M-Learning: Are We Ready to Go Mobile?

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Abstract. Mobile devices, which have been incorporated to everyday life all over the world – call a cab, order food, pay bills, search the Internet, listen to music, communicate with friends etc. – are heavily supported by cell phones. This technology has also become a part of the learning process. It can happen in an informal way since a lot of knowledge is available on the Internet. In this scenario, higher Education Institutions must be ready to fulfill the needs of their students. This work addresses the steps in the preparation for an institution to introduce Mobile Learning in its courses in Electrical Engineering and related areas. The starting point is an experience of over two decades in Information and Communication Technology supported learning which includes courses in Blended Learning with Flipped Classroom. A large collection of learning objects of different natures is also available. The Information and Communication Technology supported education is hosted on a platform with the unique characteristic of managing contents, users, remote labs and courses in an integrated way. The steps discussed in this work address the different characteristics of Mobile Learning and also key issues that have been under discussion in the University and in the Engineering Education community in the country. This paper reports a work in progress.

Keywords: Mobile Learning (m-learning) · Blended Learning (b-learning) · Educational resources

1 Introduction – The Context

A group of faculty in Electrical Engineering and related areas has adopted ICT – Information and Communication Technology supported learning since 1995. This has happened step-by-step due to the need to motivate faculty (mostly resistant to changes), the maturing process of the ones motivated and truly involved, the inclusion of new learning approaches and the evolution of ICT.

In the very beginning, simple courseware was made available as linear text for download and in HTML format with images, graphics and very limited animation – it is important to remark that the beginning was in the second half of the 1990s.

With the passing of the years, ICT has undergone an enormous change. New products are made available all the time to substitute for the old ones and to introduce new functionalities. Old products have been enhanced. The Internet has become a lot

A. M. B. Pavani—Member IEEE.

M. E. Auer and T. Tsiatsos (Eds.): IMCL 2019, AISC 1192, pp. 317–326, 2021.
https://doi.org/10.1007/978-3-030-49932-7_31

faster and also ubiquitous. Mobile phones have become cheaper and are affordable across the social spectrum in most countries. In the same time frame, the team at the university has grown more mature and has adopted new learning methods both in pedagogy and in the use of ICT. The number of faculty involved in ICT supported learning, though small, has considerably grown. Concerning the faculty profile in Electrical Engineering and related areas, three groups were be identified by the authors: (1) persons who actively innovate and drive the necessary changes; (2) persons who passively accept the new methods and technologies; and (3) persons who resist and do not want to change old teaching habits. Among the innovators, there is a subtype – those who innovate but do not work in a team; they are loners and do not accept a common practice. The profile of faculty will be addressed in Sect. 3.4.

In the 1990s, a platform was created that integrated the LMS – Learning Management System [1] and the IR – Institutional Repository [2], which at the time was designated Digital Library. This integration was presented and discussed [3]. It is of paramount importance in the organization of contents and accesses to them 24/7 from any location [4], regardless of the courses in which the student is enrolled. The platform is named Maxwell and its URL is www.maxwell.vrac.puc-rio.br.

New features have been added to both 'personalities' of the platform and new types of contents and activities have been introduced: videos, hypermedia learning objects, simulators, podcasts as well as more textual courseware. Apps have started being created. The Android version of first app was published last June; the iOS version is almost finished. Three other apps are under development, two of them using AR – Augmented Reality. Online tests and exercise-based homeworks were implemented. In order to develop simulators, SciLab (www.scilab.org) was integrated to the platform; currently there are over 40 objects with simulators.

In 2014, undergraduate and graduate courses started being taught in the Blended Learning (b-learning) mode; they employ the Flipped-Classroom approach. Currently, five undergraduate and two graduate courses are taught in such manner. Other courses use the platform and courseware as a support to the traditional face-to-face mode.

In 2016, a Remote Lab for Electric Circuits was installed and has been in regular use in two undergraduate courses since 2017. A second Remote Lab, for Control System, is in the final stage of deployment and is planned to be ready for use in September 2019.

A large number of learning objects has been developed to support all learning/teaching activities and most of them are in Open Access (OA). Since there is a large number of OER – Open Educational Resources, in September 2018 an aggregator – OER @PUC-Rio (www.maxwell.vrac.puc-rio.br/projetosEspeciais/OER/) – was deployed to make access to them easier. The current number of OER items is 524. A team of undergraduate students supervised by faculty and technical staff are the main developers of courseware.

In the first week of May 2019, a new responsive version of the platform was made available. The objective is to offer mobile device users a friendly interface. The responsive version included the latest version of AWSTATS that allows the identification the operational system of the devices accessing the platform. Accesses from mobile devices were: (1) 20.58% in May; (2) 18.96% in June; (3) 19.73% in July and

(4) 24.27% in August. The numbers were a surprise to the authors whose expectations were for higher percentages.

Deploying a responsive platform was one first step towards m-learning. The website of The University of Sydney School of Education and Social Work (sydney.edu.au/education_social_work/learning_teaching/ict/theory/mobile_learning.shtml) defines m-learning as:

> "The terms M-Learning and Mobile Learning are usually used to refer to teaching and learning with mobile technologies. The "mobile" in "mobile learning" has two implications:
>
> - Learner mobility: learners are able to engage in educational activities without the constraints of having to do so in a tightly delimited physical location. To a certain extent, learning can happen outside a classroom or in various locations, requiring nothing more than the motivation to do so wherever the opportunity arises – from books, electronic resources, places and people.
> - Mobile devices: portable, lightweight devices that are sometimes small enough to fit in a pocket or in the palm of one's hand. Typical examples are mobile phones, smartphones (like the iPhone), palmtops, and handheld computers like the iPad or PDAs (Personal Digital Assistants); Tablet PCs, laptop computers and personal media players like the iPod can also fall within its scope. These devices can be carried around with relative ease and used for communication and collaboration, and for teaching and learning activities that are different from what is possible with other media."

The presentation of the context had the objective of introducing the reader to the sections that follow in which the efforts to adopt m-learning are addressed and the readiness to go mobile is assessed. This work has 5 sections. Section 2 states the objective of the work. Section 3 addresses the steps to go mobile. Section 4 presents an overview of the current situation at the University. Section 5 is that of conclusions and final comments. It is a report of a project in progress.

2 Objective

Students have been using mobile devices, mainly mobile phones, in a fast growing rate; they seem very comfortable with this technology. They positively commented when the responsive version of the platform went into operation. For this reason, the percentages of users with mobile devices shown in Sect. 1 were quite disappointing.

Though the system is responsive, learning objects are still in the process of being modified to also become responsive. In order to better serve our students and people who access the system and the OERs, a goal was set to move towards m-learning. This idea is also based on international trends in ICT supported learning.

As far back as 2008, the NSF National Task Force on Cyberlearning [5] addressed the view of students being connected all the time and being able to study, learn and

communicate (with peers and teachers) everywhere 24/7. The term Cyberlearning was created to describe such situation.

In January 2019, a report was published on the EDUCAUSE website – Higher Education's 2019 Trend Watch & Top 10 Strategic Technologies (https://library.educause.edu/resources/2019/1/higher-educations-2019-trend-watch-and-top-10-strategic-technologies). Among them, two are worth mentioning: (1) Mobile Learning; and (2) Open Educational Resources (OER). The EDUCAUSE report reinforced the idea of adopting m-learning and of going on with OER.

This work is devoted to identifying the aspects that are necessary to implement m-learning and examining the degree of compliance to each one. This means the stage of readiness of the faculty, the educational resources and the system infrastructure.

The Flipped-Classroom + b-learning mode will be maintained in the courses that are already taught in this mode. The first courses to use m-learning will be Electric and Electronic Circuits I and II. Courses like General Electricity, Electric and Magnetic Measurements and even Control Systems can benefit from some of the new educational resources and tools as well.

It is important to mention that the LMS – Learning Management System [1] and the IR – Institutional Repository [2] modules of the system are already responsive. The LMS module offers all tools that are necessary for b-learning, so it is ready for use. This is important because the use of a responsive LMS vs apps is an aspect to consider in the introduction of m-learning.

3 Steps to Go Mobile

The project to go mobile has four different steps to follow. They have been identified reviewing the literature and using the experience that has been acquired in many years of ICT supported learning at the university. Once the steps were defined, the different alternatives had to be analyzed in order to make decisions. Some have already been made and others are planned for the near future. Implemented decisions require analysis of the results to apply necessary reviews/corrections. It is important to mention that the steps can be taken in parallel and indeed this is what is happening. The steps are listed below.

3.1 Identification of the Key Characteristics of an M-Learning Environment

The characteristics of the learning environment are an important point because they impact the infrastructure of the institution. This means they require financial resources and time for implementation. Two important points were identified: (1) the nature of the platform (responsive LMS vs. apps) as discussed by Gautam [6]; and (2) laboratories as discussed by El-Medany and Ismail [7].

- **Nature of the platform:** The literature discusses a responsive LMS vs apps [6]. The responsive LMS is already deployed. It was a decision not related to m-learning but to facilitating the access to ETD – Electronic Theses and Dissertations, Senior

Projects, journals, technical reports, OER etc. which are items of the IR collection. The technical staff is discussing the pros and cons of also having an app option. At the moment, the cons seem to dominate due to the complex nature of the platform, the large number of items of the collection and the fast pace of change due to new items being added every week.

- **Remote Laboratories:** A Remote Lab has been in use for over 2 years and the second will start operating very soon. The artifact for the third Remote Lab is already completed and the integration to the platform will start in August 2019. The real hard work was to integrate the first and the second Remote Labs into the platform, since they are based on different technologies. The first was not developed at PUC-Rio; from the second on they come from the Mechatronics Systems Development Lab and use the same technology to communicate with the platform.
- **Interactive solutions:** Any m-learning platform would hugely benefit from the ability to allow interactions between students, both in-classroom or otherwise. The most common interactive activities involve polling sessions, where the students select one among a set of answers to a problem that must be solved individually or in groups. Polling, of course, can be performed without mobile phones, but as will be discussed in Sect. 3.2 there is a huge advantage in m-learning concerning the learning analytics from the generated data. It is important to remember that the "m" in m-learning also represents mobile devices according to the definition quoted in Sect. 1. Also, there is usually a greater degree of commitment from the students in sending an answer via the m-learning system, where a record will be kept, than simply raising a hand when asked by the teacher. Currently, an app is in its final stage of development for both Android and iOS. It will probably be called *Assistente de Aulas* (Class Assistant).

3.2 Identification of the Key Characteristics of Teaching Methodology

The teaching methodology is a key point since, depending on the way ICT is used at the institution, a considerable change in habits will be necessary. Stylianidis [8] suggested that b-learning is the most effective methodology to implement m-learning, specially if case-based learning is used. The same author addresses content organization & personalization, learning analytics and gamification. Additionally, considerations on curriculum design and on assessment methods have to be taken into consideration. This is a step that requires some effort in the following areas.

- **b-learning:** b-learning is has been adopted since the first semester of 2014. Thus it is a consolidated mode of delivering courses. The plan is to start m-learning with a pilot project with one of them – Electric and Electronic Circuits. A high percentage of courseware implemented to use in mobile devices (podcasts, apps) is on circuits. All other contents that were not developed for mobile devices are being adapted to become responsive.
- **Content Organization:** Content organization is a practice that comes from the platform that integrates an LMS and an IR [3]. All contents are described with metadata elements compliant to international standards and best practices. All contents on the IR are described with DCMES – Dublin Core Metadata Element Set

which is ISO 15836 (https://www.iso.org/standard/71339.html), ETDs have additional elements that are necessary to describe theses and dissertations, and Learning Objects have specific elements that are present in LOM – IEEE 1484.12.1-2002 – IEEE Standard for Learning Object Metadata (https://standards.ieee.org/standard/1484_12_1-2002.html). In addition, there are elements defined to help manage them, specially concerning the subjects in the University curricula that can benefit from the resources. Since contents are items of the IR, levels of access to them are attributes of the items and not of the courses that use them. For example, if the access level is any user that belongs to the institution, when the courses that use the item are over, students keep having access to the items.

- **Personalization:** Currently, the courses that will employ m-learning – Electric and Electronic Circuits I and II – have a rudimentary form of personalization, where the student can choose between two "tracks". In the first track, the student is graded not only by tests and exams but also by projects that involve circuit simulation, whereas in the second track the projects are not mandatory. As projects are usually graded much higher than exams, this choice between both tracks means a tradeoff between difficulty and time to dedicate to the course. However, the topic of personalization is much broader and has not yet been fully addressed. Therefore, it will require further study, though not necessarily related to content description. Content description may be used to match students profiles with contents though.
- **Learning Analytics:** Learning analytics is under consideration due to the importance of using data to make decisions. The characteristics of the platform allow abundant data to be available. Data are related the students and the contents, as well as students use contents. These data have already been used [4]. Datasets can be found at Open Research Data @PUC-Rio (www.maxwell.vrac.puc-rio.br/projetosEspeciais/ResearchData/). All datasets corresponding to articles that have been published are part of this collection and made available in OA; each one is identified by a DOI – Digital Object Identifier.
- **Learning Assessments:** One of the advantages of m-learning is the possibility of adopting different learning assessment strategies that would be uneffective in other teaching methodologies. Interactive polling problems in the classroom, answering to simple questions after listening to a podcast, solving a problem using Augmented Reality (AR) or solving an in-classroom problem that involves multimedia content are only a few examples of what could be achieved by implementing m-learning. Currently, Learning Objects related to sound (in the context of Fourier Series) are under development and simple modifications of these objects will be performed to generate completely new kinds of assessments that would not be feasible for in-classroom situations. Other usages, e.g. circuit simulation using the mobile phone are also under consideration as well as Fourier analysis and filtering.
- **Curriculum Design:** Integration of teaching methodologies among courses has an impact on the curriculum structure. A fully integrated curriculum is not only desirable but essential to give students a global understanding. Currently, the curriculum of Electrical Engineering has a design where "contents" are studied in individual courses that do not interact with each other. The implementation of m-learning comes along the creation of "integrative courses", a change in the curriculum.

- **Gamification:** Gamification has not been addressed so far. However, the m-learning environment must be gamification-ready, i.e., be able to implement a reward system with customizable game mechanics – or at least be compatible with third-party software that perform such functions. This is the case of the platform.

3.3 Identification of the Key Characteristics of Contents

Contents play a key role in any type of ICT supported learning. Besides the usual focus on the topics being taught and how they are addressed in the learning objects, study guides etc., m-learning poses an additional concern – the wide range of devices with very different hardware and software characteristics.

Moreover, mobile devices offer functions that are not available in desktops and laptops – they allow speaking, taking pictures, making videos etc. A new way of thinking the design of courseware must be introduced to use the functions mobile devices offer. The app that implements AR – Augmented Reality uses the phone camera. A second app (under development) implementing AR uses the phone microphone. It is important to note that AR can also be used from non-mobile devices [9]. In the case of this reference, AR is used with markers on a schematic representation on a table, and the camera and screen are on a desktop computer. This is not in the scope of this work since our interest is m-learning.

Spyropoulou et al. [10] discussed different aspects of content development/adaptation to the mobile environment and their work is a good guide on the problems to face, specially concerning formats that can be supported by different devices. This a real problem and obsolescence is a permanent challenge.

Kiat et al. [11] compared three alternatives in ICT supported learning – Augmented Reality, Virtual Learning Environment and Mobile Learning. Though they are analyzed as separate options, AR and m-learning can be integrated. At the moment, the focus is on AR apps. A Virtual Learning Environment has not been considered.

3.4 Identification of the Faculty to Join the Effort

Faculty are key players in the ICT supported learning transformation. Students are very enthusiastic about innovation that is based on ICT, but care must be taken concerning their readiness to adapt to a sudden move to online learning. For example, a previous study with undergraduate students by Scheepers [12] showed that only 53% reported being fully prepared to use the technological tools employed by the lecturers. This means that the students must be prepared, for example, with video tutorials.

Involving faculty, on the other hand, is a bigger challenge because technological readiness alone is not enough. They will need to leave their comfort zones.

As mentioned before, the authors experience is that besides innovators, there is a group that does not participate in the discussions but nevertheless adopts ICT supported solutions and even suggests enhancements. These two groups are the ones to expand the m-learning project. Innovators belong to the team involved in the pilot project. The numbers are: (1) innovators – 6; and (2) adopters – 5. There is a third group that resists to innovations and at the moment will not help in the project. Rogers [13] identified five ideal types of adopters of innovation: (1) innovators – 2.5%; (2) early adopters –

13.5%; (3) early majority – 34.0%; (4) late majority – 34.0%; and (5) laggards – 16.0%. The observation of the authors is a gross simplification of the Rogers theory and should further be studied and complemented by considering additional faculty and how they react.

A situation that must be addressed is related to an innovator that does not work as a team member. The courseware that he creates is not made available on the platform and, therefore, is not shared with other faculty to be used in different courses.

Important members of the ICT supported learning are undergraduate and graduate students. They have been involved with the Remote Labs as developers of the solutions, developers of courseware (simulators included), Teaching Assistants in lab classes and developers of apps. They also give excellent suggestions of topics to address in order to support the learning process.

The authors consider that involving faculty is the hardest step while involving students is very easy.

4 Current Situation

Since the objective of this project is "to go mobile", it is necessary to assess compliance with each identified step. The current situation is summarized in Table 1. The three status columns are: (1) Done – indicates that the decisions were made and the solutions were implemented and have been working well; (2) Analysis – indicates that the solution is under analysis for possible implementation with no decision was made so far; and (3) Later – indicates that the topic will be addressed later on.

Table 1. Status of the main steps toward m-learning

Step		Done	Analysis	Later
Learning environment	**Responsive LMS**	✓		
	App LMS		✓	
	Remote labs	✓		
	Interactive solutions		✓	
Teaching methodology	**b-learning**	✓		
	Content organization	✓		
	Personalization			✓
	Learning analytics		✓	
	Learning assessment		✓	
	Curriculum design		✓	
	Gamification			✓
Key characteristics of contents		✓	✓	
Faculty		✓	✓	

Some comments are necessary concerning Table 1. The first is related to the Key Characteristics of Contents for which two columns are checked – this means that some

decisions have been made (p.ex. the development of apps) and some must be further studied (p.ex. some learning objects with virtual reality). The second is related to faculty for which two columns are checked too – this means that 11 have already been identified, though one of them is a loner, and other faculty must be contacted.

5 Conclusions and Final Comments

Mobile learning offers the potential of introducing previously unfeasible teaching tools and modalities that can increase student interaction and activity, both in-classroom and otherwise. However, the required infrastructure of the Learning Management System is nontrivial; moreover, unless specific content is created to the m-learning environment and suitable teaching methodologies are adopted, as well as a structured curricula that take all these matters into consideration and the participation of a significant part of faculty members, the mere use of mobile phones is innocuous.

The main goal of this project is to have three undergraduate courses in the curricula of Electrical, Computer and Control & Automation Engineering running in the mobile mode by the end of 2019. If this target is not met, at least two will be in m-learning. They may work as a showcase to faculty of other courses.

This is a project under way and is a natural consequence of all the work that has been done for over two decades.

All solutions developed and adopted so far have also been enhancing the b-learning mode of the courses and in a few cases adding functionalities of traditional (face-to-face) courses that use ICT tools. For this reason, the development of new materials can go on until full mobile mode is achieved – well can go on because there is always room for improvement.

The following steps for the adoption of m-learning involve: (1) personalization - not only of the LMS functionalities but also of the learning experience as a whole; (2) development of new learning assessments that can exploit mobile solutions for enhancing understanding; (3) review of course curricula to integrate contents; (4) introduce gamification elements; and (4) seek the support of the University high administration to aggregate more individuals that are willing to adopt m-learning in their courses.

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