Challenges for e-Learning Environments in m-Learning Contexts

A survey about the hardware, software, and educational dimensions

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Abstract— e-Learning environments are applications that use the Web infra-structure to support teaching and learning activities. Their user interfaces were designed to have good usability using a desktop computer with keyboard and mouse as input devices and a high resolution medium-size display and speak loud as output devices. Devices, such as tablets and smartphones, have computational power enough to render Web pages, allowing mobile users navigate through the e-Learning environments and closing the e-Learning environments to the m-Learning contexts. But to have an effective use in the mobile context, the e-Learning environments need to be analyzed in three dimensions: hardware, software, and educational. This paper presents a survey about works in merging e-Learning environments and m-Learning and discusses about challenges such hardware and software integration, integration between the browser and the environment and changes on the teaching and learning activities.

Keywords-Human-Computer Interaction; Electronic Learning Environment; Mobile Devices; Interaction Styles.

I. INTRODUCTION

e-Learning environments, such as Moodle [1], SAKAI [2], TelEduc [3], Ae [4], are applications that use the Web infra-structure to support teaching and learning activities. The e-Learning environments are designed to support a variety of users and learning contexts, but they are designed to conventional computers, usually equipped with keyboard and mouse as input and a medium screen and speakers as output; a limited interaction style for nowadays devices. These modalities and the technology shape the teaching and learning activities done in the e-Learning environments; they focus on reading and writing skills. Despites these technology impact, the e-Learning environments need to have good usability, accessibility, performance, security, availability and other software attributes.

Devices, such as smartphones and tablets, are becoming increasingly popular; most of them have touch screen displays, access to the Internet and enough computing power to process Web pages. So, Web sites and Web applications, initially developed to be used with keyboard, mouse and a medium size display, are being accessed by small touchscreen devices. This can be considered as another aspect of accessibility, so the environments´ development teams are building solutions to provide access on mobile devices, and the use of mobile devices with educational purposes is called m-Learning. Two motivations for m-Learning are to allow participants interact anytime and anywhere with the content and with each other.

The Internet was built to connect many technologies, so allowing mobile users to access e-Learning environments make the boundary between e-Learning and m-Learning not so clear. This brings some challenges for e-Learning environments developers and m-Learning practitioners. This paper presents a survey about the works to merge these fields. Section II presents a literature review about e-Learning, m-Learning and e-Learning environments. Section III presents the three dimensions to analyze the use of e-Learning environments to support mobile users. Section IV presents challenges to have an effective use of the e-Learning environments in the m-Learning context. Section V presents final considerations.

II. E-LEARNING AND M-LEARNING

e-Learning refers to the use of Information and Communication Technologies (ICT) in education. So, e-Learning is any distributed learning experience through the Internet, Intranet, Extranet, CD or DVD-ROM, because the e-Learning main concern is related with the teaching form and not with technology [5]. The e-Learning term refers broadly the terms Web-based learning, Internet-based learning, online learning, distributed learning, and computer-based learning. e-Learning is suited to distance learning, but it can also be used in conjunction with face-to-face teaching, calling blended learning.

Online systems that support e-Learning through the Web are called e-Learning environments or Virtual Learning Environments (VLE) or Learning Management Systems (LMS). Moodle [1], SAKAI [2], TelEduc [3] and Ae [4] are examples of e-Learning environments.

The first e-Learning environments are designed to integrate the content with communication tools arranged on the Internet (such as chat, mail and forum). They evolved increasing the number of tools for content publishing, participant´s communication and course administration, taking advantages of the Web to offer content with text, images, audios and videos in a hypertext document. Tools like chat, forums, portfolios, repositories are widely used, and tools those explore the audio and video resource to user communication, such as instant messenger and video-conferences, are becoming common among the environments.

The environments´ development teams are building solutions to provide access on mobile devices, and the use of mobile devices with educational purposes is called m-Learning.

m-Learning is any kind of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies [6]. m-Learning Technology includes handheld computers, MP3 players, notebooks, mobile phones and tablets; devices that have owner autonomy and it is easy to portable. Two motivations for m-Learning is allow the participants interacting anytime and anywhere with the content and with each other.

The recent technology forwards brings a broad of new applications made to support many areas, such Education. One of the mobile devices that are gained repercussion in this scenario is the Tablet PC (Tablet Personal Computer), a device with height as similar to a notebook and had an input device similar a pen. The paper and pen metaphor implies that tasks performed before in paper, like draw or manuscript writing, can be more natural in the Tablet PC than in the another computing devices. Resuming, the Tablet PC has the following hardware characteristics: (i) Pen sensitive screen; (ii) Screen that allows different positions; (iii) Wireless network access by Wireless Local Area Network (WLAN) and bluetooth technology; (iv) Microphones and embedded loudspeakers; (v) Keyboard (some models the keyboard are detachable); (vi) Batteries. Usually, the screen size ranges from 9 inches to 12 inches.

Other devices used in m-Learning are smartphones, which have touchscreen with computation power enough to render Web pages. Usually, the screen size ranges from 3 inches to 5 inches. Resuming, the smartphones have the following hardware characteristics: (i) touch sensitive screen; (ii) Screen that allow two different positions (landscape and portrait); (iii) Wireless network access by WLAN (Wireless Local Area Network), by 3G and bluetooth technology; (iv) Microphones and embedded loudspeakers; (v) Virtual keyboard (some models have a physical keyboard); (vi) Batteries.

Gay *et al*. [7] suggest that the introduction of wireless computing resources in learning environments can potentially affect the development, maintenance, and transformation of learning communities.

It is possible to use e-Learning environments for support m-Learning and three kind of solution are emerging: i) specific device application; ii) web site specific for mobile devices; and iii) improve the web site for mobile and desktop access [8]. Each solution has its vantages and disadvantages due the hardware and software restrictions of the mobile device.

Building specific device application allows designing a suitable user interface for the device and taking advantages of smartphone´s features, such as touchscreen and camera, but needs develop an application for each mobile platform. So, the applications to be developed needs specific knowledge programming skills and increases the code lines number to maintain. Moodle community offers the Moodle

App [9] and Moodbile [10], two native mobile applications with versions for the most popular smartphone´s platforms.

Moodle, since version 2.1, offers a Web site specific to mobile devices, an example for the second type of solutions for access e-Learning environments in mobile devices. Building a specific Web site to mobile device allows designing a suitable user interface for mobile devices taking account some common characteristics, such small touchscreen, but depends of the browser to access some platform features, such GPS, and increases the code lines number to maintain too.

The latter solution considers that smartphones and tablets have enough computational power to render Web pages and to do some adaptation if it is necessary, and offer the same user interface for any device. But the interaction styles may vary, so to design this kind of user interface it is necessary to do some usability studies to found barriers or user interaction problems for each interaction style. Disadvantages of this solution are to depend of browsers to use the mobile features and the difficult of consider many interaction styles in the same user interface. Da Silva, Freire and da Rocha [8] point out some problem that happen when a user interface designed to be used with specific interaction hardware is used with other interaction hardware.

Another e-Learning environment characteristic is to be used in many of learning contexts, e.g., teacher training, undergraduate courses, and team training in all areas of knowledge. We call this property as learnability. But, the actual hardware of conventional computers increases the difficulty to use the environment to produce content for any area and support student activities, e.g., to post a mathematic exercise that needs write formulas to resolve, the user need to use a specific software and post the file since the e-Learning environments do not support directly this kind of content.

The e-Learning environments need to be usable and accessible for many users in many social, physical, technological and learning contexts. So, e-Learning environments need to be evaluated in the usability, accessibility, mobility and learnability dimensions.

III. DIMENSIONS FOR ALLOWING e-LEARNING AND m-LEARNING MERGING

Khan [11] defines eight dimensions for a good e-Learning environment: Resource Support, Ethical, Institutional, Pedagogical, Technological, Interface Design, Evaluation and Management. Since in our work we want to use e-Learning environments in m-Learning contexts, the Technological, Interface Design, and Pedagogical dimensions need to be discussed due the impact caused by the device changing. We will join the Technological and Interface Design dimensions, since there is an intrinsic relation between them, and our focus is on mobile users. The Pedagogical dimension is related about the teaching and learning activities developed by the teachers and done by the students.

For technological dimension, we propose the e-learning environments needs to be evaluated about their usability, accessibility, mobility, and other software requirements, such

performance, scalability and availability. Due the diversity of users whom may use the e-Learning environments, these systems need to have good usability so that the user interface does not prejudice the teaching and learning activities, so the user interface cannot be a barrier between the student and the content or the users and their goals or injure the course activities.

Nielsen [12] defines usability as a combination of five elements: easy to learning, efficient, easy to remember, low probability of users do mistakes and user satisfaction. Nielsen proposes a method for evaluating the user interface usability, and other methods can be found on the Human-Computer Interaction literature [13] [14].

Accessibility, another important requirement, is about to allow disabled people use the environment, and can be understood as to be accessed by anyone, whatever their hardware or software. So to have a high level of accessibility, a Web page needs to be accessed by computers or any other computational device, such the smartphones and Tablet PCs, which can have assistive technology installed. Some methods can be found to evaluate the application accessibility, mainly for Web pages and applications, e.g., evaluating the interface conformance with the W3C guidelines [15].

In the educational dimension, the teacher needs to dispose content, to plain activities, to ask questions of the students about the activities and the content, to evaluate activities and other tasks. Pedagogically, the teacher needs to select the tools to be used to dispose the content and to run the activities. Usually, due the e-Learning environment tools and the hardware used to interact, a desktop computer, the activities are discussions by Forums, writing individual or collaborative texts. The texts may have pictures, but it is similar as works done in presence education, where the work can be delivered in a printed format. This kind of work does not take advantages of multimedia and the hardware available in the mobile devices. We discuss these problems in the next sections as challenges for e-Learning environments in the mobile contexts.

IV. CHALLENGES FOR E-LEARNING ENVIRONMENTS IN THE M-LEARNING

About the technology issues, it is need to analyze the hardware and the software and, since there are a variety of computing devices, aspects of human-machine interaction (such as ergonomics) and the device characteristics need to be considered. The most visible problem in browsing e-Learning environments using mobile device is the user interface adaptation. One of the adaptation issues is the content readability. For tablets it is not a big problem, since it is possible render the web page without injure de readability; the size of the tablet´s screen is not so small compared to the desktop display. But, in the case of smartphones, the screen size is not large enough to ensure readability, so it is necessary to have a page adaptation or techniques to visualize the entire page and use zooming to see the page details.

The user interface adaption is not a trivial task, a challenge not only for e-Learning environments, but for the Human-Computer Interaction, is to build system with adaptive user interface. Bickmore and Schilit [16] present a heuristic-based approach for Web page adaptations to be rendered in mobile devices with small screens, but their work does not consider audio and video adaptation. Zhang [17] purposes a framework to do content adaptation for systems accessed by a sort of devices (multidevices), increasing accessibility and doing a distribution optimization over the network. Oliveira and da Rocha [18] purpose priorities for consistence in the adaptation to maintain the same conceptual model for mutidevices, whom done a study case over an e-learning environment. Pyla *et al.* [19] discuss about the task migration between devices: the user starts the task in one device, go to another one to perform some sub-task, and change the device until the task be done.

But, Web applications should consider the Web architecture model, i.e., the client-server, to have a better adaptation. Client is responsible to render the user interface through a browser. It is in the client side that the user interacts with the system using input and output hardware. The server is responsible to process client´s requests and data persistence, but it knows few about the input and output devices in client side. Since the server is responsible to produce the user interface code to be displayed on the client, the server needs to know about the user device, the user location and user preferences to do a better adaptation. The generated interface needs to have good usability.

For example, smartphones are good to read and write small texts, such as post-it notes. The tablet with touchscreen allows users have mobility and a good readability, but it is not so efficient to write texts. The tablets equipped with pen sensitive screen should be used to write formulas or do sketches, instead of only as a pointing device. Da Silva and da Rocha [20] propose the InkBlog tool, a blog tool that receives input data from stylus in a pen sensitive tablet so that the user can handwriting her posts (Fig. 1a).

The InkBlog is a tool for the Ae e-Learning environment, and take advantages of the Pen-based computing to allow users interact with the e-Learning environment with a pen. The authors comment that using the InkBlog is possible a better support to disciplines such Graph Theory and Computer Theory. Without the InkBlog, the user needs to use paper and pencil to resolve an exercise and use specific hardware, such scanner, to digitalize the solution. Or the user needs to use a special application to draw a graph. In both solutions, the user posts the picture as an attached file in weblog post. Using the InkBlog the user can sketch the graph direct on the weblog tool through direct manipulation (Fig. 1b). InkBlog was tested in iPhone (Fig. 2) and Android devices using the stock browser in each device. Both devices display correct the posts, but due the platform does not distinguish between touch and stylus press, it is not possible to handwrite a post in these smartphones; both devices recognize the input as page scrolling. This is another challenge, the web pages depends on the browser, because the browser is responsible to the capture of the user input and the page rendering. So, the hardware and the browser needs be more integrated to enhance the Web application.

(a)   (b)
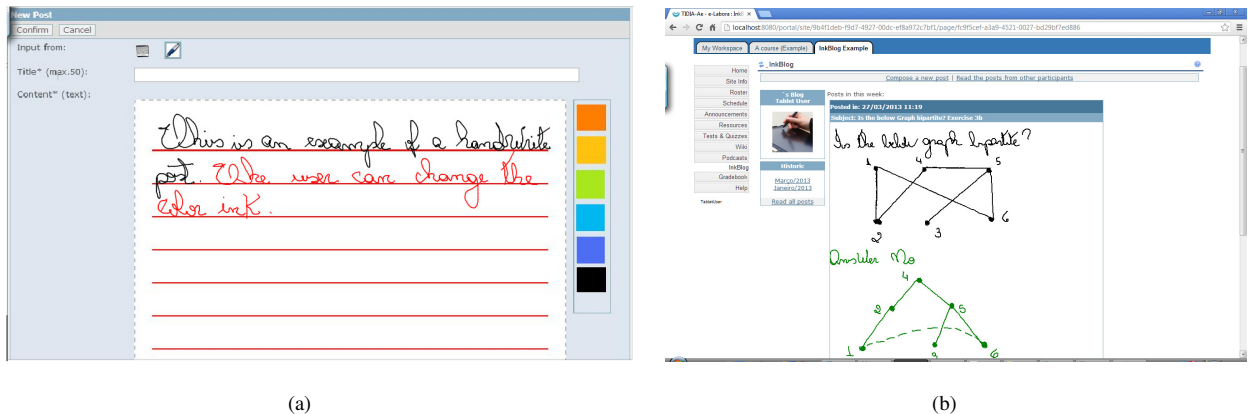
Figure 1. Using InkBlog to (a) handwriting a post and (b) to share a solution for an exercise about Graph Theory. Both pages rendered by Chrome Browser.

Figure 2. InkBlog rendered by stock browser on iPhone.

In the case of use e-Learning environments on mobile devices, is important to study the interaction problems that happen, since the actual environments was designed to be used in a desktop computer, and mobile phones have other interaction devices. da Silva, Freire, Arruda and da Rocha [21] present some problems when the users uses an mobile phone to interact with the Teleduc environment using an Android-based mobile device and a iPhone. Da Silva, Freire and da Rocha [8] present some problems when user uses an android-based smartphone and a Tablet PCs. They present a taxonomy about the interaction problems: cross-platform problem, cross-modality problem and platform and modality-independent problem. These problems are barriers or difficulties to the user navigate thought the environment. So one challenge is identify these problems and correct.

The environments need to have good usability and accessibility, but the content created inside the environments needs to. Since the environments are used by a diversity of people, most of them do not have knowledge about Web accessibility, they can create content with low accessibility in mobile devices. Fig. 3 shows an agenda on a course in TelEduc created by the teacher to describe about the topics and activities to be done in a week. Some problems when the agenda is rendered in iPhone (b) can be viewed with compared with the desktop computer (a). So, another challenge is to develop authoring tools that easily create accessible contents and to develop features to allow the mobile users to visualize the published content [22].

Allowing access by mobile devices is not the only challenge to facing it. The mobile devices have specific hardware that can be used to produce content and to use to interact with the environment. The camera can be used to take photos or do videos and the microphone can be used to create audio files to be published by the teacher or by the students as content in the e-Learning environment. To allow this it is necessary to have a better integration between the mobile hardware, the browser and the environment to easily allow users create content using camera, microphone or any other input device. These devices can too be used as communication if integrated with communication software. The actual versions of e-Learning environments only dispose an action button that trigger a dialog box where the user can choose the photo or video he want upload. Depending on the solution adopted to integrate the environment in the mobile device, it is possible to turn the publishing task easier. In the case of a specific device application it is possible to customize the mobile Operation System and include sharing option in the photo and video gallery, similar as Facebook app does (Fig. 4). So, the mobile user has options to publish the media in her virtual space on the e-learning environment, like a Portfolio item on TelEduc environment, or a resource item on SAKAI and Ae.

The TelEduc e-Learning environment has a notification tool that send e-mails for the course participants describing what happen since the last logging. This feature could be integrated with the mobile device advisor management system. So one more challenge is identify e-Learning features that can be integrated with mobile devices features.

The e-Learning environment has data about the course participants, whom can be added on the mobile device

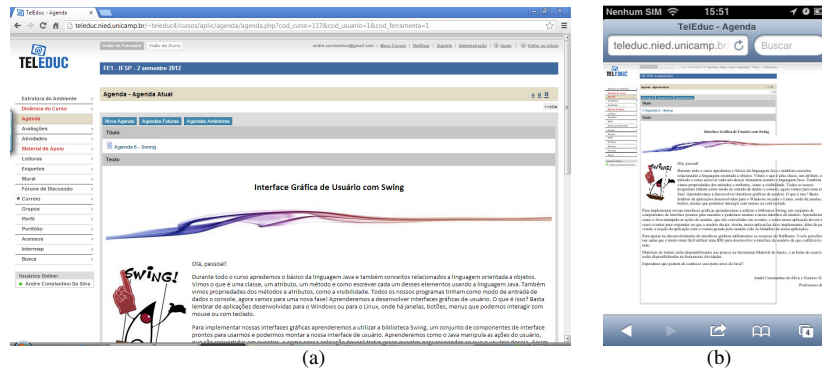(a)   (b)

Figure 3. A content created by a user in TelEduc with accessibility problems displayed on desktop computers (a) and on a mobile device (b).

Contacts tool to turn easily sent messages between the participants. Another one feature is synchronizes the activities deadline or important dates to the mobile device´s Calendar tool.

Allowing student to create multimedia content in activities, the teacher needs to select the best media or a set of them to planning the activities. The student´s works not need be more only texts, allowing them to produce videos, audios, photos or a multimedia work. If the teachers allow user to use the mobile phone, it is important elaborate activities that explore the mobile hardware, such take photos, make videos or record an audio. The student can write some text too, but it is important notice (and this is must be clear on the activity) that usually it is not expected a small texts for student´s activities; since writing on smartphones can be a difficult task, the teacher must specify how long the text must be. This perception impacts on the pedagogical use of the e-learning environment.

The actual user interface design techniques take account just a limit set of input and output hardware, limited to the context, such as techniques to design user interface for desktop or for mobile platforms. But, there is a lot of input or output hardware in these devices and these techniques are asked to consider all of them. Some input and output devices are: touchscreen, microphones, pen sensitive screen, touchpad, TrackPoint, accelerometers, joysticks, loudspeakers, small screen, large screen, printers, etc. One solution to deal with this variety of devices is use multimodal techniques on the e-Learning environment´s user interface. Multimodal interaction is a research proposal to turn the interaction between humans and machines more natural, i.e., more close to the interactions between two humans, and have the benefits to increase the usability, flexibility and convenience [23]. According to Oviatt [24] "multimodal interfaces process two or more combined user input modes (such as speech, pen, touch, manual gesture, gaze, and head and body movements) in a coordinated manner with multimedia system output". But, developing multimodal interaction systems is a complex task [25]; da Silva and da Rocha propose the |Ae| environment, an e-Learning environment with multimodal user interface, discuss how multimodal architecture changes the e-Learning environment architecture. Despite these works, the challenge is to have an

Figure 4. The integration between iPhone´s Photo Gallery and Facebook App.

e-Learning environment to deal with the variety of input and output modes in the device, using it in a proper way.

V. FINAL CONSIDERATIONS

e-Learning is the use of the Web structure to support teaching and learning activities. There is some Web-based software, the e-Learning environments, which support these activities in courses. Due the technology development, it is possible to use mobile devices to teaching and learning activities, calling m-Learning. The mobile devices can access e-Learning platform, but to an effective course accessed by mobile devices it is necessary that the e-Learning does not have barriers or difficulties for the mobile devices, and the content and activities must be shaped to consider the mobile devices and their hardware, such camera and microphone.

We believe that e-Learning and m-Learning will merge in the case of have an environment to support the teaching and learning activities and brings benefices on learning. But to plain an effective course, it is important to consider the hardware and software that the students will used. So, the technology needs to be considered in the instructional design process, together with the educational issues. Future works are detail each part of these dimensions.

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