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# Using Information and Communication Technology Tools to Enhance Traditional Electrical Engineering Education

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***Abstract*—This work presents a cenario of international activities and results in Information and Communication Technology, and how they can be applied to support traditional face-to-face education. Some activities and results are in an area that can be complementary to technology assisted learning – digital libraries and digital publishing. It also addresses activities in the Electrical Engineering Department of PUC-Rio, both in the undergraduate and the graduate levels, showing the use of these complementary tools in education. Finally, it mentions the challenges faced by the team that is leading the activities and addresses plans for the near future.**

***Keywords* — Institutional Repositories; Open Access; Courseware; ETD**

## I. INTRODUCTION

The last two decades have seen a dramatic change in technology. It has been changing at a very fast pace and has been getting cheaper all the time, making it affordable to more persons in a worlwide scale. This applies to hardware and software as well. If software is considered separately, free and open products are available for many types of applications.

This introduction addresses some points that are important to the understanding of the following sections.

### *A. Some Highlights about Activities at PUC-Rio*

PUC-Rio, the Pontifícia Universidade Católica do Rio de Janeiro, is a private university in Rio de Janeiro, Brazil. It is devoted to education, research, development and innovation.

In 1995, a team of the Electrical Engineering Department of PUC-Rio started the Maxwell Project as a twofold activity. The first concerned the development of courseware for undergraduate disciplines – this activity posed quite a challenge then due to limitations of the available software solutions for the hypermedia implementation of mathematical expressions, diagrams, etc. The second aspect of the project was the 'construction' of an ICT – Information and Communication Technology platform to deploy the courseware.

Since a platform was to be created, it was not necessary to restrict it to managing courseware; other functions could and indeed were added. In [1], it was shown that this system used ICT tools to implement the relations that there exist in a university – learning & teaching, accessing (digital) library contents, administrating agendas, grades, etc and communicating with one another.

The Project grew bigger and started serving other departments of the university as mentioned in the reference.

Research universities are sources of scholarly publications as well as of works that are required to obtain degrees. The univesity community produces preprints, articles, technical reports, manuals, theses, disssertations, senior projects, etc.

PUC-Rio is not different from other institutions. In 2000, the ETD – Electronic Theses and Dissertations program was created. In the 2002, ETDs became mandatory to all graduate programs of the institution. The growth rates associated to ETDs in the last 5 complete years are: (1) average number of defended theses & dissertations – 547.2; and (2) average number of new ETDs on the system – 662.0. The difference in numbers is due to retrospective digitization; this process was completed in the Graduate Program in Electrical Engineering and is under way in Mechanical Engineering.

In 2003, the first online journal was published and a collection of senior projects began. Senior projects have not become mandatory; they are deposited and made available on a voluntary basis..

Books came in 2005 and interactive books in 2008.

Currently, there are almost 6,000 ETDs, over 2,600 senior projects, 10 online journals and 4 books. There is a collection of interactive books that will be addressed later since the contents are in Electrical Engineering, that is a specific focus of this work.

As activities consolidated and expanded to different areas of the university, and a large variety of types of digital contents were added, the name of the project changed to become the Maxwell System. PUC-Rio registered the system with INPI – Instituto Nacional de Propriedade Industrial (http://www.inpi.gov/) that is the Brazilian Patent Office. In March 2009, v. 4 was deployed; it offered new interfaces that are accessible to the blind and the visually impaired; this is the current version.

The Maxwell System can be found at http://www.maxwell.lambda.ele.puc-rio.br/.

### *B. Institutional Repositories and Open Access*

Clifford Lynch [2] introduced the term IR – Institutional Repository with the following definition:

"A university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate as well as organization and access or distribution."

Lynch's concept commits the university not only with making contents available but also with the stewardship of digital materials. This is important to a later comment on the activities at the Electrical Engineering Department.

Creating an IR is a challenge to a university because it requires that the community contribute with contents. In the case of ETDs and senior projects this can be achieved by administrative actions. When preprints, articles and similar items are considered, the institution must rely on the willingness of faculty and research groups. Some institutions have mandates for the depositing of works on the IR, but this is not the case with PUC-Rio.

At the same time, there has been a world wide movement towards OA – Open Access to scholarly communication. Harnad and Brody [3] compared citations between articles published in journals that were not OA with the ones of the same article made OA by the author(s). The numbers they presented, though as of 2004, show that the later present higher numbers of citations since access is a necessary condition for this to happen. Another interesting aspect is the latency of traditional publishing – the whole process may take years. If works are made OA, they started being accessed earlier.

An excellent option to authors is the use of a Creative Commons License. The Creative Commons (http://www.creativecommons.org/) is an organization founded in 2001 whose mission is defined as:

"CC develops, supports, and stewards legal and technical infraestructure that maximizes digital creativity, sharing and innovation."

The mission is defined on the website at http://creativecommons.org/about.

By no means it advocates the violation of IPR – Intellectual Property Rights, rather it stimulates and guides those who want to use the Internet to share their contents.

Some examples of cooperation can be found by organizations that work as aggregators of information of OA digital contents. Three examples follow and are specific of higher education contents and/or scholarly communication.

The first example of cooperation is about sharing higher education courseware; it is MERLOT – Multimedia Educational Resource for Learning and Online Teaching (http://www.merlot.org/). MERLOT is a program of the State University of California, in the United States, in partnership with other higher education institutions, professional societies and the industry. Groups who want to contribute (by making their contents available) register, describe and indicate the URLs where courseware can be found. Courseware must be of OA and licensed through a Creative Commons License.

Currently, MERLOT hosts almost 31,000 items in 23 disciplines of higher education. Among them, there are over 800 in Engineering, over 800 in Chemistry, almost 2,400 in Mathematics & Statistics, and almost 2,000 in Physics.

The second example is DOAJ – Directory of Open Access Journals (http://www.doaj.org/). DOAJ is a project of the University of Lund, in Sweden, in partnership with other institutions. As its name indicates, the purpose of this service is to inform about journals that are OA; at the same time, it imposes a condition for a journal to be listed – authors and readers are not be charged any fees.

Currently, DOAJ hosts more tha 7,000 journal titles in 17 areas of kwnoledge . Among them, there are almost 800 in Technology & Engineering, 142 in Chemistry, 236 in Mathematics & Statistics, and 95 in Physics & Astronomy.

The third example is the ETD community. Institutions all over the world make available their ETDs. Since the ETD community is quite organized, a way of describing the works and best practices for interoperability have been established. Institutions that comply to them can make their ETDs internationally known .

There are many aggregators of ETD information. In Brazil, BDTD – Biblioteca Digital de Teses e Dissertações (http://bdtd.ibict.br/) stores and makes available information about more than 167,000 ETDs of 96 Brazilian institutions. In the international cenario, NDLTD – Networked Digital Library of Theses and Dissertations (http://www.ndltd.org/) performs the same function and has over 1.75 million information items (metadata records of ETDs). There are many more aggregators in different countries of the world. Information harvesting from institutions is automated due to the interoperability best practices.

The three examples have some common characteristics: (1) all contents are stored in digital files accessible through the Internet; (2) contents are created in institutions of higher learning; (3) (most) authors and managers are devoted to sharing digital contents; and (4) works are accessed by users from all over the world in a 24/7 operation.

### *C. The Challenge of Digital Preservation*

McMillan and Skinner [4] pointed out that, currently, more than 93% of the world's information is born digital. This is true for all contents that are created at the universities. ETDs are a good example because, besides being created using ICT products, in some institutions paper copies are not required anymore. This means that digital versions are both the dissemination and the archival documents. For being archival documents their preservation is of paramount importance. Theses & dissertations are documents that show that students fulfilled requirements towards the degrees. They can be viewd as products of higher education, besides being inputs when used as reference materials. They also are part of the history of graduate programs and institutions.

Other examples of contents that only have digital versions are interactive learning objects, simulators and animations. Their very nature imposes this limitation and a careful thought on how to preserve them is necessary.

## II. CYBERLEARNING

NSF – The National Science Foundation (http://www.nsf.gov/) of the United States Government commissioned a Task Force on Cyberlearning. Its report

[5] starts the Executive Summary with the following paragraph:

"Imagine a high school student in the year 2015. She has grown up in a world where learning is as accessible through technologies at home as it is in the classroom, and digital content is as real to her as paper, lab equipment, or textbooks. At school, she and her classmates engage in creative problem-solving activities by manipulating simulations in a virtual laboratory or by downloading and analyzing visualizations of real-time data from remote sensors. Away from the classroom, she has seamless access to school materials and homework assignments using inexpensive mobile technologies. She continues to collaborate with her classmates in virtual environments that allow not only social interaction with each other but also rich connections with a wealth of supplementary content. Her teacher can track her progress over the course of a lesson plan and compare her performance across a lifelong "digital portfolio," making note of areas that need additional attention through personalized assignments and alerting parents to specific concerns. What makes this possible is cyberlearning, the use of networked computing and communications technologies to support learning. Cyberlearning has the potential to transform education throughout a lifetime, enabling customized interaction with diverse learning materials on any topic—from anthropology to biochemistry to civil engineering to zoology. Learning does not stop with K–12 or higher education; cyberlearning supports continuous education at any age."

High school students in 2015 will be university students the later in 2018!

The report examines important aspects of the changing environment in education and points out that the whole way of learning will change. Schools & universities, teachers & higher education faculty, authors, developers, ICT teams, and administratos must be ready for such a change.

Creation and deployment of open courseware, and collaboration are considered key issues. Last but not least, knowledge about the process of learning is considered a must.

Courseware, journals and ETDs can be viewed as an important knowledge infrastructure of Cyberlearning.

## III. ELECTRICAL ENGINEERING AT PUC-RIO

Current PUC-Rio's engineering students have been brought up surrounded by ICT tools and use them 'even for educational purposes'; all of them have portable devices. The author's experience of teaching in the last few semesters has shown that during classes students use the portable devices to access information about the subjects being taught. This is accomplished in many ways – accessing the Maxwell System for some topic of the discipline, Google to search for something all over the Internet or specific sites, as for example Wolfram MathWorld™ (http://mathworld.wolfram.com/) or GeoGebra (http://www.geogebra.org), when they have specific questions.

Examining the situation from another point of view, one must think of faculty and the university administration. ICT tools are being enhanced all the time and thus are allowing richer solutions to technical contents as well as to administrative functions. System interoperability allows the integration of different platforms as long as administrators define it a priority and use the necessary concepts and tools. Integration starts with a managerial definition; technology follows. This seems to be the difficult part of it.

The Electrical Engineering Department of PUC-Rio has used ICT as a complement to its traditional face-to-face disciplines for well over a decade. The use has been under constant evolution due to new ideas, enhanced technology and willing students.

At the same time, faculty face the problem of the low availability of learning objects in Portuguese. This has yielded a positive consequence – the development of learning objects by groups of faculty and students; many of them are available in Open Access through Creative Commons Licenses.

The objective of the use of ICT to complement traditional face-to-face education has always been to offer students additional ways of learning besides lectures, simulation using MATLAB®, Circuit Maker® and others, and experimental lab classes. ICT solutions have been added to the existing learning options.

A secondary objective has been offering an administrative infrastracture (related to educational activities) to make every day chores easier – agendas, mailing lists, bulletin boards, grades, etc have always been a part of the Maxwell System.

Since students feel very comfortable with ICT, they appreciate being offered to use the system. The university administrative system is also automated and accessible throught the Internet. The Maxwell does not duplicate functions with the university system, rather, it receives data from the later. There is not an online integration between them though. Data are received as batch files, so update is not instantaneous. It is also a one way only information flow.

The following subsections present the actions and their results.

### *A. ETDs*

The graduate program in Electrical Engineering started publishing ETDs in August 2000, following Civil Engineering in May and Business Administration in June of the same year.

Afterwards, there was retrospective digitazation of the old printed versions. Currently, all theses and dissertations are available in digital format and online from the Maxwell System.

Authors of the old works were seeked in order to request authorization to make their ETDs OA – all that were reached did agree with OA. Unfortunately, this number is below 50% of the total number of old works.

The graduate program in Electrical Engineering has almost 1,100 ETDs.

The Maxwell System complies with standards and best practices, for this reason information on the ETDs is available from many national and international service aggregators, including the ones mentioned in the previous section.

In the undergraduate level, ETDs are reference materials for students who are engaged in research

projects and also for the ones who are developing their senior projects. Graduate students are eager readers of ETDs, as well as researchers.

### B. Series

In order to enhance visibility of research results two series were created to publish works. They contain preprints, postprints and internal research communications. The first series is called Internal Research Reports and started in July 2009 with 2 articles; currently there are 20 in this series. The second is called *Publicações em Antenas* (Publications in Antennas) and it started in January 2011 with 1 article; currently there are 3 in this series. All contents are published in OA.

A faculty member of the Department of Electrical Engineering contacted the IEEE – Institute of Electrical and Electronics Engineers (http://www.ieee.org/) to seek authorization to make articles available from the Maxwell System in three situations – works submitted to one of the Institute's many publications, works already accepted and the ones that had been published. The authorization was granted under the condition that, at least, one of the authors belonged to PUC-Rio..

Other editors were contacted and agreed too. Articles from already OA conference proceedings are also published.

The series follow what Harnad et al. [6] called the green road to OA – publication in a traditional journal or proceedings, that gives green light to OA from an Institutional Repository, and then publish on the IR, and the gold road to OA – publication directly in an OA journal or proceedings.

Undergraduate and graduate students engaged in research activities are coauthors of some articles. This is very important activity to undergrads who will pursue graduate education.

### C. Courseware

Since 1995, many courseware items have been developed and later on gone out of use. This mainly applies to hypermedia objects, mostly based on html, images and small animations.

A project that has been going on for more than 12 years is the *Livros Interativos de Engenharia Elétrica* (Interactive Books on Electrical Engineering). It is a collection of interactive exercises structured as a set of 3 books – Electric Circuits, Control and Servomecanisms, and Signals and Systems. Each book is divided into chapters with the same topics that traditional text books have; instead of texts, sets of interactive exercises on the topics are available.

Each exercise has, at least, 3 sets of parameters and/or functions. A set is randomly selected each time the exercise is clicked. The exercises are checked online, in the case the user wants, and a proposed solution is also presented upon request to the system. Currently, there are more than 600 exercises.

An interesting characteristic of this project is that, besides faculty, undergraduate and graduate students are active members of the development group. More information on this project can be found in [7] and [8].

The books were published under Creative Commons License 3.0 since they were partially financed with grants from funding agencies. The books are cataloged and described on the MERLOT database in the Engineering Community. MERLOT also makes the URL available.

A new project started 6 months ago – *Coleção Didática em Engenharia Elétrica* (Learning Collection in Electrical Engineering). It is a series of class notes in different disciplines of the undegraduate course. Currently there are 11 titles in this collection.

### D. Reference Materials

Three books that are references on Engineering and Science Education are also available. All three are in Portuguese and published as OA materials.

### E. Accesses to the Works

The Maxwell System yields many statistics of accesses to the works. This is an aspect of dissemination that lets authors know how many times their works are accessed and from what countries users are from.

Data from access logs have been stored and processed since June 2004.

In this time frame, it was possible to observe that ETDs have been accessed from 203 countries other than Brazil. It is important to remark that over 99% of the ETDs are in Portuguese since only in the last couple years the university has been accepting their publishing in foreign languages. In the same time frame, accesses from Brazil represented 73% of the overall number. The second country in number of accesses is the United States. The group of Portuguese speaking countries is the third; Portugal would be third even if the other countries in the group were disregarded.

The ETD with the highest number of accesses has close to 100,000 from 65 countries besides Brazil. It was published as an OA ETD in October 2005. Since it is instanciated in 10 digital objects, this number is equivalent to 10,000 accesses to the complete work; this is an average behavior since data on the accesses to the individual objects are not available. The second highest number is over 73,000 for a work with 8 partitions; this yields more than 9,000 equivalent full-text accesses. It was published as an OA work in May 2004 and accesses came from 58 countries other than Brazil.

When the works in the series are considered it is important to observe that most of them are in English due to previous publication in international journals or proceedings.

Accesses to works in the Internal Research Reports series have an average of 6.8 per work per month. The total number of countries is 32 and the United States accounts for over 58% of the accesses. Accesses to works in the *Publicações em Antenas* series are in an average of 3.7 per work per month. The total number of countries is 11 and accesses from the United States account for over 20% of the total.

The accesses to the Interactive Books on Electrical Engineering come from many parts of the world, totalling 27 different countries. Since they are in Portuguese, most accesses come from Brazil. Faculty in another university in Rio de Janeiro have said they have recommended students to use the books.

Accesses to the reference books are also very international. One of the books is on how to educate engineers for innovation; it has had an average of 177 accesses per month since it was published in November

2005. Only 84% of the accesses are from Brazil, though the book is in Portuguese; the number of countries is 60. The other 2 books, also in Portuguese, have accesses from Brazil that are 63% and 54%; the number of countries are, respectively, 24 and 19. The numbers of countries do not take into account Brazil.

It is interesting to observe that users from all parts of the world access OA contents.

### *F. Stewardship*

The definition of an IR [2] that Lynch created contains the commitment of the institution with the stewardship of the digital contents.

This is addressed by the work that the Maxwell team engages with the university community. Some of the fundamental aspects of this interaction are:

- Discussing (with faculty) topics related to IPR and working with the university legal counsel when necessary.
- Teaching students matters related to IPR, Creative Commons and use of third part materials..
- Making access statistics available so that authors and administrators can observe the interest that contents arise .
- Suggesting ICT solutions to faculty and university officers.
- Keeping close contact with international institutions to guarantee that standards and best practices are followed.
- Seeking international opportunities to make the works known.
- Dealing with digital preservation – the team has examined solutions and recommended that the university become a member of a distributed network cooperative. Since this requires customization of the data that are preserved with items, some programming is required. For this reason, each type of content is included separately. At the moment all ETDs have been included and senior projects are next in line.
- Keeping abundant backups of all digital contents and of data on the database.
- Publishing results of the activities.
- Suggesting new applications of ICT to learning
- Suggesting new ways of making scholarly publications available throught ICT.
- Seeking support from funding agencies to expand the activities.

All activities are important to keep the university visible in the national and the international cenarios.

## IV. CHALLENGES AND NEXT STEPS

The first and most obvious challenge is keeping up with the evolution of ICT. Not only new products are permanently made available but, most important, new trends arise.

This is particularly important when the concept of Cyberlearning is considered. A new way of relating to learning and ICT mediated learning will be necessary. It will impact faculty and administrative staff who will need coaching to adjust to the 'new world'. Curricula will have to be reviewed as well as the use of conventional laboratories and traditional face-to-face classes.

This is a road that is not clearly drawn in the map.

Disregarding Cyberlearning, the Maxwell team has some (smaller) challenges that will guide the next steps of the work and of the interaction with faculty, administrators and students. Some examples follow:

- Making the system and contents suitable to portable devices – this is the most urgent step in the enhancement of usability. Most students and faculty use portable devices and this is a trend in the near future, so the applications must be made available. External users will also benefit, since the use of portable devices is widespread. A good effort must be devoted to the digital contents since there are large objects that contain images, tables, mathematical expressions and graphs. There also are different types of information (linear texts, hypermedias, videos, animations, interactive exercises) that are instanced in various digital formats.
- Continuing the activities devoted to digital preservation. A special concern is related to the exercises in the Interactive Books that are implemented in Adobe® Flash®. A possible migration to html 5 is under consideration.
- Expanding accessibility of contents. This is a twofold activity. The first part is devoted to working with the university administration to seek support in requiring that authors write accessible documents. The second is making the Adobe® Flash® accessible to TTS – Text-toSpeech software products, which at the moment does not seem possible, or migrating interactive objects to html 5.
- Adding a new book to the Interactive Books Collection. A faculty member and one of his graduate students are already developing the exercises; the Maxwell team will have to develop the tool box for PRESTO to be used in this new discipline – Protection of Power Systems.
- Working with two faculty members to develop animated objects to teach dynamics in electric circuits and control systems. Ten objects are already planned and must be implemented.
- Developing new applications to search , retrieve and access items of the collection. There are some requests from faculty.
- Developing new statistics to better inform the university community.
- Examining the use of social networking in the process of learning. Students have been heavy users of social networks and there has been research in their use as learning tools; this must be addressed.
- Working with faculty and their students so that more contents are made available.

There is still a lot of work to do.

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