous counterpart. While real-time communication is beneficial, it limits users to contacting each other while they are online simultaneously. The asynchronous communication methods in conventional e-learning applications do not enforce such a limitation. While it would be easy to incorporate asynchronous technologies into the design, at present CLEV-R does not provide direct access to e-mail, forums or message boards. As a result it restricts the times when students can contact each other. Additionally, asynchronous e-learning applications permit students to access learning material in their own time. While this facility is available in CLEV-R (via the virtual Library), live online learning activities are the predominant learning technique, which could be seen as a limiting factor by some individuals. However by offering both methods to students, the onus is on them to decide if the many benefits of real-time interaction outweigh the impact of time constraints.

Implementing the enhancements and addressing the limitation discussed here would enhance and improve the learning experience offered by CLEV-R. Together

with the further evaluation measures proposed in the previous section, these additional features would add further weight to the argument that 3D environments have potential to be a useful instrument within mainstream e-learning.

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