mCLEV-R: Design and Evaluation of an Interactive and Collaborative M-Learning Application

T. Monahan, G. McArdle and M. Bertolotto
University College Dublin, School of Computer Science and Informatics

Abstract— **Continuous enhancements in computer technology and the current widespread computer literacy among the public have resulted in a new generation of students that expect increasingly more from their e-learning experiences. To keep up with such expectations, e-learning systems have gone through a radical change from the initial text-based environments to more stimulating multimedia systems. E-learning functionalities are now also being extended to mobile platforms in order to be more available and convenient for users. Many mobile learning applications have now been developed and they too are becoming more advanced. However, providing truly collaborative and interactive mobile learning tools still remains a challenge. In this paper, we present a desktop e-learning system called CLEV-R and in particular a component of the system that we have developed for mobile devices. This mobile component explores the possibility of providing collaboration tools for mobile learners while also presenting the learning experience through an engaging 3D environment.**

***Index Terms*— Collaborative M-Learning, Interactive Learning, Virtual Reality.**

I. Introduction

Researchers are currently seeking ways to make the e-learning experience more interactive and engaging for students. It is no longer sufficient to provide mere online repositories of course content which students can access. Vast improvements in technology and networking performance over the last decade now allows for the development of much more sophisticated and complex online systems. Many Learning Management Systems (LMSs) and Course Management Systems (CMSs) are now available to help manage online learning content and to support course instructors and students. Examples include BlackBoard [1] and Moodle [2]. While these systems have proved effective, they also have their limitations. Course material is often provided in text formats, which is not very stimulating for the user. Also communication tools available tend to be in the form of asynchronous discussion boards and forums which can result in long delays between user postings. Often students can feel isolated and lonely as they access the learning material in these environments, and the lack of communication and collaboration tools can make e-learning a solitary experience. Recognising this, today much research is being carried out to provide a more stimulating learning experience with specialised communication tools being employed for students to work together. Our system CLEV-R (Collaborative Learning Environments with Virtual-Reality) [3, 4], is one such web-based application. Realising the need to stimulate students, it uses a 3D environment enriched with multimedia features to provide an engaging and motivating environment for students. The 3D world is augmented with a suite of communication facilities, which permit students to communicate in real time. The need for social interaction within e-learning applications is paramount [5, 6], and so the tools and facilities provided in CLEV-R can be adapted for use as a collaboration tool to facilitate group work, or utilised as a medium for socialising. Social interaction is furthered encouraged by providing specialised features so students can share videos, music and photos within the 3D environment.

Over the past decade, the use of mobile technologies has emerged as an important field within the research community. While at first these devices were mainly used as personal organisers with limitations on the tasks they could perform, today they are far more sophisticated, providing users with instant access to email and the Internet as well as a host of Global Position System (GPS) tools. The ever-increasing amount of wireless networks along with improvements in the computing power of these devices has fuelled much research into developing innovative applications for them. As e-learning grows in popularity, researchers are investigating the use of mobile devices within this domain, leading to the introduction of the term m-learning. The ability to learn while on the move is an extremely attractive prospect; accessing learning material while waiting at the dentists or commuting on the train is a very beneficial use of time.

When designing m-learning applications, it is important to follow the current trend in e-learning by providing an equally interactive and collaborative means of learning. Users should be engaged in the learning experience and resources should be available to support communication among students and tutors. To this end we are developing mCLEV-R, an extension of CLEV-R, which has been specifically tailored for use on Personal Digital Assistants (PDAs). The system offers a stimulating 3D environment which users can interact with in order to access course material and communication controls. Synchronous text and audio communication facilities are provided which ensure that mobile users can be constantly connected to others in their online learning community. Also mobile users can access an announcements page to remain up to date with all new developments in their course.

The remainder of this paper is organised as follows. Section 2 presents some related work within the fields of e-learning and m-learning. Section 3 briefly describes CLEV-R before detailing its mobile component, mCLEV-R, and the various features it provides. We then discuss a recent evaluation study that was carried out in section 4, and present the main results obtained regarding the mobile system. Finally we conclude with a brief discussion of future work in section 5.

II. Related Work

Many different techniques are currently being researched in the field of e-learning to provide a more appealing and stimulating experience for online learners. One area of high interest at the moment is the addition of software agents to traditional e-learning systems. These agents are intelligent entities that can monitor students' progress and manage the system more efficiently. They can also be used to personalise the learning experience for each user tailoring the interface or the delivery of learning content to their individual preferences. Some systems have been developed where the agent is a visual aid on a users computer screen. For example, the Bio-World project [7] has developed ADELE, an assistant agent represented as a 2D image that acts as a medical consultant. Students are monitored as they diagnose patients in training situations presented to them on screen. ADELE provides feedback to students as well as making suggestions during the diagnosis session. This visualisation can be further enhanced by using 3D models for the agent representation where the agent can then demonstrate certain tasks to the user. Some training systems have used this technique where the aim is to teach users very specific tasks [8-10]. Jacob [8] is an intelligent agent in a Virtual Reality (VR) environment that guides the user through the steps involved in solving the towers of Hanoi problem. By following the directions of Jacob the user learns how to solve the problem themselves. Likewise, STEVE [9, 10] is an software agent that has been developed for use in naval training to show individuals or groups of students how to operate and maintain complex equipment. STEVE can demonstrate certain tasks and then watch while users carry out these tasks, correcting them when mistakes are made.

Recently, the use of Virtual Environments (VEs) within e-learning has also been explored. The EVE [11] and INVITE [12] projects looked into this possibility for use in training. The Intelligent Distributed Virtual Training Environment (INVITE) project carried out much research into collaborative e-learning and designed a detailed system specification. However, this project was then discontinued due to insolvency of the project partners and so its development phase never reached completion. The Educational Virtual Environments (EVE) platform offers a multi-user VR environment for training purposes that delivers multimedia content to users and enables the sharing of some applications. Indeed our own research also explores this area through the development of CLEV-R. This system provides an interactive interface to a general 3D learning environment where different types of courses can be run simply by uploading the appropriate material. As many studies have now shown the significance of social interaction amongst students in learning environments [5, 6], support for social interaction and collaboration is an important aspect of the system.

For some time now, researchers have been interested in the potential of mobile devices as learning aids. While laptop computers are commonplace and capable of delivering large amounts on information efficiently, smaller mobile devices such as PDAs and mobile phones also show promise in this area. Many have explored different ways to provide learning services on these mobile platforms. European-led projects including M-learning and MOBIlearn have carried out much research into learning through a mobile environment. The MOBIlearn project (www.mobilearn.org) concentrates on adapting existing e-learning content for mobile devices as well as creating pedagogy for learning on these devices. The M-learning project (www.m-learning.org) focuses on delivering learning content to young adults who are no longer taking part in formal education or training. They have developed a wide range of learning tools for palmtop computers and mobile phones ranging from interactive quizzes for teaching languages, driver theory tests and activities designed to develop aspects of literacy and numeracy. Indeed companies are also active in m-learning research. For example, Ericcson has been at the forefront in m-learning since 1999. Under the Leonardo Da Vinci Programme of the European Commission, they have designed pedagogical scenarios and developed courses for both PDAs and mobile phones in their "From e-learning to m-learning" project [13a]. They are currently working on the "Mobile learning: the next generation of learning" project which is exploring the use of email, web-browsing, streaming audio and video, and multimedia messaging (MMS) for m-learning using the most recent of technologies [13b].

Other researchers have explored the potential of m-learning for teaching a second language [14]. Students can wirelessly download learning material to a mobile device and access it at any time. Some researchers see games and interactive challenges as the way forward in mobile learning. Ketamo designed a game for handheld devices that teaches geometry to 6 year old kindergarten children [15]. Göth et al developed a location based game to help new university students become familiar with the university and it's surroundings [16]. The use of 3D graphics for learning has also been investigated on mobile devices. An effective system for teaching mobile users the art of origami was designed in [17].

The extension of our own system, CLEV-R to a mobile platform is a new and innovative undertaking. CLEV-R's m-learning component supports "anytime-anywhere" access to learning content. Unlike existing m-learning systems, mCLEV-R offers an interactive 3D learning environment with a host of communication tools. These tools offer the prospect of collaboration with other users, either those connected on a desktop PC or those logged in on another mobile device. The next section describes the CLEV-R system briefly before detailing the features provided in mCLEV-R.

III. System Description

A. CLEV-R

CLEV-R is a web-based e-learning system for use on desktop computers. It delivers the learning experience to students through a 3D multi-user environment enabled with multiple tools to support its user's needs. Each person is represented as an avatar within the environment

which allows users to easily recognise each other. The environment mimics a real university setting. It contains a lecture room for synchronous online lectures, a number of meeting rooms for group work and collaboration and a library for accessing course notes. A number of social areas are also provided where students can interact informally with each other. Communication within CLEV-R is paramount and so multiple forms are supported. Students and tutors can interact freely through text-chat, audio-chat and web cam broadcasts. Also each user's avatar is enabled with gestures which allow them to communicate visually during lectures and group meetings. Learning content can be uploaded to the lecture room by a course tutor, which all users can then see. At present PowerPoint files, word documents, images, videos and MP3s are supported. Also a lecturer can use a live web cam feed to further illustrate learning content. Fig. 1 shows an example of an online lecture taking place within the CLEV-R environment. In addition, students can upload their own files to the environment in meeting rooms and social areas. This greatly aids collaboration on group projects and also allows students to share personal files while interacting socially.

Through the development of CLEV-R, we are researching the potential of 3D environments for e-learning and are now also exploring their potential for m-learning. We are currently extending the functionality of the CLEV-R system to a mobile platform. In particular we are developing a 3D interface for PDAs to create an engaging and motivating m-learning environment and are exploring the possibility of providing synchronous communication methods so that mobile users can always be connected to others in their learning environment. The features of mCLEV-R are discussed in the next section.

B. mCLEV-R

Due to current limitations of PDAs including slow download times, low processing power and small screen size it was not possible to simply access the desktop version of CLEV-R on these devices and so a lightweight, scaled down version called mCLEV-R has been developed. The system is again presented through a series of web pages and access to learning materials is provided through a 3D environment. This VR world is however different to that in the full-scale CLEV-R system. It is a much smaller environment with simplified features. It resembles an office and acts as a place that users can go to access course materials and communication facilities. This environment, as seen in Fig. 2, consists of a number of features: a filing cabinet, download board, desk, laptop computer and telephone.

The filing cabinet and accompanying download board provide functionality for downloading course material. A student can interact with the filing cabinet by opening and closing drawers and selecting the lecture notes they wish to download. Links to these lecture files are then placed on the download board and can be saved to the user's device. Screen size and resolution limitations mean that it is not possible to display course notes within the VR environment. Thus it is necessary to use external applications such as Pocket Word, Pocket Acrobat Reader and Pocket Slides to view the learning content. Lecture notes from a user's desktop PC can also be downloaded to their mobile device through synchronisation.

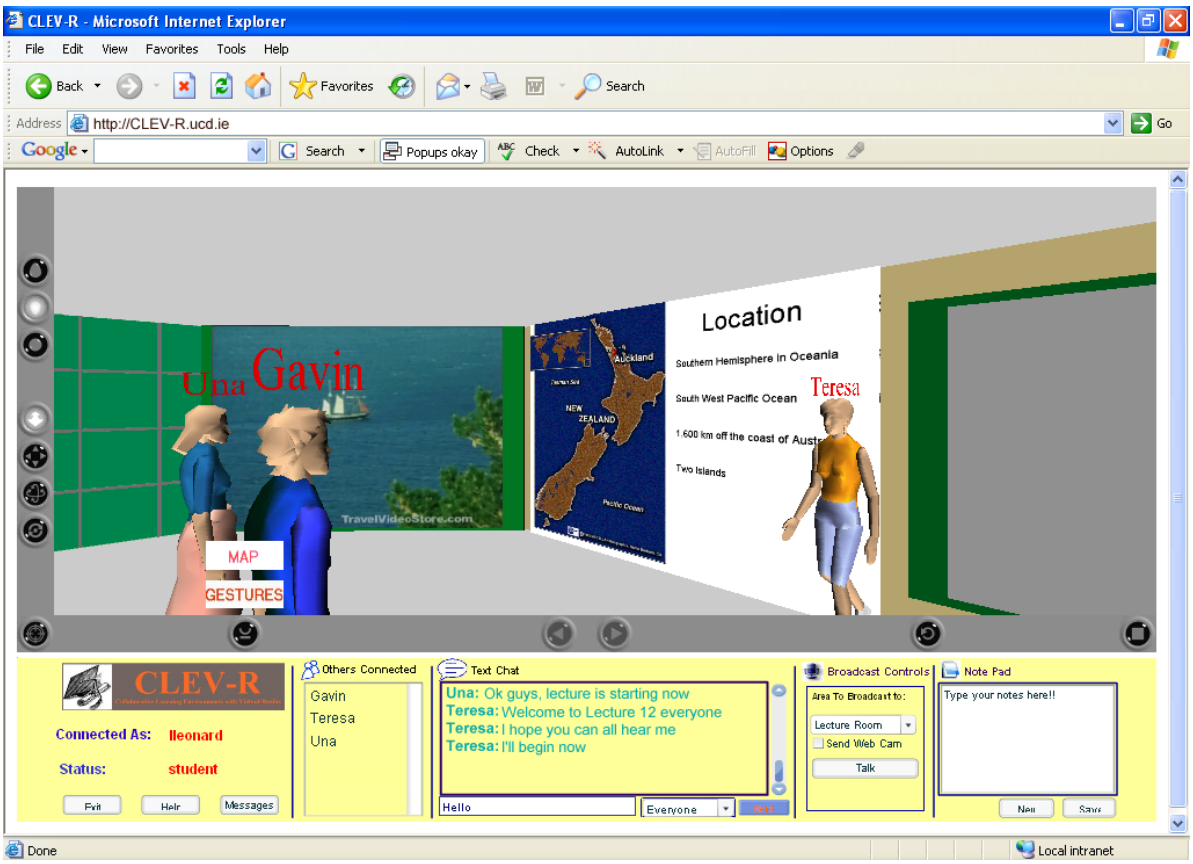

Figure 1: Online lecture taking place within the CLEV-R environment.

Figure 2: The 3D environment of mCLEV-R

Figure 3: The text-chat interface of mCLEV-R

The desk provides an area where students can access communication facilities and so interact with other users of the system. A laptop on the desk links the user to the same text-chat facility as the desktop version of CLEV-R and displays a list of all currently logged in users (see Fig. 3). All those connected can converse freely through this service thus linking mobile and desktop users. A 3D telephone links to a voice-chat facility, which allows users to chat via audio with others. This is particularly effective for mobile learners to listen to a live lecture commentary even if they are not present in the virtual lecture. It can also be used to collaborate with others during group meetings. Users can also link to announcements about the course. Unfortunately due to software limitations it is not possible to share events between mobile and desktop users. Therefore avatars are not present within the mobile 3D environment, and hence movements and gestures from the desktop system are not portrayed on the mobile device. The communication features provided do however create a social presence for mobile users and heightens their awareness of other system users.

A major challenge when developing for PDAs is their small screen size and low resolution. Web pages have to be designed carefully so that the content is displayed in a legible manner. Limited input methods must also be taken into account when designing these pages so that the user can navigate easily. This limitation is a greater problem when the web page contains a 3D environment, which the user has to interact with. The mouse primarily controls navigation and interaction in the desktop system. This is intuitive for many; however, interaction on the PDA depends on a stylus, which may be unfamiliar to users. Thus it is necessary to provide further aid for the user. In mCLEV-R, a predefined list of viewpoints is provided for easy navigation from one location to another. Users can select a viewpoint from this list and are then moved to that position in the VR environment. To attract the user's attention, the interactive features in this 3D environment are highlighted through the use of flashing objects. This learning environment with its communication tools will engage students and assist in making m-learning a more interactive experience.

IV. Evaluation

We have carried out a preliminary user evaluation on both the desktop and mobile systems to determine the usability of the systems and to gauge user feedback on the features the systems provide. We designed a set of 4 tasks for the user trials that ensured the test subjects would be exposed to all the different features of the systems. The tasks are outlined in Table 1.

TABLE I.
Task Outline for User Evaluation

Name	Description
Task 1 - Social Interaction	Communicate with others using the communication tools provided
Task 2 - Online Lecture	Attend a synchronous online lecture and download the appropriate course material
Task 3 - Group Meeting	Attend a group meeting and participate in a group discussion
Task 4 - Free Session	Fully explore the various features of the system and converse with other users as desired

Users alternated between the desktop and mobile systems carrying out the different tasks on both platforms. In total 9 users evaluated CLEV-R, while 5 participants took part in the evaluation of mCLEV-R. Overall the results are positive and test-subjects believe CLEV-R and mCLEV-R have potential in online learning. Further details of the evaluation of CLEV-R can be found in [4].

Each of the test-users of the mobile system carried out a minimum of 2 tasks using mCLEV-R. They completed task evaluation questionnaires after each task and then an overall system evaluation after their last session. In general, the system functioned as expected. However some users did encounter a few unanticipated problems. One of the biggest issues revealed was with the communication interface. Participants found scrolling between the text and audio communication sections of the interface frustrating and many suggested that the controls should be placed in closer proximity to each other. Also, while using the audio communication tool, mobile users disliked that they had no visual indication of who the current speaker was.

100% of the test subjects found the mCLEV-R environment effective for attending an online lecture. They all downloaded the lecture slides successfully and could easily listen to the live audio stream and follow the lecture notes simultaneously. One drawback highlighted by 75% of the users that took part in this task, was the inability to view media files during the online lecture. mCLEV-R did not support the download of movie or music files as we felt that users would prefer to sacrifice this functionality in favour of waiting for these files to download across a wireless connection. This, however, proved an incorrect presumption. All participants found the mCLEV-R environment an acceptable means of taking part in group collaborations. However, 66% of the test-users did highlight the fact that they couldn't see files uploaded by other users during a group meeting as a disadvantage. Feedback on the social interaction task was the most negative of all the tasks. This task relied most heavily on the text and audio communication facilities and the negative feedback was largely due to the problems experienced with the communication interface discussed above. Also in comparison to the desktop system, users felt less engaged in this particular task on a mobile device.

The audio controls of the system worked perfectly during the online lecture and all mobile users could hear the lecturer clearly. However, in the remaining tasks some users had difficulty hearing others. In order to broadcast their voice, users of the desktop system must click and hold a button on their interface. We feel that users may have been operating these controls incorrectly and so will give clearer instructions on their use for the next evaluation study to alleviate this problem.

In general, users' opinions of the system were positive. When asked if mCLEV-R is a useful tool for learning when students cannot be present at a desktop PC or fixed location, 80% strongly agreed and the remaining 20% agreed. Users showed a particular liking for the presentation of the system through a 3D environment and agreed that it was more engaging than a text-based alternative.

While this evaluation did uncover some usability problems with the system, overall feedback was encouraging. We have now addressed many of the issues raised in this preliminary user-study. In particular we have redesigned the communication interface so that it is easier to navigate between the audio and text communication controls. Also, the name of the current speaker is now displayed for all mobile users and we have added functionality which enables users of mCLEV-R to download media files. We are currently preparing for a more extensive evaluation study with a larger number of test-users.

V. Conclusions

This paper has introduced our desktop system CLEV-R, a 3D environment allowing students to learn, collaborate and socilise online. In particular, we describe an extension of CLEV-R for use on PDAs. This scaled down version, contains many of the features of the desktop system including an interactive 3D environment, access to learning material and communication facilities. Students can listen to live audio from a lecture and partake in group discussions with other students using either text or audio communication. They can download and browse course material while on the move and can keep up to date with course announcements at all times.

Following a preliminary evaluation of the desktop and mobile systems, we have received valuable feedback on both systems. Some usability and technical problems were uncovered which have now been addressed; however general reaction to the systems and the functionality they provide was encouraging. We are now making preparations to carry out a larger scale evaluation study to determine the usability of the systems and their true effectiveness as tools for online learning. Based on the positive response of users in our first evaluation study, we are confident that the engaging environments provided by CLEV-R and mCLEV-R, together with their support for various types of communication, will create appealing and effective learning tools for online students.

References

[1] Blackboard, 2007. www.blackboard.com

[2] Moodle, 2007. www.moodle.org

[3] G. McArdle, T. Monahan and M. Bertolotto, "3D collaborative virtual environments for e-learning and m-learning," *Proceedings of the 5th International Conference on Web-Based Education (WBE)*, Puerto Vallarta, Mexico, 2006, pp 1-6.

[4] T. Monahan, G. McArdle and M. Bertolotto, "Virtual reality for collaborative e-learning," *Computers and Education*, Elsevier publishers, 2007 (in press).

[5] J. Laister and S. Kober, "Social aspects of collaborative learning in virtual learning environments," *Proceedings of the Networked Learning Conference*, Sheffield, England, 2002.

[6] S. Redfern and N. Naughton, "Collaborative virtual environments to support communication and community in Internet-based distance education," *Proceedings of the Informing Science and IT Education, Joint International Conference*, Cork, Ireland, 2002, pp 1317-1327.

[7] E. Shaw, W.L. Johnson and R. Ganeshan, "Pedagogical agents on the web," *Proceedings of the Third International Conference on Autonomous Agents*, 1999, pp 283-290.

[8] A. Nijholt, "Agent-supported cooperative learning environments," *Proceedings of the International Workshop on Advanced Learning Technologies*, New Zealand, 2000.

[9] J. Rickel and W.L. Johnson, "Virtual humans for team training in virtual reality," *Proceedings of the Ninth International Conference on AI in Education*, 1999, pp 578-585.

[10] J. Rickel and W.L. Johnson, "Integrating pedagogical capabilities in a virtual environment agent," *Proceedings of the First*

International Conference on Autonomous Agents, California, USA, 1997, pp 30-38.

[11] C. Bouras, E. Giannaka, and T. Tsiatsos, "Virtual collaboration spaces: The EVE community," *Proceedings of the 2003 Symposium on Applications and the Internet (SAINT)*, Orlando, Florida, USA, 2003, pp 48-55.

[12] C. Bouras, V. Triantafillou, and T. Tsiatsos, "Aspects of collaborative learning environment using distributed virtual environments," *Proceedings World Conference on Educational Multimedia, Hypermedia & Telecommunications (ED-MEDIA)*, Tampere, Finland, 2001, pp 173-178.

[13] Ericcson Education Online:

a) From e-learning to m-learning – http://learning.ericsson.net/mlearning2/project_one/

b) Mobile Learning: The Next Generation of Learning - http://learning.ericsson.net/mlearning2/

[14] A. Trifonova and M. Ronchetti, "Hoarding content in an m-learning system," *Proceedings World Conference on Educational Multimedia, Hypermedia & Telecommunications (ED-MEDIA)*, Montreal, Canada, 2005.

[15] H. Ketamo, "mLearning for kindergarten's mathematics teaching.," *Proceedings of IEEE International Workshop on Wireless and Mobile Technologies in Education*, Växjö, Sweden, 2002, pp 167-170.

[16] C. Göth, U.P. Häss and G. Schwabe, "Requirements for mobile learning games shown on a mobile game prototype," *Proceedings of Mlearn*, Rome, Italy, 2004.

[17] G. Zimmerman, J. Barnes, and L.M. Leventhal, "A comparison of the usability and effectiveness of web-based delivery of instructions for inherently-3D construction tasks on handheld and desktop computers," *Proceedings of Web3D*, Saint Malo, France, 2003, pp 49-54.

AUTHORS

T. Monahan is studying for her PhD in the School of Computer Science and Informatics in University College Dublin, Ireland. (e-mail: teresa.monahan@ucd.ie).

G. McArdle is studying for his PhD in the School of Computer Science and Informatics in University College Dublin, Ireland. (e-mail: gavin.mcardle@ucd.ie).

M. Bertolotto is a senior lecturer in the School of Computer Science and Informatics in University College Dublin, Ireland. (e-mail: michela.bertolotto@ucd.ie).

Manuscript received 16 March 2007. The CLEV-R project is funded by the Irish Research Council for Science, Engineering and Technology (IRCSET) and the Culture 2000 Project TARCHNA EC Grant No. 2004-1488/001001, CLT- CA22.